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Measuring Entrepreneurial Competencies of Science University Students in Indonesia: An Analysis of Validity and Reliability

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Developing entrepreneurial competencies is essential for science students to effectively transform scientific knowledge into economically valuable innovations. However, existing instruments for measuring entrepreneurial competencies remain generic and insufficiently aligned with the scientific context. This study aimed to evaluate the validity and reliability of an entrepreneurial competency measurement instrument, particularly within the context of biotechnology, for science university students in Indonesia. This study involved 346 students from 17 higher education institutions across Indonesia. The instrument comprised 52 items representing three core constructs: entrepreneurial knowledge, skills, and attitudes. Construct validity and reliability were assessed using item-total correlation, Cronbach's Alpha, and Confirmatory Factor Analysis (CFA). The findings indicate that, this instrument demonstrates good fit, established convergent and discriminant validity, and satisfactory internal reliability. Most indicators exhibit significant factor loadings, with AVE values ranging from 0.51 to 0.68 and CR values ranging from 0.60 to 0.90. However, one construct had an CR below the recommended threshold of 0.7 (Knowledge Competency) and one indicator showed a factor loading below the threshold of 0.196 (Entrepreneurial Knowledge). Additionally, the three entrepreneurial competency constructs demonstrate significant positive correlations. These findings provide an instrument for measuring entrepreneurial competencies in the context of

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Indonesian science students. Further refinement of the indicators is recommended to improve greater validity and reliability.

Introduction

The increasingly competitive global economic environment necessitates that higher education graduates possess both strong academic mastery and well-developed entrepreneurial competencies (Mapanga & Faleni, 2025; Pedroza & Salayandia, 2025; Villa & Gordon-Isasi, 2025). Entrepreneurship has been widely recognized as a key driver of economic growth, job creation, and science- and technology-based innovation (Acs et al., 2016; Pham et al., 2023; Zarkua et al., 2025). Within the context of higher education, particularly in science-related disciplines, strengthening entrepreneurial competencies has become increasingly critical, as it directly contributes to graduates' readiness to navigate a dynamic labor market, promotes the commercialization of research outputs, and supports sustainable development (Fayolle & Gailly, 2015; Liu et al., 2025; Nabi et al., 2017; Park & Kim, 2025).

Entrepreneurial competency is a multidimensional framework including knowledge, attitudes, and skills that interact to shape entrepreneurial behavior (Man et al., 2002; Morris et al., 2013). However, in the context of science education, the literature emphasizes the need to redefine entrepreneurship as a cross-disciplinary competency that integrates scientific capacity, creativity, and a values-based orientation in creating innovation (Lackéus, 2020). Within the framework of STEM education, entrepreneurship is no longer limited to business activities but encompasses research-based problem-solving, sustainable innovation, social value creation (Bybee, 2013), real-world application, critical thinking (Ozyazici et al., 2025), and creativity (Kaya-Capocci et al., 2024). In this context, entrepreneurial competencies are understood as the ability to transform scientific ideas into environmental, economic, and social value through the integration of disciplinary knowledge, innovation skills, and ethical and regulatory considerations (Bacigalupo et al., 2016; OECD, 2018). Entrepreneurial competencies in biotechnology include the capacity to recognize opportunities, think creatively, solve problems, and develop research-based innovations. These competencies also involve transforming research outcomes into commercial products or practical solutions (Tittel & Terzidis, 2020; Treanor et al., 2021).

In Indonesia, higher education policies encourage the integration of entrepreneurship into the curriculum across various academic programs, including science. As an integral part of the science curriculum, biotechnology provides a relevant learning context for developing entrepreneurial competencies. Biotechnology education not only focuses on mastering scientific concepts but is also geared toward developing students' ability to solve contextual problems and generate innovative, science-based solutions. Science students are increasingly prepared solely as researchers or professional practitioners, but also as *sciencepreneurs* who are capable of transforming scientific knowledge into commercially viable products, services, and innovative solutions with social impact (Etzkowitz, 2014; Guerrero et al., 2016; Guindalini et al., 2021). Therefore, biotechnology can be viewed as a concrete example of science education focused on strengthening entrepreneurial competencies. Entrepreneurial competencies constitute a key factor in ensuring that biotechnology research outcomes do not remain confined to laboratory settings but are further developed into innovations with economic value (Nielsen et al., 2022).

Several studies have shown that entrepreneurial competence has been measured using various

instruments encompassing a range of dimensions, including behavioral indicators (Schelfhout et al., 2016); as well as conceptual, strategic, relational, opportunity, organizing, and commitment competencies (Minimol, 2021); entrepreneurship competence, business & management, interpersonal, and human resource (Silveyra et al., 2020); identifying opportunities, developing solutions, learning from failure, and entrepreneurial awareness (del Arco Bravo & Gimeno, 2024); multidimensional (Kyndt & Baert, 2015; Riyanti et al., 2022); experience, risk-taking propensity, perceived capability, micro-business performance, and need for accomplishment (Al Mamun et al., 2016); personal, social, and professional competencies (Tittel & Terzidis, 2020); general entrepreneurial competencies based on personal characteristics (Schneider & Albornoz, 2018).

However, recent literature reviews indicate that research on entrepreneurial competencies in higher education continues to face conceptual and methodological challenges, particularly with regard to instrument validation and cross-disciplinary contextualization (Pedroza & Salayandia, 2025). For instance, most existing instruments for measuring entrepreneurial competencies remain generic and are designed for broad student populations, without adequately accounting for the distinctive characteristics of specific disciplines such as science or biotechnology (Riyanti et al., 2022; Silveyra et al., 2020). In fact, science students operate within different learning contexts, career orientations, and problem-solving approaches, especially in integrating scientific knowledge, technological innovation, and market opportunities (Etzkowitz, 2014; Guerrero et al., 2016). The gap becomes increasingly apparent in studies focusing on science students in developing economies, including Indonesia, where the adaptation of international instruments often fails to sufficiently consider local characteristics and disciplinary specificities (Nabi et al., 2017; Pedroza & Salayandia, 2025). As a result, existing instruments may inadequately capture the entrepreneurial competencies possessed by science students.

The need to develop instruments that are not only statistically valid but also contextually relevant to the field of study and cultural setting in which they are applied has been widely highlighted in earlier studies (Nabi et al., 2017; Riyanti et al., 2022). To ensure measurement quality, instruments for assessing entrepreneurial competencies must meet key psychometric criteria, namely content validity, construct validity, and reliability (Karakuş & Akbaş, 2026; Özdemir et al., 2025). Content validity indicates how effectively the measurement items comprehensively reflect the relevant construct domain, as evaluated through expert judgment (Polit & Beck, 2006). Construct validity tests the suitability of theoretical factor structures with empirical data, typically analyzed using Confirmatory Factor Analysis (Brown, 2015; Kline, 2016). Reliability denotes an instrument's ability to consistently capture the same construct in a stable manner (Hair Jr et al., 2021). Systematic testing of validity and reliability constitutes an indispensable psychometric prerequisite for entrepreneurial competency measurement instruments (Riyanti et al., 2022). Effective validation helps identify shortcomings, address them, and ultimately improve the quality of education and public literacy (Fidiastuti et al., 2026).

The issues outlined above offer a solid justification for the current study. This study is intended to assess the validity and reliability of a measurement instrument for entrepreneurial competencies specifically tailored to science students, particularly in the context of biotechnology. The instrument tested is a contextually adapted version of previous research (Al Mamun et al., 2016; Kyndt & Baert, 2015) that includes the dimensions of knowledge, skills, and attitudes. The findings may support a more effective evaluation of entrepreneurial competencies among science students pursuing biotechnology courses.

Methods

Research Design

This study used a quantitative cross-sectional approach to evaluate the psychometric quality of an entrepreneurial competency instrument for science students in the field of biotechnology, through validity and reliability testing. The study was conducted between January and June 2024.

Participants

A total of 346 respondents were included from 17 private and state universities in Indonesia. Purposive sampling was used as the sampling strategy in this study, with inclusion criteria consisting of students enrolled in science-related study programs who had received instruction in entrepreneurship and biotechnology. The respondents' characteristics in this study are presented in **Table 1**.

Table 1. Respondent Characteristics

Variables	Category	Frequency	Percentage (%)
Study programs	Science education	46	13.3
	Biology education	260	75.14
	Biology	40	11.56
Semester	5	202	58.38
	7	144	41.62
Gender	Male	69	19.94
	Female	277	80.06
Note: n = 346			

Research Instrument

The instrument design was grounded in a theoretical review of entrepreneurial competency frameworks (Man et al., 2002; Morris et al., 2013) and existing measurement models proposed by Al Mamun et al. (2016); Kyndt & Baert (2015). The instrument comprised 52 items encompassing three dimensions: entrepreneurial knowledge, skills, and attitudes. The knowledge dimension consists of 15 items related to *self-knowledge* and *entrepreneurial knowledge*. The skills dimension includes 16 items addressing *planning for the future*, *results orientation*, *learning orientation*, and *independence*. The attitudes dimension comprises 21 items associated with *building networks*, *risk-taking*, and *seeing opportunities*. Each measurement item was rated on a five-point Likert scale, ranging from 1 ('strongly disagree') to 5 ('strongly agree').

Data Collection

The instrument confirmed to be content-valid was subsequently administered through Google Forms and shared with respondents via WhatsApp. All participants provided voluntary consent to participate. The collected data were then analyzed anonymously.

Data Analysis

The instrument's content validity was evaluated through expert judgment using structured criteria that covered several aspects, such as alignment with the construct, clarity of wording, and representativeness of the indicators. Each item was assessed by three experts with expertise in entrepreneurship, biotechnology, and learning assessment to ensure that the

instrument met conceptual validity before being tested empirically. The assessment results were used as the basis for revising and refining the instrument items. In the context of this study, the involvement of experts with such expertise provided a solid foundation for assessing item validity prior to further empirical testing.

Subsequently, construct validity and reliability analyses were conducted in two stages. First, the data were analyzed using IBM SPSS software employing Pearson's product-moment correlation to compute item-total correlations and the instrument's internal reliability, measured by Cronbach's alpha. Based on a sample of 346 students, the critical r-value (r{344;0.05}) was 0.103. An item was considered valid if its correlation coefficient exceeded the critical r-value. The instrument was deemed reliable when the Cronbach's alpha coefficient was ≥ 0.60. Next, data analysis was conducted using AMOS software with Confirmatory Factor Analysis (CFA) to examine the adequacy of the measurement model fit and its construct validity. Model fit was evaluated based on the following criteria: $\chi^2/df < 3$, $p > 0.05$, RMSEA ≤ 0.08, and CFI, NFI, GFI, and AGFI values ≥ 0.90. Convergent validity was assessed using factor loadings of ≥ 0.70 and AVE values of ≥ 0.50, whereas discriminant validity was evaluated based on construct correlation coefficients of 0.85–0.90, and construct reliability was examined using CR values of ≥ 0.70 (Hair Jr et al., 2021; Hanseler et al., 2009).

The two analytical methods were conducted sequentially and in a complementary manner. The initial analysis employing item-total correlations and Cronbach's alpha aimed to screen problematic indicators and to ensure basic internal consistency prior to testing the measurement model. Subsequently, CFA was applied to evaluate whether the factor structure aligned with the underlying theoretical model. This two-stage approach is widely recommended in instrument development, as CFA requires indicators that satisfy basic statistical quality criteria to enhance the measurement model's precision (Brown, 2015; Hair Jr et al., 2021; Kline, 2016).

Results

The results of item-level validity and reliability evaluations for the entrepreneurial competency instrument are presented below.

Validity and Reliability Testing Using Pearson's Product–Moment Correlation

The outcomes of the validity and reliability assessments for the knowledge, skills, and attitude dimensions, as evaluated through Corrected Item-Total Correlation and Cronbach's Alpha, are summarized in **Tables 2–4**.

Table 2. Validity and Reliability Test Results for The Knowledge Competency Dimension

Indicators	Item Code	Corrected Item-Total Correlation	Cronbach's Alpha
Self-knowledge (SK)	P23	0.610	0.802
	P24	0.589	
	P25	0.659	
	P26	0.624	
Entrepreneurial Knowledge (EK)	P42	0.359	0.861
	P43	0.722	
	P44	0.378	
	P45	0.628	
	P46	0.489	
	P47	0.674	
	P48	0.596	
	P49	0.692	
	P50	0.464	
	P51	0.520	
	P52	0.564	

Based on **Table 2**, all items within the knowledge dimension, encompassing the *Self-knowledge* and *Entrepreneurial Knowledge* indicators, exhibited Corrected Item-Total Correlation values exceeding the critical r-value (0.103), thereby meeting the validity criteria. In addition, a Cronbach's alpha coefficient above 0.60 indicates acceptable internal reliability.

Table 3. Validity and Reliability Test Results for The Skill Competency Dimension

Indicators	Item Code	Corrected Item-Total Correlation	Cronbach's Alpha
Planning for the Future (PF)	P14	0.698	0.814
	P15	0.692	
	P16	0.656	
	P17	0.494	
Results Orientation (RO)	P18	0.642	0.829
	P19	0.672	
	P20	0.704	
	P21	0.670	
	P22	0.456	
Learning Orientation (LO)	P27	0.625	0.755
	P28	0.650	
	P29	0.484	
Independence (ID)	P30	0.571	0.758
	P31	0.597	
	P32	0.589	
	P33	0.479	

Based on **Table 3**, all items within the skill competencies dimension, encompassing the indicators of *Planning for the Future, Results Orientation, Learning Orientation,* and *Independence*, exhibited Corrected Item-Total Correlation values exceeding the critical r-value (0.103), thereby satisfying the validity criteria. Furthermore, Cronbach's alpha coefficients above 0.60 reflect a good level of internal reliability.

Table 4. Validity and Reliability Test Results for The Attitude Competency Dimension

Indicators	Item Code	Corrected Item-Total Correlation	Cronbach's Alpha
Building Networks (BN)	P1	0.600	0.849
	P2	0.590	
	P3	0.625	
	P4	0.466	
	P5	0.577	
	P6	0.572	
	P7	0.508	
	P8	0.537	
	P9	0.580	
	P10	0.441	
Risk-taking (RT)	P11	0.689	0.804
	P12	0.721	
	P13	0.551	
Seeing Opportunities (SO)	P34	0.737	0.945
	P35	0.738	
	P36	0.798	
	P37	0.803	
	P38	0.834	
	P39	0.813	
	P40	0.838	
	P41	0.838	

As shown in **Table 4**, all items within the attitude competencies dimension, encompassing the indicators of *Building Networks*, *Risk-taking*, and *Seeing Opportunities*, exhibited Corrected Item-Total Correlation values exceeding the critical r-value (0.103), thereby meeting the validity criteria. Furthermore, Cronbach's Alpha coefficients above 0.60 indicate good internal reliability. Accordingly, all items across the three core dimensions of entrepreneurial competence demonstrate satisfactory validity and reliability.

Validity and Reliability Testing Using CFA

The CFA produced the measurement model of entrepreneurial competencies, as presented in Figure 1.

Table 5. Fit Indices of the Measurement Model Fit

Fit Criteria	χ^2	df	p	RMSEA	NFI	CFI	GFI	AGFI
Model Value	24.983	21	0.248	0.023	0.988	0.998	0.984	0.966

The findings presented in **Table 5** indicate that the measurement model is demonstrates good fit. The χ^2/df value is 1.19, which meets the recommended criterion (< 3), and the p-value is 0.248 ($p > 0.05$). Additionally, the RMSEA value of 0.023 indicates a low level of approximation error. Other fit indices also show adequate results, with an NFI value of 0.988 and a CFI of 0.998, both of which exceed the threshold of ≥ 0.90. Furthermore, the GFI and AGFI values of 0.984 and 0.966, respectively, are also above the recommended cutoff. In general, these findings suggest that the measurement model achieves acceptable goodness-of-fit criteria.

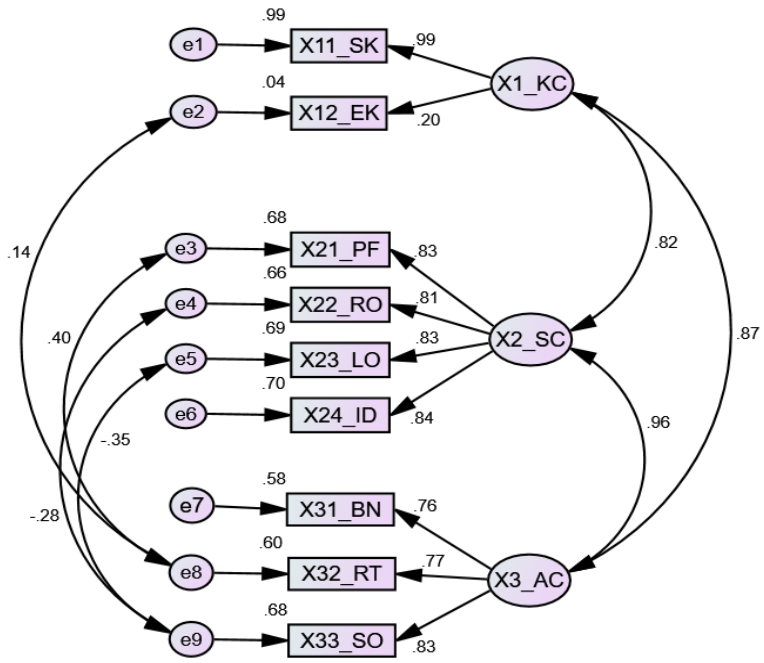

Figure 1. CFA Results for the Entrepreneurial Competency Measurement Model

Furthermore, the values of factor loadings, AVE, and CR are presented in **Table 6**.

Table 6. Standardized Factor Loadings, AVE, and CR

Construct Variables	**Indicator Variables**	**Standardized**	**AVE**	**CR**
Knowledge	Self-knowledge	0.993	0.51	0.60
	Entrepreneurial knowledge	0.196		
Skill	Planning for the future	0.826	0.68	0.90
	Results oriented	0.812		
	Learning orientation	0.83		
	Independence	0.839		
Attitude	Building networks	0.763	0.62	0.83
	Risk taking	0.774		
	Seeing opportunities	0.826		

Table 6 shows that most indicators had adequate and significant factor loadings; however, one indicator from the Knowledge Competency construct—specifically, the Entrepreneurial Knowledge indicator—had a low factor loading of 0.196. Furthermore, the values of AVE range from 0.51 to 0.68, meeting the minimum requirement of 0.50. Although the Knowledge Competency construct showed a Cronbach's alpha value above the minimum acceptable level ($\alpha \geq 0.60$), its Composite Reliability (CR = 0.60) was below the recommended threshold of 0.70, indicating that the construct reliability was not fully supported.

Table 7. Correlations among Entrepreneurial Competency Constructs

Construct Variables	Construct Variables	Correlation estimate	Covariance estimate	p-value
Knowledge Competency	Attitude Competency	0.870	10.745	< .001
Knowledge Competency	Skill Competency	0.817	4.926	< .001
Skill Competency	Attitude Competency	0.955	9.450	< .001

Table 7 shows strong positive correlations among the entrepreneurial competency constructs, namely *Knowledge Competency*, *Skill Competency*, and *Attitude Competency*. The inter-construct correlation values range from 0.817 to 0.955, indicating significant relationships among the constructs within the measurement model. All correlation coefficients were statistically significant, indicating strong relationships among the three entrepreneurial competency constructs. The highest correlation was observed between the Skill Competency and Attitude Competency constructs (r = 0.955). However, this value exceeded the recommended range of 0.85–0.90 for correlations among constructs.

Discussion

Validity and reliability evaluation of the entrepreneurial competence measurement instrument in this study were assessed through Pearson's product-moment correlation analysis, followed by CFA. CFA is essential for assessing the internal structural validity of educational measurement instruments (Rogers, 2024). Preliminary analysis results reveal strong internal consistency for all constructs, as evidenced by Cronbach's Alpha values ≥ 0.60 (Hair Jr et al., 2021). Thus, all indicators had met the basic statistical quality requirements for conducting measurement model testing.

Informed by CFA analysis, the formulated measurement model demonstrates a good fit with the empirical data. The values for $\chi^2/df < 3$; $p > 0.05$ indicated that the model-implied covariance matrix did not differ significantly from the observed covariance matrix, suggesting an acceptable model fit. Thus, the proposed construct structure is statistically acceptable and consistent with the obtained data. High NFI (0.988) and CFI (0.998) values indicated that the proposed model adequately captured the relationships among the latent variables and demonstrated a good fit to the data (Hair Jr et al., 2021; Hu & Bentler, 1999). Additionally, the low RMSEA value (0.023) confirms that the model has a low approximation error. This indicates that the model fits the sample data well and provides support for the adequacy of the proposed factor structure (Browne & Cudeck, 1992). Furthermore, the GFI (0.984) and AGFI (0.966) values, which are above the 0.90 cutoff, further reinforce that the model has an adequate overall fit and is suitable for use in further analysis (Fornell & Larcker, 1981; Hair Jr et al., 2021).

The CFA findings indicate that all constructs have AVE values exceeding the minimum criterion of 0.50, and most indicators exhibit factor loadings of ≥ 0.70. However, there is one indicator within the Knowledge Competency construct—Entrepreneurial Knowledge—that exhibits a relatively low factor loading (0.196). Despite its relatively low magnitude, the factor loading may still be statistically significant. As noted by Cheung et al. (2024), CFA often involves relatively large sample sizes to ensure convergence and produce reliable estimates, allowing even small standardized factor loadings to become statistically significant. However, this must be interpreted with caution. In this study, relatively low factor loadings indicate that these indicators have a weak contribution in representing the latent construct. Standardized factor loadings below 0.7 indicate that the factor explains less than 50% of the item variance (Hair Jr et al., 2021), highlighting the need for careful evaluation of the indicator's contribution to the construct. However, as noted by Hair Jr et al. (2021), the presence of indicators with low loadings is not always viewed as a weakness, but rather as part of the empirical evaluation process to identify indicators that need to be refined or reconstructed. Furthermore, the Composite Reliability (CR) value of 0.60 for the Knowledge Competency construct indicates that the construct's internal consistency remains below the recommended threshold (≥ 0.70). Therefore, these results should be interpreted as an

indication of the need to strengthen the construct, either through revising the indicators or developing additional, more representative items.

From a theoretical perspective, entrepreneurial knowledge functions as a fundamental basis for individuals to understand their personal potential, market opportunities, and the dynamics of complex business environments (Man et al., 2002; Morris et al., 2013). In the context of biotechnology, mastery of entrepreneurial knowledge is particularly critical, as students are expected to transform scientific knowledge into economically valuable innovations (Guerrero et al., 2016; Nielsen et al., 2022). This study's results corroborate the findings of Silveyra et al. (2020), which indicate that entrepreneurial knowledge is one of the core competencies; however, the low contribution of the Entrepreneurial Knowledge indicator to the Knowledge Competency construct suggests that science students rely more on self-knowledge than on formal business knowledge. This is consistent with the context of biotechnology students, who have a stronger background in science than in management.

The CFA results also revealed strong positive correlations among the knowledge, skill, and attitude competency constructs. Evidence from this study demonstrates that the three dimensions of entrepreneurial competencies are interrelated and jointly contribute to students' overall entrepreneurial competencies. This finding aligns with the perspective that entrepreneurial competencies constitute a multidimensional construct in which knowledge, skills, and attitudes develop in a mutually reinforcing manner (Man et al., 2002; Morris et al., 2013). The strong correlation between knowledge and skill competencies indicates that mastery of entrepreneurial knowledge contributes significantly to the formation of entrepreneurial skills, especially among science students who are oriented toward applying scientific knowledge in innovative practices. Similarly, the strong relationship between skill and attitude competencies suggests that entrepreneurial action capacity is closely linked to attitudes such as risk-taking and opportunity recognition, consistent with findings from prior studies on entrepreneurial learning in university-level education (Nabi et al., 2017; Sánchez, 2013).

Nonetheless, the literature indicates that the correlation coefficient between constructs should not exceed the threshold of 0.85–0.90 to ensure adequate discriminant validity (Hanseler et al., 2009). This study revealed a high correlation between the Skill Competency and Attitude Competency constructs ($r = 0.955$), indicating a potential issue with discriminant validity. A very high correlation between constructs suggests that the two constructs are strongly interrelated, making them empirically difficult to distinguish (Cheung et al., 2024). In other words, the high correlation value indicates a high conceptual overlap between attitude and skill within the current item structure (Fidiastuti et al., 2026). In SEM literature, discriminant validity requires that each construct be unique and not show excessively high associations with other constructs. Fornell & Larcker (1981) assert that a construct must be able to explain a greater proportion of its indicator variance than its correlation with other constructs.

This situation may be due to the similarity of the indicators used or to respondents' tendency to view skills and attitudes as closely interrelated aspects within the context of entrepreneurial competence. Related findings have been reported in several studies, suggesting that constructs with very high correlations may represent broader dimensions. Consequently, further evaluation of the proposed model structure (Voorhees et al., 2015) and additional theoretical refinement are needed, particularly to clarify the operationalization of the affective dimension (Fidiastuti et al., 2026).

Conclusion

In general, according to the outcomes of validity and reliability evaluations, this instrument has demonstrated satisfactory performance regarding validity (convergent and discriminant) and reliability. Therefore, it can be concluded that the instrument is adequate for use as an instrument for measuring entrepreneurial competency, encompassing the dimensions of knowledge, attitudes, and skills. Nevertheless, some findings indicate the need for further refinement of indicators with low factor loadings to better represent the specific constructs being measured. Additionally, future applications of the instrument should carefully consider the translation process, adaptation to the science context, and alignment with the curriculum. The clarity of the operational definitions of the constructs needs to be strengthened to minimize ambiguity and ensure that each indicator measures the appropriate dimension. The addition of relevant, theory-based indicators may be considered to enhance the representativeness of the constructs.

Although this study makes a significant empirical contribution, it has several limitations. First, the data were collected using a questionnaire, which may introduce respondent bias. Second, instrument validation was conducted using a CFA approach on a sample of science students who had taken biotechnology courses; therefore, generalizing the findings to broader populations should be done with caution. Third, the application of the instrument to different disciplines or cultural contexts requires retesting to ensure the suitability and stability of the construct structure.

The findings of this study contribute to a more contextual understanding of entrepreneurial competencies, particularly in the field of science (biotechnology). These findings also support the application of entrepreneurial theory within science-based disciplines. Despite some limitations of this study, these findings not only contribute to the development of an entrepreneurial competency instrument that meets most validity and reliability criteria, but also provide empirical evidence regarding indicators that require further refinement. The resulting instrument may provide a valid, reliable, and contextually appropriate tool for use in both research and entrepreneurial education practices in Indonesia. Practically, the instrument tested in this study can be employed to evaluate entrepreneurial competencies of science students. Findings regarding the strong interrelationships among constructs also imply that entrepreneurship learning approaches need to be designed in an integrated manner so that they can develop knowledge, skills, and attitudes simultaneously.

Declarations

Note: The findings of this study were orally presented at the international seminar Championing Optimal Resources for Enhanced Personalized Learning and Adaptation, held in Denpasar, Bali, Indonesia, on November 23-24, 2025, with the presentation focusing on the relationships among the dimensions of entrepreneurial competency.

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Conflict of Interest: The authors affirm the absence of any financial or personal conflicts of interest relationships existed that could have affected the results of this study.
Informed Consent: Prior to participation, all respondents provided informed consent. Participants were given comprehensive information about the study and data confidentiality, and were assured that participation carried no consequences.
Data availability: Data are accessible from the authors on request.

References

Acs, Z., Szerb, L., & Autio, E. (2016). *Global Entrepreneurship and Development Index 2016*. Washington: CreateSpace Independent Publishing Platform. https://doi.org/10.1007/978-3-319-63844-7

Al Mamun, A., Subramaniam, P., Nawi, N. B. C., & Zainol, N. R. B. (2016). Entrepreneurial Competencies and Performance of Informal Micro-Enterprises in Malaysia. *Mediterranean Journal of Social Sciences*, *7*(3), 273–281. https://doi.org/10.5901/mjss.2016.v7n3p273

Bacigalupo, M., Kampylis, P., Punie, Y., & Van den Brande, G. (2016). *EntreComp: The Entrepreneurship Competence Framework*. Luxembourg: Publication Office of the European Union. https://doi.org/10.2791/593884

Brown, T. A. (2015). *Confirmatory Factor Analysis for Applied Research*. New York: The Guilford Press.

Browne, M. W., & Cudeck, R. (1992). Alternative Ways of Assessing Model Fit. *Sociological Methods & Research 1992*, *21*(2), 230–258. https://doi.org/10.1177/0049124192021002005

Bybee, R. W. (2013). *The Case for STEM Education Challenges and Opportunities*. USA: The National Science Theachers Association.

Cheung, G. W., Cooper-Thomas, H. D., Lau, R. S., & Wang, L. C. (2024). Reporting Reliability, Convergent and Discriminant and Best-practice Recommendations. *Asia Pacific Journal of Management*, *41*, 745–783. https://doi.org/10.1007/s10490-023-09871-y

del Arco Bravo, I., & Gimeno, M. M. (2024). Construction and Validation of an Entrepreneurship Measurement Instrument for Nursing Students. *Investigacion y Educacion En Enfermeria*, *42*(1), e12. https://doi.org/10.17533/udea.iee.v42n1e12

Etzkowitz, H. (2014). The Entrepreneurial University Wave from Ivory. *Industry & Higher Education*, *28*(4), 223–232. https://doi.org/10.5367/ihe.2014.0211

Fayolle, A., & Gailly, B. (2015). The Impact of Entrepreneurship Education on Entrepreneurial Attitudes and Intention: Hysteresis and Persistence. *Journal of Small Business Management*, *53*(1), 75–93. https://doi.org/10.1111/jsbm.12065

Fidiastuti, H. R., Lestari, S. R., Suhadi, S., & Prabaningtyas, S. (2026). Validation of the Microbiology Literacy Instruments in Indonesia: a Report of Confirmatory Factor Analysis. *Asian Education and Development Studies*, 1–16. https://doi.org/10.1108/AEDS-06-2024-0131

Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*, *18*(1), 39–50. https://doi.org/10.2307/3151312

Guerrero, M., Urbano, D., Fayolle, A., Klofsten, M., & Mian, S. (2016). Entrepreneurial Universities: Emerging Models in the New Social and Economic Landscape. *Small Business Economics*, *47*, 551–563. https://doi.org/10.1007/s11187-016-9755-4

Guindalini, C., Verreynne, M.-L., & Kastelle, T. (2021). Taking Scientific Inventions to

Market: Mapping the Academic Entrepreneurship Ecosystem. *Technological Forecasting & Social Change*, *173*, 1–12. https://doi.org/10.1016/j.techfore.2021.121144

Hair Jr, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., & Ray, S. (2021). *Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R*. Switzerland: Springer. https://doi.org/10.1007/978-3-030-80519-7

Hanseler, J., Ringle, C. M., & Sinkovics, R. R. (2009). The Use of Partial Least Squares Path Modeling in International Marketing. *Advances in International Marketing*, *20*, 277–319. https://doi.org/10.1108/S1474-7979(2009)0000020014

Hu, L., & Bentler, P. M. (1999). Cutoff Criteria for Fit Indexes in Covariance Structure Analysis: Conventional Criteria Versus New Alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Karakuş, S., & Akbaş, Y. (2026). Water Literacy of Secondary School Students: A Scale Development Study. *Participatory Educational Research (PER)*, *13*(1), 256–275. https://doi.org/10.17275/per.26.14.13.1

Kaya-Capocci, S., Pabuccu-Akis, A., & Orhan-Ozteber, N. (2024). Entrepreneurial STEM Education: Enhancing students' Resourcefulness and Problem-solving Skills. *Research in Science Education*, *55*, 103–134. https://doi.org/10.1007/s11165-024-10189-y

Kline, R. B. (2016). *Principles and Practice of Structural Equation Modeling*. New York: The Guilford Press.

Kyndt, E., & Baert, H. (2015). Entrepreneurial Competences: Assessment and Predictive Value for Entrepreneurship. *Journal of Vocational Behavior*, 1039. https://doi.org/10.1016/j.jvb.2015.07.002

Lackéus, M. (2020). Comparing the Impact of Three Different Experiential Approaches to Entrepreneurship in Education. *International Journal of Entrepreneurial Behavior & Research*, *26*(5), 937–971. https://doi.org/10.1108/IJEBR-04-2018-0236

Liu, Y., Alias, B. S., & Hamid, A. H. A. (2025). Student Entrepreneurship Competence and Its Contribution to Sustainable Development: A Systematic Review in the Context of Chinese Higher Education. *Sustainability*, *17*(7), 1–20. https://doi.org/10.3390/su17073148

Man, T. W. Y., Lau, T., & Chan, K. F. (2002). The Competitiveness of Small and Medium Enterprises A Conceptualization with Focus on Entrepreneurial Competencies. *Journal of Business Venturing*, *17*(2), 123–142. https://doi.org/10.1016/S0883-9026(00)00058-6

Mapanga, A., & Faleni, N. (2025). Integrating Entrepreneurship Education into STEM Curricula in Global South Higher Education Institutions. *Discover Education*, *4*(335), 1–23. https://doi.org/10.1007/s44217-025-00798-8

Minimol, M. C. (2021). Measurement and Validation of Entrepreneurial Competency Scale. *Journal of Contemporary Issues in Business and Government*, *27*(2), 3778–3794. https://doi.org/10.47750/cibg.2021.27.02.389

Morris, M. H., Webb, J. W., Fu, J., & Singhal, S. (2013). A Competency-Based Perspective on Entrepreneurship Education: Conceptual and Empirical Insights. *Journal of Small Business Management*, *51*(3), 352–369. https://doi.org/10.1111/jsbm.12023

Nabi, G., Liñán, F., Fayolle, A., Krueger, N., & Walmsley, A. (2017). The Impact of Entrepreneurship Education in Higher Education : A Systematic Review and Research Agenda. *Academy of Management Learning & Education*, *16*(2), 277–299. https://doi.org/10.5465/amle.2015.0026

Nielsen, J., Tillegreen, C. B., & Petranovic, D. (2022). Innovation Trends in Industrial Biotechnology. *Trends in Biotechnology*, *40*(10), 1160–1172. https://doi.org/10.1016/j.tibtech.2022.03.007

OECD. (2018). *The Future of Education and Skills Education 2030*.

Özdemir, T. Y., Gurbuz, O., & Dogan, A. (2025). Tokenism Perception Scale: Validity and Reliability Study. *Participatory Educational Research (PER)*, *12*(1), 84–97. https://doi.org/10.17275/per.25.5.12.1

Ozyazici, G., Wang, Q., & Tillotson, J. W. (2025). Promoting Entrepreneurial Career Development in STEM: Developing and Validating a STEM Entrepreneurial Career Development Measure (SECDM). *Journal of Science Education and Technology*, *35*, 313–327. https://doi.org/10.1007/s10956-025-10251-y

Park, J.-H., & Kim, S.-J. (2025). Entrepreneurial Competencies in the Era of Digital Transformation: A Systematic Literature Review. *Digital*, *5*(4), 1–27. https://doi.org/10.3390/digital5040046

Pedroza, J. D., & Salayandia, K. V. (2025). Entrepreneurial Competencies in Higher Education: A Literature Review. *Ingente Americana*, *5*(5), 1–14. https://doi.org/10.21803/ingecana.5.5.923

Pham, M., Nguyen, A. T. ., Tran, D. T., Mai, T. T., & Nguyen, V. T. (2023). The Impact of Entrepreneurship Knowledge on Students' E-Entrepreneurial Intention Formation and The Moderating Role of Technological Innovativeness. *Journal of Innovation and Entrepreneurship*, *12*(80), 1–30. https://doi.org/10.1186/s13731-023-00351-7

Polit, D. F., & Beck, C. T. (2006). The Content Validity Index: Are You Sure You Know What's Being Reported? Critique and Recommendations. *Research in Nursing Health*, *29*(5), 489–497. https://doi.org/10.1002/nur.20147

Riyanti, B. P. D., Suryani, A. O., Sandroto, C. W., & Soeharso, S. Y. (2022). The Construct and Predictive Validity Testing of Indonesian Entrepreneurial Competence Inventory-Situational Judgment Test Model. *Journal of Innovation and Entrepreneurship*, *11*(3), 1–19. https://doi.org/10.21203/rs.3.rs-136238/v1

Rogers, P. (2024). Best Practices for your Confirmatory Factor Analysis: A JASP and lavaan Tutorial. *Behavior Research Methods*, *56*(7), 6634–6654. https://doi.org/10.3758/s13428-024- 02375-7

Sánchez, J. C. (2013). The Impact of an Entrepreneurship Education Program on Entrepreneurial Competencies and Intention. *Journal OfSmall Business Management*, *51*(3), 447–465. https://doi.org/10.1111/jsbm.12025

Schelfhout, W., Bruggeman, K., & De Maeyer, S. (2016). Evaluation of Entrepreneurial Competence through Scaled Behavioural Indicators: Validation of an Instrument. *Studies in Educational Evaluation*, *51*, 29–41. https://doi.org/10.1016/J.STUEDUC.2016.09.001

Schneider, K., & Albornoz, C. (2018). Theoretical Model of Fundamental Entrepreneurial Competencies. *Science Journal Education*, *6*(1), 8–16. https://doi.org/10.11648/j.sjedu.20180601.12

Silveyra, G., Herrero, Á., & Pérez, A. (2020). Model of Teachable Entrepreneurship Competencies (M-TEC): Scale Development. *The International Journal of Management Education*, *19*(1), 1–20. https://doi.org/10.1016/j.ijme.2020.100392

Tittel, A., & Terzidis, O. (2020). Entrepreneurial Competences Revised: Developing a Consolidated and Categorized List of Entrepreneurial. *Entrepreneurship Education*, *3*, 1–35. https://doi.org/10.1007/s41959-019-00021-4

Treanor, L., Noke, H., Marlow, S., & Mosey, S. (2021). Developing Entrepreneurial Competences in Biotechnology Early Career Researchers to Support Long-Term Entrepreneurial Career Outcomes. *Technological Forecasting & Social Change*, *164*, 1–12. https://doi.org/10.1016/j.techfore.2020.120031

Villa, M. L., & Gordon-Isasi, J. (2025). Entrepreneurial Competence in Higher Education : An Assessment of the Importance Attributed to It by Final-Year Undergraduate Students. *World*, *6*(110), 1–18. https://doi.org/10.3390/world6030110

Voorhees, C. M., Brady, M. K., Calantone, R., & Ramirez, E. (2015). Discriminant Validity

Testing in Marketing: An Analysis, Causes for Concern, and Proposed Remedies. *Journal of the Academy of Marketing Science*, *44*, 119–134. https://doi.org/10.1007/s11747-015-0455-4

Zarkua, T., Heijman, W., Benešová, I., & Krivko, M. (2025). Entrepreneurship as A Driver of Economic Development. *Entrepreneurial Business and Economics Review*, *13*(1), 61–77. https://doi.org/10.15678/EBER.2025.130104

Appendix 1. Statement Description

No.	Item Code	Statement Item
1	P23	If I am unable to understand an issue related to the biotechnology business field, I seek assistance from others.
2	P26	I am able to enhance my capability to develop biotechnology-based business products.
3	P42	A biotechnology entrepreneur builds networks with diverse business communities.
4	P43	In my opinion, a biotechnology business must clearly identify the firm and its target market.
5	P25	I am able to develop biotechnology products with economic value.
6	P14	I am able to adjust my business activity plans when conditions change.
7	P17	I am able to develop new business activity plans when the plans I am implementing differ from expectations.
8	P18	I strive to remain focused on the outcomes I intend to achieve when operating a biotechnology-related business.
9	P44	I believe that the use of computers is useful for systematically managing business information in the biotechnology sector.
10	P45	In my opinion, many local biotechnology businesses are developing new products and services that are marketed beyond their local regions.
11	P20	I am capable of pursuing biotechnology-based business targets through innovative and responsible approaches.
12	P22	I am able to complete all stages of biotechnology-based business development.
13	P28	I keep myself informed about the latest developments in biotechnology to ensure that my entrepreneurial competencies remain up to date.
14	P15	I am able to adjust my business activity plans when I do not achieve optimal results.
15	P46	In my opinion, the biotechnology business I run possesses a competitive advantage over other competitors.
16	P47	Entrepreneurs in the biotechnology sector build networks by seeking new members with whom to share information.
17	P30	I am able to determine independently what I do and do not do when running a biotechnology-related business.
18	P1	I am able to communicate effectively with various stakeholders in biotechnology business development, not solely for personal interests.
19	P11	I have the courage to take risks while operating a biotechnology-related business.
20	P31	I am able to resolve problems independently that arise while running a biotechnology-related business.
21	P4	I can easily meet new individuals who possess specific expertise in biotechnology-based entrepreneurship.
22	P36	I am aware of biotechnology products that have the potential to be developed into business ventures.
23	P13	I am able to identify work-related risks involved in running the biotechnology-based business I undertake.
24	P9	I am able to meet individuals who may be important in supporting my biotechnology-based business.
25	P2	I am able to approach various stakeholders spontaneously and professionally to develop a biotechnology-based business.
26	P21	I have a high level of responsibility in managing and developing a biotechnology-based business.
27	P35	I am aware of biotechnology business products that have not yet been marketed.
28	P37	I have original ideas for creating new biotechnology products in the market.
29	P24	I am able to clearly understand my capabilities in creating biotechnology product innovations.

30	P48	In my opinion, unmet societal needs for particular products can open up new business opportunities in the biotechnology field.
31	P16	I am able to adjust my planned approach when new opportunities arise in the biotechnology sector.
32	P29	I learn from others who are more experienced in biotechnology entrepreneurship.
33	P49	In my opinion, current technologies for marketing biotechnology products are highly diverse.
34	P50	Relationships within a biotechnology-based business network can encourage new members.
35	P33	I am responsible for my own actions while operating a biotechnology-related business.
36	P3	I regularly attend biotechnology-based entrepreneurship events where I can meet interesting individuals.
37	P7	I have the courage to approach others when I need information related to the development of a biotechnology-based business.
38	P12	I am able to manage risks in running a biotechnology-related business.
39	P38	I know when consumers demand new biotechnology-based products.
40	P41	I am able to respond creatively to business opportunities in the biotechnology sector.
41	P8	I help others by connecting them with my colleagues and biotechnology business networks.
42	P51	Government policies influence the biotechnology business I operate.
43	P19	I consistently maintain my commitment throughout every stage of biotechnology-based product development in order to achieve optimal results.
44	P52	Relationships established in biotechnology-related business activities aim to solve problems.
45	P32	When I feel free, I do my best to develop a biotechnology-based business.
46	P5	I undertake various necessary efforts to maintain professional relationships with business partners in the biotechnology sector.
47	P34	I provide solutions to market needs through the development of a biotechnology-based business.
48	P27	I participate in training programs to better manage a biotechnology-based business.
49	P10	I am able to easily establish relationships with others to develop my biotechnology-based business.
50	P40	I am able to easily establish relationships with others to develop my biotechnology-based business.
51	P6	I know the appropriate parties to contact when support is needed in developing a biotechnology-based business.
52	P39	I am able to think ahead about emerging developments in the biotechnology sector.