INTERNATIONAL JOURNAL TRENDS AND DEVELOPMENTS IN EDUCATION
JTADE

5(1), 2025
www.jtade.com
ISSN: 2791-9951

Development of the STEAM+E (Entrepreneurship) Skills Scale for Teachers: A Validity and Reliability Study

Assoc. Prof., Mehmet BAŞARAN, Gaziantep University, mehmetbasaran@gaziantep.edu.tr, 0000-0003-1871-520X

Denizhan YAĞLI, Gaziantep University, denizhanyagli@gmail.com, 0000-0001-6382-1226

Fatma Tuba ER, Gaziantep University, tubaerriletisim@gmail.com, 0000-0003-3161-5668

Prof. Dr., Ömer Faruk VURAL, Sakarya University, omervural@sakarya.edu.tr, 0000-0002-1520-3762

Keywords

STEAM
STEAM+E
Entrepreneurship
Scale Development

Article Info:

Received : 03-02-2025
Accepted : 09-02-2025
Published : 30-06-2025

DOI: 10.5281/zenodo.15712032

Abstract

This research aims to develop a valid and reliable measurement tool for teachers' STEAM (Science, Technology, Engineering, Art, and Mathematics) and entrepreneurship skills. While STEAM education aims to develop students' 21st-century skills, such as problem-solving, creativity, and collaboration, with an interdisciplinary approach, entrepreneurship education encourages transforming these skills into value-added products. Research: It was conducted with 146 teachers in Turkey, Spain, Portugal, Greece, Lithuania, and Italy who are actively teaching in branches in the field of STEAM. The study used the expert opinion method to ensure appearance and scope validity, and Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were used to ensure construct validity because of EFA obtained a measurement tool consisting of 37 items and four factors (interdisciplinary cooperation, entrepreneurial skills, risk-taking and decision-making, creativity and innovation), which explains 72.42% of the total variance value. As a result of CFA, it was determined that 37 items and the four-factor model obtained in EFA had the desired and sufficient fit indices. Cronbach's Alpha coefficient confirmed the reliability of the scale. Cronbach's Alpha coefficients of interdisciplinary cooperation, entrepreneurial skills, risk-taking and decision-making, creativity, and renewal factors in the scale were determined as .935, .935, .960, and .961, respectively, and Cronbach's Alpha coefficient for the whole scale was determined as .977. Considering these findings, it can be said that the STEAM+E (Entrepreneurship) Skills Scale for Teachers is a valid and reliable measurement tool.

This article has been created within the scope of the Erasmus+ Cooperation Partnerships in the field of Higher Education (KA220-HED) project titled ***'Defining Standards in STE²AM (Entrepreneurship) Education'*** with project number 2022-1-TR01-KA220-HED-000088047.

INTRODUCTION

With the rapid advancements occurring across multiple domains in today's fast-evolving world, the ability of individuals to generate creative ideas and develop innovative solutions has become increasingly significant (OECD, 2018). As societies transition into a digital era dominated by information and communication technologies (ICT), individuals must acquire essential skills that enable them to access, analyze, and effectively utilize high-quality information necessary for their personal, academic, and professional lives (Kardeş, 2020). The contemporary era, often referred to as the "age of technology," necessitates a unique set of competencies that empower individuals to thrive in a highly competitive and dynamic global landscape. These competencies, collectively termed "21st-century skills," have been extensively studied by researchers and organizations worldwide, highlighting their role in preparing individuals for the challenges and opportunities of the modern world (O'Neal et al., 2017).

Despite the widespread recognition of 21st-century skills, researchers and institutions have faced difficulties in establishing a universally accepted framework that precisely defines these competencies (Beers, 2011; Geisinger, 2016). While various organizations have proposed differing conceptualizations of these skills, the overarching objective remains the same: to equip individuals with the competencies needed to navigate and succeed in the 21st century (Voogt & Roblin, 2012). Among the diverse frameworks proposed, the Partnership for 21st-Century Learning (P21) framework stands out as one of the most widely adopted due to its comprehensive and structured approach to categorizing these skills in a globally applicable manner (Beers, 2011).

The P21 framework (2008) categorizes 21st-century skills into three broad domains: learning and innovation skills, literacy skills, and life and career skills. The learning and innovation skills category includes competencies such as creativity and innovation, problem-solving, critical thinking, communication, and collaboration, all of which are fundamental for fostering adaptability and ingenuity in an ever-changing world. The literacy skills category encompasses information literacy, media literacy, and technology literacy, which are crucial for individuals to critically assess information sources, engage responsibly with digital content, and navigate the complexities of the digital age. Lastly, the life and career skills category comprise essential attributes such as flexibility and adaptability, social and cultural awareness, leadership, productivity, accountability, and responsibility, which contribute to an individual's personal and professional growth, enabling them to work effectively in diverse environments.

Further expanding on the P21 framework, Lamb et al. (2017) proposed the inclusion of metacognitive thinking and motivation as critical components of 21st-century skills, emphasizing the importance of self-regulated learning and intrinsic drive in academic and professional success. In alignment with this perspective, the OECD (2018) report, "Education 2030: The Future We Want 2030," introduced a broader classification of essential skills, incorporating knowledge, skills, attitudes, and values. According to the OECD, knowledge should be categorized into disciplinary, interdisciplinary, and epistemic knowledge, while skills should encompass cognitive, metacognitive, social-emotional, and physical/practical abilities. Additionally, the report underscores the necessity of cultivating attitudes and values at multiple levels, including personal, local, societal, and global dimensions.

The OECD (2018) further highlights the importance of basic literacy competencies, including traditional literacy, health literacy, information literacy, and digital literacy, as foundational elements of education systems. Beyond literacy, the report calls for fostering a sense of responsibility, the ability to develop new values, and the capacity to generate practical solutions to complex global challenges. This holistic approach to education reflects the growing consensus that 21st-century skills extend beyond academic proficiency to include the development of well-rounded individuals who can contribute meaningfully to their communities and the global society.

Nowadays, STEAM education is a significant focus for educators and various specialists, along with 21st-century skills. STEAM education has been formed by integrating art into STEM education, which consists of four basic disciplines. STEAM (Science, Technology, Engineering, Arts, and Mathematics) stands out as one of the effective teaching methods in modern education and offers an interdisciplinary approach based on the principles of experiential learning (Tsuprus et al., 2009). This educational model combines knowledge and methods from different disciplines, allowing students to integrate this knowledge into problem-solving (Glass & Wilson, 2016; Herro et al., 2017). STEAM education aims to develop students' skills to produce solutions to real-world problems by giving them a chance to combine this knowledge with practical applications (Honey et al., 2014). It significantly contributes to developing essential critical thinking and problem-solving skills by enriching students' physical, intellectual, and cultural worlds (Çorlu & Aydın, 2016). Through project-based, collaborative, and experiential learning methods, students participate in an active learning environment and can better understand real-world problems by connecting with them (Kardeş, 2020). This approach provides students with knowledge and the ability to use this information effectively and produce solutions. By combining the fundamentals of mathematics and science with the fields of engineering and technology, the STEAM education model allows students to develop creative and original solutions, helping students to develop an interdisciplinary perspective while developing critical thinking and creativity skills (Yakman & Lee, 2012; Kennedy & Odell, 2014). One reason the arts are included in STEM education is that it offers students a wide range of jobs. The art sector includes many occupational groups, such as musicians, artists, dancers, actors, directors, graphic designers, architects and photographers. In addition, there has been significant growth in computer technologies, digital video, visual technologies, animation, and game sectors. For a country to stand out in global competition, it needs to show itself in areas with this growth potential, and art plays an important role for STEAM in this context (Mercin, 2019).

In light of all this information, Yakman (2008) developed the STEAM pyramid to understand better and analyze the interactive nature of science, technology, engineering, mathematics, and art. This pyramid is designed to visualize how these disciplines interact and how their applications can be structured. Below is the framework for interdisciplinary teaching of STEAM education created by Yakman (2008) in Figure 1:

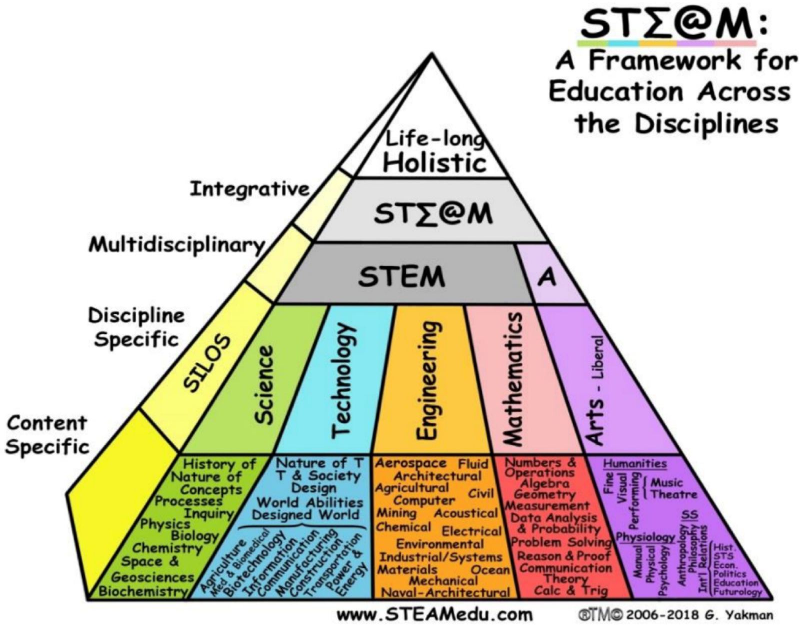

Figure 1. *STEAM Education Scheme Framework for Interdisciplinary Teaching (Yakman, 2008)*

Yakman (2008) aims to classify various fields of study broadly and show how these fields are interconnected. This approach aims to teach subjects more comprehensively and integratively by providing inter-curricular integration. Yakman (2008) revealed these connections by classifying fields such as science, technology, engineering, mathematics, and art in detail in the pyramid. For example, science includes sub-disciplines such as biology, chemistry, and physics, while technology covers various application areas such as agriculture and energy. Engineering includes a wide range from architecture to computing, while mathematics includes subjects such as algebra and geometry. Art, on the other hand, includes fine arts, language, and other social sciences. STEAM education aims to develop student's academic and life skills by using the relationships between these fields in an objective and personal context in teaching settings. This educational approach is underpinned by various recognized educational philosophies and classroom management strategies, thus enabling a deeper understanding and knowledge transfer between subjects. STEAM aims to provide a more effective and lasting learning experience by increasing the competencies of students and educators (Liao, 2016).

In addition to contributing to the development of various skills of students, STEAM education also attaches importance to teachers' acquisition of new competencies beyond their traditional roles. A study by Hunter-Doniger and Sydow (2016) stated that teachers should have the following roles in the STEAM education process:

- Guidance
- Facilitator
- Focus on learning methods based on interdisciplinary connections and critical approaches,
- To show students that the problems they face are opportunities for them to demonstrate their skills,
- Providing constructive feedback without judgment,
- Conducting evaluations in a process-oriented manner, not product-oriented.

As can be seen from these items, STEAM education aims to encourage self-directed learning, to bridge the gap between students' daily life experiences and their education, and to enable teachers to carry out the process effectively with feedback as a guide for students.

STEAM and Entrepreneurship

One of the main goals of STEAM education is to equip individuals with the skills that can respond to the needs of the 21st century (Sanders, 2009). In today's world, individuals need various competencies such as creative thinking, problem-solving, critical thinking, and collaborative learning (OECD, 2005; P21, 2009; HERE, 2007). These skills are desired to be acquired through multidimensional learning processes supported by interdisciplinary teaching methods (Smith & Karr-Kidwell, 2000). By integrating science, technology, engineering, art, and mathematics, the STEAM approach enables students to structure knowledge, relate it to their daily lives, and produce more flexible and creative solutions to their problems (Wiles & Bondi, 2011). STEAM education is a model that requires students to solve problems with an interdisciplinary approach by using different disciplines together and developing innovative solutions in this process. This process improves students' problem-solving skills and emphasizes their entrepreneurial skills. Students should be able to market the multidisciplinary solutions they have developed and transform these solutions into value-added products by following the problem-solving steps. Thus, STEAM education encourages students who are successful in different fields to work together, enables students to complete each other's deficiencies, and allows original solutions to be produced following scientific processes. These solutions are supported by entrepreneurial skills and transformed into high-value-added products.

As a result, STEAM education plays a critical role in training the qualified workforce that countries increasingly need due to rapidly developing technologies and communication tools, and in this context, it substantially contributes to developing 21st-century skills. This close relationship with entrepreneurship ensures that STEAM has a privileged place among today's education models. STEAM education provides a foundation for identifying opportunities (Flanagan, 2014), while entrepreneurship is the ability to explore and evaluate these opportunities (Nambisan, 2014).

When the relevant literature is examined, the primary motivation for this research is that no quantitative measurement tool measures teachers' STEAM and entrepreneurship skills. The aim of this research, which is based on filling the relevant gap identified in the literature, is to develop a measurement tool that measures teachers' STEAM and entrepreneurship skills and to examine the validity and reliability of this measurement tool. Since there is no measurement tool in this context in the literature, it is expected that the relevant scale will measure the skills of teachers in terms of STEAM and entrepreneurship and identify the deficiencies at this point. By offering a new perspective on STEAM standards, this scale aims to base the place of STEAM and entrepreneurship in education on a firmer foundation and to meet the measurement needs of teachers in this field.

METHOD

This section aims to develop the STEAM + E scale using quantitative methods. Information about the research working group, data collection tools, data collection process, data analysis, and other stages of scale development are included.

STUDY GROUP

During the research process, data were collected online through Google Forms. The descriptive information of 146 participants in the study group of the study according to some variables is presented in Table 1 below:

Table 1. *Percentages and distributions of the working group according to some variables*

Variable	Sub-dimensions of the variable	Number of People (N)	Weight (%)
Gender	Woman	109	74.6
	Male	37	25.4
	Sum	146	100
Professional Experience	1-5 Years	37	25.3
	6-10 Years	26	17.9
	10+ Years	83	56.8
Branch	Science	78	53.4
	Mathematics	15	10.3
	Engineering	12	8.2
	English	7	4.8
	Information Technologies	4	2.7
	Other	30	20.6
How to apply a scale	Online	146	100
	Sum	146	100

The participants in the study were selected based on the voluntary participation of the teachers using a random sampling method.

DATA COLLECTION PROCESS

In this study, Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were applied to different study groups following the research purpose. When the literature is examined, it is seen that the application of EFA and CFA to different study groups will affect the validity and reliability of the study more positively (Fabrigar et al., 1999; Worthington and Whittaker, 2006). Of the 146 participants in Turkey, Spain, Portugal, Greece, Lithuania, and Italy who constituted the research study group, EFA processes were carried out with 110 and CFA processes with the remaining 36. The adaptive validity and reliability study was conducted with all 146 participants. Then, the tests of the participants who did not participate in the first or any of the second test-retests, which were applied at intervals of 15 days, were eliminated, and the analyses were continued on 34 teacher forms of the remaining participants. In order to increase the reliability of the analyses, in the first and second applications, each teacher was given a four-digit code to match the forms without using the teachers' names, and these codes were asked to be written while filling out the forms. In Table 2 below, the number of participants in the EFA-CFA and Test-Retest reliability of the study group is included in the analysis, and the branches of the participants are given.

Table 2: *Branches and numbers of participants included in the analyses*

Analysis Type		Branches	f	%
Construct Validity	Exploratory Factor Analysis	Science	60	54.5
		Mathematics	12	10.9
		Engineering	10	9.1
		English	5	4.5
		Information Technologies	3	2.7
		Other	20	18.2
		Sum	110	100
	Confirmatory Factor Analysis	Science	18	50
		Mathematics	3	8.4
		Engineering	2	5.6
		English	2	5.6
		Information Technologies	1	2.7
		Other	10	27.7
		Sum	36	100
Test-Retest Reliability Analysis		Participating Teachers	34	100

Ensuring the validity and reliability analyses are conducted properly in the scale development process requires determining an appropriate sample size. Various perspectives have been proposed regarding the adequate sample size for Exploratory Factor Analysis (EFA). Tabachnick et al. (2019) suggest that the required sample size for factor analysis depends on factors such as the data structure and the number of variables, while Field (2013) emphasizes that a sufficient sample size is essential for producing reliable results in factor analysis.

DATA COLLECTION TOOL

The STEAM+E (Entrepreneurship) Skills Scale for Teachers has been developed in light of up-to-date information obtained after a detailed literature review on STEAM and Entrepreneurship. According to the examination, the prominent concepts are creativity and innovation, risk-taking and decision-making, interdisciplinary cooperation, and entrepreneurship skills. Along with the concepts, a detailed literature review was carried out for these concepts, considering the skills (cooperation, problem-solving, communication, creativity, analytical and critical thinking, digital literacy skills, etc.) desired by the students in STEAM education. A pool of 45 items was created, and appropriate items were decided upon due to the literature review. The answer key for the scale in which these items will be included has been prepared in five-point Likert type, and the "Strongly Disagree-1, Disagree-2, Undecided-3, Agree-4, Strongly Agree-5" system was used in the scoring.

SCALE DEVELOPMENT PHASES

As the first of the scale development stages, the content of the items was created by conducting a detailed literature review on the above-mentioned entrepreneurship concepts and the skills expected to be gained by students with STEAM. After the literature review, the substance pool of the items was revealed. Preliminary interviews were held with 2 experts working in Curriculum and Instruction, 2 experts working in STEAM Education, and 2 experts working in Entrepreneurship with the prototype material pool created. According to the opinions received from the experts, a positive consensus has been reached that the items in the item pool of the scale include the concepts of creativity and renewal, risk-taking and decision-making, interdisciplinary cooperation, and entrepreneurship skills and that there are items for all of the skills that are desired to be gained by students with STEAM education. 45 items in the item pool were transferred to the Expert Opinion Form prepared by the researchers to be submitted for expert opinion. Then, expert opinions were collected from 6 people, including 2 teachers, 2 experts working in Curriculum and Instruction, and 2 experts working in Measurement and Evaluation. After the expert opinions were obtained through the expert opinion form, 5 items were eliminated from the item pool, and the corrections among the rest were revised in line with the experts' opinions. The draft of the 40-item scale was finalized and presented to a Turkish grammar expert, and errors in expression disorders, spelling mistakes, grammar rules, and punctuation marks in the scale were identified and corrected.

In the second phase of scale development, the scale was piloted to the participant list detailed in the study group. At this stage, the scale was delivered to the participants online via Google Forms.

ANALYSIS OF DATA

After the end of the process of applying the scale to the participants, data analysis was carried out through the SPSS 27.0 package program. Validity analyses of the scale were examined by dividing it into subcategories within the scope of structure, appearance, scope, and compliance validity. In order to analyze the construct validity for the scale, an exploratory factor analysis (EFA) and a confirmatory factor analysis (CFA) were performed first. The structural features of the pilot form prepared for the scale with EFA were examined, and its sub-dimensions were revealed. After the CFA was performed, this structure's accuracy level was measured. The CFA phase is implemented to conform the structure unearthed in EFA with scientific processes and to ensure that the structure is built on more solid foundations. In order to interpret appearance and scope validity, the expert opinion method was used. Regarding fit validity, since there is no other scale with a similar quality in the literature review, the correlation values between the overall scale and its subcategories were examined. In terms of reliability, the Cronbach Alpha internal consistency coefficient of the scale was analyzed, and factor eigenvalue analyses were performed to determine the scale's factors.

RESULTS

In order to test the construct validity of the STEAM+E (Entrepreneurship) Skills Scale for Teachers, Exploratory Factor Analysis (EFA), which is the most basic analysis among factor analyses, was used to determine the construct validity in scale development studies, and Confirmatory Factor Analysis (CFA) was used to determine the accuracy of this structure.

EXPLORATORY FACTOR ANALYSIS

Before performing the factor analysis of the scale, it is necessary to determine whether the data obtained are suitable for this analysis. For this purpose, according to the results of the KMO and Barlett Test conducted on 40 items in the scale, the KMO value was determined as .948 and the Barlett Test as 5.616. After the evaluation, the items that did not create the desired factor load in any factor and the items that were distributed to two factors and whose load values were less than .1 were eliminated from the scale within the scope of validity and reliability measures (Büyüköztürk, 2016; Kline, 2011). At this point, three items were removed from the scale after factor analysis. Then, the analysis was made once again on the remaining 37 items. As a result of the findings obtained from the factor analysis applied for the second time, the KMO coefficient and Barlett's Sphericity test were performed to examine the correlation matrix and to understand whether items still need to be removed. At this stage, the KMO coefficient was determined as .951, while the Barlett Sphericity test values produced statistically significant results (χ^2=6.091, p<.01).

Table 3. *KMO and Barlett Test Findings*

KMO Sampling Adequacy Measurement		.951
Barlett Sphericity Test	x^2	5616.72
	sd	666
	p	.000

Considering the findings obtained from the second KMO and Barlett's Test, where the STEAM+E (Entrepreneurship) Skills Scale was applied for teachers, it was deemed appropriate to apply EFA with the remaining 37 items on the scale. Then, factor analysis was started, and the principal component analysis (Varimax rotated) was applied to determine whether the items were distributed to independent factors. As a result of the analysis, the items related to the scale were distributed under four factors. The number of items distributed by factors: 10 for the first factor, 10 for the second factor, 9 for the third factor, and 8 for the last factor. These items are named after considering the basic concepts of STEAM and entrepreneurship. According to this nomenclature, the name of the first factor is "Interdisciplinary Cooperation," the name of the second factor is "Entrepreneurial Skills," the name of the third factor is "Risk Taking and Decision Making," and the name of the last factor is "Creativity and Innovation." The values related to the factor loads of the items collected under these four headings are given in Table 4.

Table 4. *Principal Component Analysis of the STEAM+E (Entrepreneurship) Skills Scale for Teachers Rotated concerning Prime Axes Item Factor Loads*

Item No	Factor 1 Interdisciplinary Collaboration	Factor 2 Entrepreneurship Skills	Factor 3 Risk-taking and Decision-Making	Factor 4 Creativity and Renewal
IC2	.905			
IC8	.820			
IC4	.816			
IC1	.814			
IC3	.801			
IC6	.768			
IC5	.762			
IC7	.706			
IC10	.637	.327		
IC9	.622			
E9		.949		
E8		.926		
E6		.870		
E7		.849		
E4		.797		
E5		.788		
E3		.754	.372	
E2		.736		
E10		.708		
E1		.633		
R1			.725	
R2			.681	
R4			.655	
R10			.618	
R3			.576	
R5	.344		.557	
R8			.496	
R9			.489	
R6			.421	
Y7				.804
Y8				.764
Y9				.737
Y5				.662
Y10				.583
Y6				.569
Y1	.302			.508
Y3	.317			.482
Variance Explained (Total: 72.42%)	%56.39	%9.23	%3.95	%2.83

Looking at Table 3, four scale factors were formed due to the varimax rotated rotation process in the EFA process in the STEAM+E (Entrepreneurship) Skills Scale for Teachers. These factors explain 72.42% of the total variance value for the scale. When the load values of the factors formed are examined, the factor loads of the items that make up factor 1 (Interdisciplinary Cooperation) vary between .622 and .905, the factor loads of the items that make up factor 2 (Entrepreneurship Skills) vary between .633 and .949, the factor loads of the items that make up factor 3 (Risk Taking and Decision Making) vary between .421 and .725. The factor loads of the items that make up factor 4 (Creativity and Renewal) vary between .482 and .804. After the factor analysis, the STEAM+E (Entrepreneurship) Skills Scale for Teachers was developed with 37 items that met the desired and sufficient conditions.

In order to test the reliability of the data obtained after the scale application, Cronbach Alpha reliability coefficient analysis was performed. Cronbach's Alpha coefficient is a reliability coefficient applied to test the internal consistency levels of the entire scale and its sub-factors (Büyüköztürk, 2016).

Table 5. *Cronbach's Alpha internal consistency coefficient values for the scale*

Dimension Name	Cronbach's Alpha Coefficient	Number of items
Factor 1	.935	10
Factor 2	.935	10
Factor 3	.960	9
Factor 4	.961	8
Sum	.977	37

As a result of the reliability analysis, Cronbach's Alpha coefficient of the whole scale was determined as .977. In addition, Cronbach's Alpha coefficient for each factor of the scale was also calculated. Accordingly, it was found to be .935 for Factor 1 (Interdisciplinary Cooperation), .935 for Factor 2 (Entrepreneurship Skills), .960 for Factor 3 (Risk Taking and Decision Making) and .961 for Factor 4 (Creativity and Renewal). In order to say that the data obtained from a scale are reliable, Cronbach's Alpha coefficient must be above .70 (Bernardi, 1994). As a result of the values obtained at this stage, the STEAM+E (Entrepreneurship) Skills Scale for Teachers has proven reliable.

CONFIRMATORY FACTOR ANALYSIS

Confirmatory factor analysis (CFA) was conducted to confirm the structure obtained in exploratory factor analysis with a different study group and an alternative statistical method. Various fit indices are used in the CFA process to assess the tested model's adequacy. In this study, the fit indices proposed by Hu and Bentler (1999) were included. These indices include CMIN/DF (X^2/sd), GFI (Goodness Fit Index), AGFI (Adjusted Goodness Fit Index), CFI (Comparative Fit Index), NNFI (Unstandardized Fit Index), IFI (Redundancy Fit Index), RMSEA (Square Root Mean Value of Approximate Errors) and SRMR (Square Root Mean of Standardized Error Squares) adjusted for sample size. These indices are important metrics for determining how well the model fits the data.

The fit indices examined within the scope of Confirmatory Factor Analysis, the best and acceptable value ranges of these indices, and the values obtained from the scale as a result of CFA are presented in Table 6.

Table 6. *CFA Index Value Ranges (Çokluk, Şekercioğlu & Büyüköztürk, 2010; Hu & Bentler, 1999) and CFA Results*

Reviewed Compliance Indices	Perfect Fit Measure	Acceptable Fit Criterion	Values for Scale
X^2/sd (CMIN/DF)	0 ≤ X^2/sd ≤ 2	2 ≤ X^2/sd ≤ 3	1,68
GFI	.95 ≤ GFI ≤ 1.00	.80 ≤ GFI ≤ .95	,842
AGFI	.90 ≤ AGFI ≤ 1.00	.85 ≤ AGFI ≤ .90	,806
CFI	.95 ≤ CFI ≤ 1.00	.90 ≤ CFI ≤ .95	,924
YOUTH	.95 ≤ IFI ≤ 1.00	.90 ≤ IFI ≤ .95	,925
RMSEA	.00 ≤ RMSEA ≤ .05	.05≤ RMSEA ≤.08	,068
SRMR	.00 ≤ SRMR ≤ .05	.05 ≤ SRMR ≤ .10	,050

When the findings obtained as a result of the CFA analysis are examined, it is seen that the X^2/sd (CMIN/DF) compliance index is excellent, and the GFI, CFI, IFI, RMSEA, SRMR values are within the acceptable range. These results prove that the level of compliance with the four factors of the scale is at the desired and sufficient level. However, the factor loads for the four-factor model that emerged as a result of CFA are presented in Figure 2.

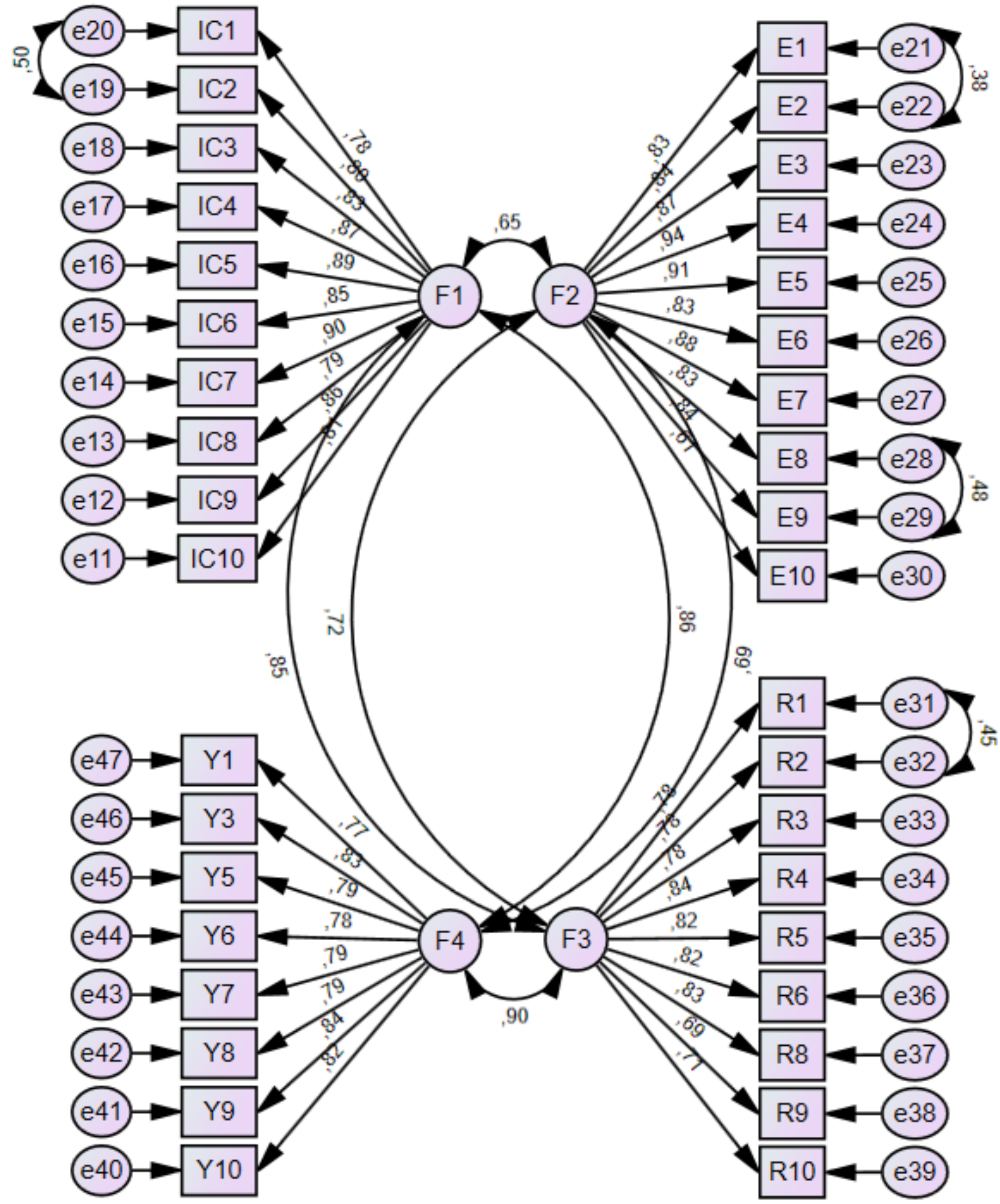

Figure 2. *Standardized Factor Loads of Scale*

Figure 2 shows factor loads between .61 and .94 but at a high level with general density. These results prove the suitability of the model. In the figure, it is seen that the error variances of some items are apportioned. This sharing was carried out by taking expert opinions to improve the items with high modification index values from the findings obtained from the analysis.

DISCUSSION AND CONCLUSION

This study was conducted by following systematic scale development methodologies (DeVellis, 2021; Boateng et al., 2018) to design the STEAM+E (Entrepreneurship) Skills Scale for Teachers. The study aimed to establish a valid and reliable measurement tool to assess teachers' competencies in integrating Science, Technology, Engineering, Arts, Mathematics, and Entrepreneurship (STEAM+E) into their teaching practices, a growing emphasis in global education systems (Yakman & Lee, 2012; Beers, 2011). The scale development process followed widely accepted psychometric analysis steps, including Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) to determine the underlying structure and factor loadings (Tabachnick & Fidell, 2019). Furthermore, the scale’s construct validity, face validity, and content validity were assessed, ensuring alignment with previous research in educational measurement (American Educational Research Association [AERA], 2014). The Cronbach's Alpha reliability coefficient (Cronbach, 1951) was applied to assess the internal consistency of the instrument, confirming the scale's reliability.

The initial version of the scale included 45 items, which were reduced to 40 items following expert panel reviews, ensuring content validity through qualitative evaluation (Lawshe, 1975; Creswell & Poth, 2016). The number of items was further refined to 37 after conducting EFA, which identified redundant or low-loading items (Worthington & Whittaker, 2006). As a result of comprehensive validity and reliability analyses, a four-factor model emerged, establishing a robust and empirically validated tool for assessing STEAM+E competencies among teachers. The final version of the scale consists of 37 positively worded items, eliminating the need for reverse coding, which improves clarity and response accuracy (Nunnally & Bernstein, 1994). The scale follows a five-point Likert-type response format, where 1 = Strongly Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, and 5 = Strongly Agree (Likert, 1932).

Participants can achieve a maximum score of 185 and a minimum score of 37, with factor scores analyzed both collectively and individually, depending on the specific research focus. The finalized version of the STEAM+E Skills Scale is included in the appendices for further reference. Given that the scale was explicitly designed for teachers, it is recommended that additional validity and reliability analyses be conducted when applying it to different sample groups such as preservice teachers, administrators, or STEM educators in international contexts (OECD, 2018; Voogt & Roblin, 2012). This study contributes to the growing body of literature on STEAM education assessment tools and aligns with global efforts to enhance teachers' entrepreneurship and innovation skills in 21st-century learning environments (Lamb et al., 2017; Blaschke, 2012).

REFERENCES

AERA, (2014). *Standards for educational and psychological testing.* New York: American Educational Research Association.

Beers, S. Z. (2011). *21st century skills Preparing students for their future.* Retrieved from https://www.mheducation.com/prek-12/(Erişim tarihi:10.07.2024).

Bernardi, R. A. (1994). Validating research results when cronbach's alpha is below .70: A methodological procedure. *Educational and Psychological Measurement, 54*(3), 766-775. https://doi.org/10.1177/0013164494054003023

Blaschke, L. M. (2012). Heutagogy and lifelong learning: A review of heutagogical practice and self-determined learning. *The International Review of Research in Open and Distributed Learning*, *13*(1), 56-71.

Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quiñonez, H. R., & Young, S. L. (2018). Best practices for developing and validating scales for health, social, and behavioral research: a primer. *Frontiers In Public Health*, *6*, 149.

Büyüköztürk, Ş. (2016). *Sosyal bilimler için veri analizi el kitabı.* 22. Baskı, Ankara: Pegem Akademi.

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*(3), 297-334.

Çokluk, Ö., Şekercioğlu, G., & Büyüköztürk, Ş. (2010). *Sosyal bilimler için çok değişkenli istatistik: SPSS ve LISREL uygulamaları* (3. Baskı). Ankara: Pegem Akademi.

Çorlu, M., & Aydın, E. (2016). Evaluation of learning gains through integrated STEM projects. I*nternational Journal of Education in Mathematics, Science and Technology, 4(*1), 20-29. http://dx.doi.org/10.18404/ijemst.35021

DeVellis, R. F., & Thorpe, C. T. (2021). *Scale development: Theory and applications*. Sage publications.

Fabrigar, L. R., Wegener, D. T., MacCallum, R. C., Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods, 4*(3), 272–299. https://psycnet.apa.org/doi/10.1037/1082-989X.4.3.272

Field, A. (2013). *Discovering statistics using IBM SPSS statistics*. Ssage.

Flanagan, J. (2014). *STEM and entrepreneurship: A fusion for the economy's sake. STEM education*. STEM and Entrepreneurship: A fusion for the economy's sake, Toronto Star: May 2014.

Geisinger, K. F. (2016). 21st century skills: What are they and how do we assess them?. *Applied measurement in education*, *29*(4), 245-249. https://doi.org/10.1080/08957347.2016.1209207

Glass, D., & Wilson, C. (2016). The art and science of looking: Collaboratively learning our way to improved STEAM integration. *Art Education, 69(*6), 8-14. https://doi.org/10.1080/00043125.2016.1224822

Herro, D., Quigley, C., Andrews, J., & Delacruz, G. (2017). Co-Measure developing an assessment for student collaboration in STEAM activities. *International journal of STEM education*, *4*, 1-12. https://doi.org/10.1186/s40594-017-0094-z

Honey, M., Pearson, G., Schweingruber, H. *STEM integration in K-12 education: Status, prospects and an agenda for research.* Washington DC, The National Academies Press, 2014. https://doi.org/10.17226/18612

Hu, L. & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Structural Equation Modeling, 6*(1), 1-55. https://doi.org/10.1080/10705519909540118

Hunter-Doniger, T., & Sydow, L. (2016). A journey from STEM to STEAM: A middle school case study. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *89*(4-5), 159-166. https://doi.org/10.1080/00098655.2016.1170461

ISTE. (2007). ISTE Standards for Student. International Society for Technology in Education. https://www.iste.org/standards/for-educators

Kardeş, S. (2020). Okul öncesi eğitim programının 21. yüzyıl becerileri ve STEAM eğitimi bağlamında incelenmesi. *Eğitimde Kuram ve Uygulama, 16*(2), 109-119. https://doi.org/10.17244/eku.703361

Kennedy, T. J., & Odell, M. R. (2014). Engaging students in STEM education. *Science education international*, *25*(3), 246-258.

Kline, R. B. (2011). *Principles and practice of structural equation modeling.* New York: Guilford Publications.

Lamb, S., Maire, Q., & Doecke, E. (2017). *Key skills for the 21st century: An evidence-based review.* Sydney: NSW Department of Education.

Lawshe, C. H. (1975). A quantitative approach to content validity. *Personnel Psychology, 28*(4), 563-575.

Liao, C. (2016). From interdisciplinary to transdisciplinary: An arts-integrated approach to STEAM education. *ART education*, *69*(6), 44-49. https://doi.org/10.1080/00043125.2016.1224873

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology, 140*, 1-55.

Mercin, L. (2019). STEAM eğitiminde sanatın yeri, I*nonu University Journal of Art and Design,* 9(19), 28-41. http://dx.doi.org/10.16950/iujad.514132

Nambisan, K. (2014). *Teachers' attitudes towards and uses of translanguaging in English language classrooms in Iowa* (Master's thesis, Iowa State University).

Nunnally, J., & Bernstein, I. (1994). *Psychometric Theory 3rd edition (MacGraw-Hill, New York)*.

Organization for Economic Cooperation and Development (OECD). (2005). *Elearning in Tertiary education*. Policy brief OECD, Paris.

OECD. (2018). *The future of education and skills: Education 2030: The future we want.* Access: https://www.oecd.org/education/2030/E2030%20Position%20Paper%20(05.04.2018).pdf

O'Neal, L. J., Gibson, P., & Cotten, S. R. (2017). Elementary school teachers' beliefs about the role of technology in 21st-century teaching and learning. *Computers in the Schools, 34*(3), 192-206. http://dx.doi.org/10.1080/07380569.2017.1347443

Partnership for 21st Century Skills. (2008). *21st century skills, education and competitiveness: A resource and policy guide.* Washington, DC: Partnership for 21st Century Skills. Erişim Tarihi: 10.08.2024 https://files.eric.ed.gov/fulltext/ED519337.pdf

Partnership for 21st Century Skills-P21. (2009). *Framework for 21st century learning.* http://www.p21.org/our-work/p21

Sanders, M. (2009). Stem, stem education, stemmania. *The Technology Teacher, 68* (4), 20- 26. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Smith, J. & Karr-Kidwell, P. (2000). *The interdisciplinary curriculum: A literary review and a manual for administrators and teachers.* https://files.eric.ed.gov/fulltext/ED443172.pdf

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2019). *Using multivariate statistics.* 2nd Edn, Vol. 5. NY, NY: Pearson.

Tsupros, N., Kohler, R., & Hallinen, J. (2009). STEM education: A project to identify the missing components. *Intermediate Unit, 1,* 11-17.

Voogt, J. & Roblin, N. P. (2010). *21st Century Skills: Discussion Paper.* University of Twente. Retrieved from (https://www.voced.edu.au/content/ngv:56611).

Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies*, *44*(3), 299-321.

Yakman, G. (2008). *"STEAM Education: an Overview of Creating a Model of Integrative Education".* Curriculum & Instruction: ISTEM Virginia Polytechnic and State University, Pulaski.

Yakman, G., & Lee, Y. (2012). Exploring the Exemplary STEAM Education in the U.S. as a Practical Educational Framework for Korea. *Journal of Korea Association Science Education, 32*(6), 1072-1086. https://doi.org/10.14697/jkase.2012.32.6.1072

Wiles, J.W. ve Bondi, J. C., (2011). *Curriculum development a guide to practice.* Pearson.

Worthington, R. L., Whittaker, T. (2006). Scale Development Research: A Content Analysis and Recommendations for Best Practices. *The Counseling Psychologist, 34*(6), 806–838. https://doi.org/10.1177/0011000006288127

AUTHOR CONTRIBUTION

-The first author contributed to data collection, analysis, interpretation, and gave the final approval for the version to be published.

-The second author made significant contributions to the concept and design, data collection, analysis, and interpretation.

-The third author made significant contributions to the development of the conceptual framework, as well as data collection, analysis, and interpretation.

-The fourth author made significant contributions in the stages of evaluating the conceptual framework and analysis results and providing the final approval.

APPENDIX

STEAM and Entrepreneurship Skills Scale for Teachers

(There is no substance to be reverse-coded.)

No	Read the items below and select the option that suits you.	Strongly disagree	Disagree	I am undecided	Agree	Strongly agree
1	I feel empowered to come up with new ideas.					
2	I can come up with creative solutions to problems.					
3	I think I have a talent for developing innovative projects.					
4	I can combine knowledge and ideas from different disciplines when I am inspired.					
5	I can turn my innovative thoughts into practical applications.					
6	I can lead innovation processes.					
7	I can develop a project or product by making use of different perspectives.					
8	My innovative way of thinking adds value to my projects.					
9	I can develop creative approaches to solving complex problems.					
10	My ability to think innovatively influences the success of my projects.					
11	I am confident in taking risks.					
12	I can make bold decisions when bringing new ideas to life.					
13	Instead of giving up in the face of my difficulties, I look for solutions.					
14	I can think strategically when assessing risks.					
15	I can be determined and motivated even under changing circumstances.					
16	I can develop effective strategies to minimize risks.					
17	When assessing risks, I can also consider opportunities.					
18	I make a detailed plan before taking a risk.					
19	I am not afraid to take risks.					
20	I enjoy collaborating with people from different disciplines.					
21	I can share knowledge and skills with people from different disciplines.					
22	By combining ideas from different perspectives, I can achieve better results.					
23	I can bring people from different disciplines together in projects or problem-solving processes.					
24	I can develop creative projects by combining different perspectives.					
25	I can effectively integrate knowledge and skills from a variety of disciplines.					

26	I can take advantage of the opportunities that arise from combining different disciplines.	
27	We can achieve common goals by combining people's strengths in different disciplines.	
28	I can develop new ideas by synthesizing different fields of knowledge.	
29	I can coordinate people from different disciplines on projects or initiatives.	
30	I am confident in turning my ideas into a business plan.	
31	I have an entrepreneurial spirit and am not afraid to take risks.	
32	I can effectively manage resources for entrepreneurial projects.	
33	I think I am keen to start or run my own business.	
34	I can make decisions in line with my entrepreneurial vision.	
35	I have experience in creating and implementing business strategies.	
36	I can evaluate business opportunities by doing market analysis.	
37	I can be successful in turning innovative ideas into commercial potential.	