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Teachers' Readiness to Implement STEM Education: Psychometric Properties of TRi-STEM Scale and Measurement Invariance across Individual Characteristics of Greek In-Service Teachers

Theano Papagiannopoulou [1], Julie Vaiopoulou [2,3,*] and Dimitrios Stamovlasis [1]

[1] School of Philosophy and Education, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
[2] School of Psychology, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
[3] Department of Education, University of Nicosia, Nicosia 2417, Cyprus
* Correspondence: vaiopoulou.cp@unic.ac.cy

Abstract: The integration of STEM—Science, Technology, Engineering, and Mathematics—education in the curricula has become a priority in contemporary education, where teachers have a decisive role. Thus, research has focused on teachers' readiness for STEM education, where the prerequisite is to ensure valid measurements. In this study, we present the psychometric properties of the TRi-STEM scale, validated to measure teachers' readiness in implementing STEM education. The proposed scale was based on questionnaires that appeared in the literature, and the final form was adopted and refined for Greek in-service teachers (N = 494), via exploratory and confirmatory factor analyses. TRi-STEM comprises four dimensions: affective conditions (AC), cognitive conditions (CC), self-efficacy (SE), and STEM commitment (SC). The reliability measures of the four factors were AC ($\alpha = 0.972/\omega = 0.972$), CC ($\alpha = 0.976/\omega = 0.976$), SE ($\alpha = 0.934/\omega = 0.935$), and SC ($\alpha = 0.886/\omega = 0.885$), and confirmatory factor analysis showed a satisfactory fit [$\chi^2_{(249)} = 981.287$, $p < 0.001$, $TLI = 0.942$, $CFI = 0.948$, $GFI = 0.993$, $NNFI = 0.942$, $RMSEA = 0.078$ (0.073–0.083), and $SRMR = 0.062$]. In addition, measurement invariance was carried out for gender, age, years of service, school level, and university degrees. The TRi-STEM scale is an essential and applicable tool to ensure validity in educational research and support further hypotheses testing.

Keywords: STEM education; attitudes; readiness; primary and secondary; scale validation

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1. Introduction

STEM education focuses on preparing students to solve real-world problems, but also equips them with skills, such as critical thinking, collaboration, creativity, and communication [1]. STEM stands for Science, Technology, Engineering, and Mathematics, and is a student-centered approach, which effectively substitutes conventional lecture-based teaching methods with more inquiry- and project-based teaching methodologies [2]. The activities that students engage in while learning are in line with their everyday lives and involve social and physical interactions among them [3].

The environmental and social concerns of the twenty-first century, which affect international security and economic stability, might be the driving force behind the urgent need for improved STEM education worldwide [4]. The integration of STEM in education can prepare the new generation to meet the problems of the twenty-first century [5]. However, the enthusiasm of students in pursuing STEM occupations has decreased or remained unchanged [6]. As a result, the demand for STEM workers has exceeded the number of students entering the labor force [7] and countries will have difficulty developing due to a lack of skilled and professional workers [8].

The current interest in STEM education is also influenced by the results of pupils' achievement on national and international exams [9]. Compared to other countries, the

Greek scores in the Program for International Student Assessment (PISA) assessment were rated lower than the Organization for Economic Co-operation and Development (OECD) average in Chemistry, Mathematics, and Physical Sciences [10]. Therefore, Greece is currently undergoing a period of changes in its education system, which promotes a modern model of education and training, harmonized with the needs created by international competition, the transition to the green and digital economy, and the shift in the division of labor between humans and machines. Because of automation and the digitalization of operations processes, the fourth Industrial Revolution (4IR) will result in a sharp drop in the demand for many jobs, particularly those requiring manual skills and physical capabilities, and the creation of new skilled jobs by 2025 [11,12]. In order to accomplish its goals, the Greek Ministry of Education (MoE) introduced, for the 2021–2022 school year, the Skills Workshops in the context of which the STEM module will also be implemented. STEM education is a student-centered pedagogical model based on interdisciplinary, exploratory, and experiential learning, teamwork, computational thinking, and problem-solving (problem-based learning, or PBL). It is consistent with the country's mission to produce excellent human capital and to improve the education system. Children learn Science and Mathematics in a realistic, meaningful, and creative context through the application of technology. In addition, the students' learning is enjoyable and effective, involves hands-on activities, and provides a direct experience that stimulates them to think [13], while teaching them ways to solve real-world problems in their everyday lives [14].

When it comes to implementing reform in education, teachers play a crucial role, given that the objectives set forth by the MoE would be difficult to be achieved without their active participation. Before implementing STEM education, teachers who will serve as mentors must become sufficiently conversant [15] and pedagogically ready in order to effectively impart knowledge, whereas they should also be aware of the challenges and hitches that pupils face [16]. The insufficient preparation of teachers can lead to a number of shortcomings making it difficult to meet MoE goals.

In the STEM process of teaching and learning, *readiness* is crucial, particularly for educators who have to adapt to any new challenging framework. Teachers should be prepared from a didactic and knowledge-based perspective to transform content information into pedagogically effective forms, which also need to be flexible enough to accommodate a range of student backgrounds and skills. Passive instructive methods may hinder students' comprehension and prevent them from accomplishing learning objectives [17,18].

The above highlights the crucial role of teachers' readiness that justifies the increasing interest and the inquest for a firm theoretical framework for answering any challenging question about how the respective changes in the curricula will be attained, which, however, has not been established. Ergo, research has taken this responsibility and explores primarily the conjectures concerning teachers' attitudes and readiness to implement STEM education. Probing these latent variables presupposes valid means of measuring them, and, on this issue, the present paper contributes by developing and proposing an instrument to assess the readiness of Greek teachers to adopt STEM in their teaching practices.

1.1. Teachers' Level of Readiness

One's beliefs, goals, and perceived ability to carry out educational reforms are mainly the factors that impact one's readiness for change. This personal attribute expresses the degree of groundwork and a final guarantee that the teachers are change-ready. Research on teachers' preparation for STEM instruction is limited and this area by far needs a theoretical premise based on accumulated empirical evidence. Theoretical elaborations have been attempted, focusing on understanding the dimensions of readiness leading to the cognitive, affective, and behavioral readiness of teachers to implement STEM education [19,20]. It is worth examining these aspects of readiness because they are associated with measurement issues and the construction of scales. In the present work, further theoretical elaboration in conjunction with a scale development is attempted and, within the following sections, the description of the underlying dimensions is presented, providing a deeper understanding of the processes involved in ensuring and maintaining readiness. These dimensions are as follows: affective conditions (AC), cognitive conditions (CC), self-efficacy (SE), and STEM commitment (SC).

1.1.1. The Readiness of Teachers from a Cognitive Aspect

In the preceding section, the readiness of a person was described as the property of being prepared for any action, and this situation involves, among other things, cognitive aspects. Thus, *cognitive readiness* can be defined as an organized process and/or the resulting state that involves adaptability, communication, creative and critical thinking, decision-making process, metacognitive strategies, pattern recognition, problem-solving skills, resilience, situational awareness, team cohesion, and interpersonal skills [21]. Therefore, the ability of a teacher to think critically and creatively when developing an idea to solve problems or overcome difficulties is referred to as cognitive preparedness. To implement a new STEM curriculum, teachers must possess the necessary knowledge and be capable of handling and use a new notion effectively once they have acquired and understood it. Then, from a cognitive perspective, they are considered to be prepared and can support the growth and expansion of the pupils' understanding [20,22]. If the degree of the teacher's cognitive preparedness falls short of what is required by the curriculum, then the STEM implementation will fail or be delayed.

Thus, it is crucial that instructors not only understand strategic methods to make an amendment but also have the necessary skills that allow them to conform to the new educational perspective. Otherwise, any attempts to reform will lead to resistance to change [23].

1.1.2. The Readiness of Teachers from an Attitudinal Aspect

The teachers' response to educational reform is closely tied to readiness from the behavioral perspective, where attitude and beliefs are crucial variables for the effectiveness of the reform's implementation in any substantial endeavor involving classroom teaching [24,25]. The way that changes in behavior could be enacted, that is, smoothly or abruptly, is not just a practical issue, but an important theoretical and methodological concern, apt to the complexity and dynamics of human experience. According to Bandura [26], people's behaviors are impacted by their perceptions of their capacities, or self-efficacy, to carry out an activity in specific domains. Self-efficacy is an indicative facet and a potential predictor of how much effort one will put into learning and practicing an activity, how persistent one will be throughout the process, and how hard one will work to get over ensuing obstacles [27]. Research has shown that teacher self-efficacy is positively correlated with behaviors and practices that contribute to high-quality teaching; i.e., strong beliefs and confidence in one's knowledge and abilities to support children's needs motivate the implementation of scaffolding tactics, leading to the desired outcomes [28].

The teachers' decision on STEM instruction and furthering its effective implementation is crucially dependent on behavior aspects that, in turn, are related to self-efficacy beliefs. The latter determines a kind of behavioral intention or preparation [29], the lack of which undoubtedly hinders any planned process of transformation, while postponement or suspension issues may arise.

1.1.3. Level of Readiness of Teachers from the Affective Aspect

The affective dimension describes how instructors' ability to perform their responsibilities may be impacted by their emotions. Affective readiness can be classified into three main aspects: positive, negative, and neutral. Positive affect refers to emotions and moods such as joy and enthusiasm, whereas negative affect consists of adverse emotional states and moods such as boredom, disappointment, stress, and anxiety. Neutral affect is referred to as a state in which no emotion is elicited at a specific moment by a circumstance [20].

It has been observed that teachers' emotions have a significant impact on the effectiveness and quality of their teaching and learning [30]. When released from their feelings of emotional labor burnout, STEM teachers will be influential allies in promoting and putting into practice STEM reform proposals. The moderate association between teacher professional development and the advancement of STEM education may be more effectively promoted in the future if more STEM instructors transform and shape their professional profiles [31]. Research in psychology has shown that emotions are crucial latent factors affecting behavior in undesirable ways associated with nonlinear and abrupt behavioral change [32].

1.1.4. Significance of Teachers' Commitment to STEM Education

Commitment, in relation to teachers' work, includes the following characteristics: (a) ideals that affirm loyalty to one's profession; (b) holding oneself to high standards; (c) ongoing reflection; and (d) significant participation [33]. Dedicated educators concentrate more on their profession, place a higher priority on meeting academic goals, and continue their education, while a lack of devotion has been linked to absences, burnout, and turnover. Additionally, committed teachers influence students' performance and goal achievement [34], by communicating with them, showing sincere concern for their growth, and meaningfully working to build their aptitude in various ways [35].

A significant predictor of educators' commitment is self-efficacy, a different construct [36] which is closely associated with dedication to teaching [37], and with the willingness to acquire new teaching techniques, as well [38]. Regardless of the difficulties the teachers have to confront in implementing STEM activities, their commitment is a primary asset and crucial to maintaining their teaching practices [39].

1.2. The Aim of the Present Researc

The preset work is committed to STEM education, a field of increasing interest, at the national and global level, where innovative research is nowadays by far needed within the challenged contemporary school system. Teachers' attitudes and readiness to implement STEM are among the factors determining a successful integration of STEM, and research on probing these latent variables presupposes a valid means of measuring them. The present paper contributes to the field by developing and proposing a valid instrument to assess the readiness of Greek teachers to adopt STEM in their teaching practices. Thus, the main goal was to identify the dimensions of readiness and including them into a usable instrument to explore its psychometric properties. Additional research questions in this inquiry are related to potential associations among the dimensions of readiness and the crucial measurement invariance. The latter was carried out for gender, age, years of service, school level, and university degrees. The TRi-STEM scale is an essential and applicable tool to ensure validity in educational research and to support further hypotheses testing.

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2. Materials and Methods

2.1. Participants and Procedures

The participants (N = 494) were educators working in primary education (N = 352) and secondary education (N = 142), 78.5% of whom were female, and whose ages ranged from 43 to 52 (Mean = 44.85, SD = 9.485). The majority of the participating teachers had between 14 and 26 years of teaching experience (Mean = 17.21, SD = 10.498) and 51.4% of them had a basic degree. Moreover, only 31.2% have attended training programs and only 22.5% have implemented a relevant program in the classroom. A web-based form was used to upload the self-completion questionnaire and the teachers responded anonymously at their convenience after being approached through social media, where the accompanying cover letter informed them about the purpose of this research, the safety, and the voluntary participation. The procedure is characterized as opportunity sampling, while the data collection followed the guidelines of the Ethics and Deontology Committee.

2.2. Instrument

The construction of the TRi-STEM scale was based on a published questionnaire for the assessment of teachers' readiness in implementing Science, Technology, Engineering, and Mathematics (STEM) education [20]. The initial form of this scale was proposed as three-dimensional including cognitive, affective, and behavioral aspects, which were merely theoretically conceived and proposed without providing the demanded validation via factor analyses. The present paper re-examines this initial battery of 33 items and proceeds with validation procedures. A collaborative and iterative translation process ensured optimal adaptation, and the scale was then utilized to collect data on a 9-point Likert scale. The responses were marked from 1 ("Doesn't describe me at all") to 9 ("Absolutely describes me"). The final instrument also included questions about personal characteristics such as gender, age, school type, years of teaching experience, and educational background.

Since the initial battery of items and the dimensions proposed [20] were not supported by factor analyses, a reconsideration of the items was made regarding their content and meaning. Thus, the formation of the final TRi-STEM scale, proposed in this work, was guided by both factor analysis and theoretical elaboration (see next section).

2.3. Analyses

Exploratory and confirmatory factor analyses were carried out to examine the psychometric properties of the scale under study. Exploratory factor analysis (EFA) using principal axis factoring (PAF) with promax rotation was conducted to examine the surveys' factor structure and uncover the latent factors influencing Greek teachers' readiness for STEM education. Note that the EFA procedure began with the initial 33 items, and through the refinement, some were eliminated from the final solution, since they did not conform to the relevant structure, or some were assigned to a new factor. Confirmatory factor analysis (CFA) was then used to assess the measurement model's goodness-of-fit for the new dimensional structure that was also theoretically interpreted. Multiple fit indices, including the chi-squared test, comparative fit index (CFI), and root mean square error of approximation (RMSEA), were utilized based on the literature, with the standard satisfactory value [CFI > 0.95, TLI > 0.95, and RMSEA < 0.05] or lower but acceptable value [CFI > 0.90, TLI > 0.90, and RMSEA < 0.10] [40]. Additionally, Cronbach's alpha and McDonald's omega coefficients for the scales' internal consistency were determined.

3. Results

3.1. Exploratory Factor Analysis

In order to identify the underlying dimensionality of the initial 33 items, EFA was initially applied to the empirical data ($N = 494$) using principal axis factoring (PAF) with promax rotation. The exploratory (trial and error) procedure and concomitant theoretical elaboration led to a factor structure different from the initially proposed one. Some items were exactly matched and grouped to the same factors, while some moved to different dimensions or a new dimension, and some were eliminated. Nine items were excluded from the model because they either did not conform to the structure, or they had low factor loadings (<0.40). In conclusion, the analysis resulted in a four-factor model with 24 questions, grouped into the following factors: affective conditions (AC), cognitive conditions (CC), self-efficacy (SE), and STEM commitment (SC). The Kaiser–Meyer–Olkin index (0.966) and Bartlett's test of sphericity (*Chi-square* = 14,789.665, $p = 0.000$) suggested sufficient variance for factor analysis. The Kaiser's criterion (eigenvalue larger than 1) along with the theoretical interpretation were taken into consideration to determine the number of components.

Table 1 displays the factors' loadings and the uniqueness, or the variance that is not shared with other variables, as well as their four-dimensional structure. The final version of the Tri-STEM questionnaire can be found in Table A1 of Appendix A.

Table 1. Factor loadings of four-dimensional structure.

	AC	CC	SE	SC	Uniqueness
08_AC_StudentWeaknesses	0.948				0.111
07_AC_StudentStrengths	0.934				0.112
09_AC_TwoWayCommunication	0.875				0.137
06_AC_EnjoyImplementingSTEM	0.838				0.157
11_AC_GraspOfKnowledge	0.747				0.131
10_AC_OrganizedAndSystematic	0.602				0.170
04_CC_UnderstandAPSDeveloped		0.995			0.047
03_CC_UndestandAPS		0.967			0.064
05_CC_UnderstandPlannedScope		0.957			0.105
02_CC_UnderstandTeacherRole		0.859			0.157
01_CC_UnderstandAPSTarget		0.855			0.157
17_SE_EnoughTime			0.885		0.334
15_SE_WorkBurden			0.791		0.334
14_SE_NotDifficultImplementing			0.694		0.224
16_SE_NotDifficultControlST			0.683		0.361
13_SE_StudentMastery			0.563		0.365
18_SE_ConfidentImplementing			0.497		0.247
12_SE_NotFeelBurdened			0.488		0.288
21_SC_FunLE				0.842	0.176
20_SC_MeaningfulLE				0.811	0.162
22_SC_EffectiveIdeas				0.793	0.510
19_SC_DiscussWithTeachers				0.761	0.443
23_SC_RequirementsMOE				0.502	0.447
24_SC_KnowledgeEnhanceCourses				0.485	0.620

Note: AC = affective conditions, CC = cognitive conditions, SE = self-efficacy, and SC = STEM commitment.

3.2. Reliability Analysis

Using Cronbach's alpha and McDonald's omega, the four factors' reliability measures were calculated as follows: AC (α = 0.972/ω = 0.972), CC (α = 0.976/ω = 0.976), SE (α = 0.934/ω = 0.935), and SC (α = 0.886/ω = 0.885). These reliability coefficients indicate that the internal consistency of the current measurements is adequate.

Table 2 shows the reliability indices along with the correlation matrix of the four dimensions. Affective conditions correlates with cognitive conditions (r = 0.774, $p < 0.001$), self-efficacy (r = 0.804, $p < 0.001$), and STEM commitment (r = 0.630, $p < 0.001$). Cognitive conditions correlates with self-efficacy (r = 0.656, $p < 0.001$) and STEM commitment (r = 0.647, $p < 0.001$). Self-efficacy correlates with STEM commitment (r = 0.423, $p < 0.001$). The corresponding percentages of variance explained were AC 23.50%, CC 20.50%, SE 17.1%, and SC 14.1%; the overall variance explained was 72.5% (Table 3).

Table 2. Factor correlation matrix, internal consistency measures, Cronbach's alpha, and McDonald's omega.

	AC	CC	SE	SC
AC	1.000			
CC	0.774 ***	1.000		
SE	0.804 ***	0.656 ***	1.000	
SC	0.630 ***	0.647 ***	0.423 ***	1.000
Mean	4.85	5.10	4.19	6.33
Stad.Dev.	2.38	2.27	2.02	1.84
Alpha, α	0.972	0.976	0.934	0.886
Omega, ω	0.972	0.976	0.935	0.885

Note: AC = affective conditions, CC = cognitive conditions, SE = self-efficacy, and SC = STEM commitment. *** $p < 0.001$.

Table 3. Factor eigenvalues and variance explained.

	Sum Sq. Loadings	Proportion Var.	Cumulative
AC	5.867	0.235	0.235
CC	5.115	0.205	0.439
SE	4.283	0.171	0.611
SC	3.528	0.141	0.752

Note: AC = affective conditions, CC = cognitive conditions, SE = self-efficacy, and SC = STEM commitment.

3.3. Confirmatory Factor Analysis (CFA)

CFA was used to provide the teachers' readiness measurement factor model (see Table 4). The proposed four-dimensional model fitted the actual data satisfactorily [χ^2 (249) = 981.287, $p < 0.001$, *TLI* = 0.942, *CFI* = 0.948, *GFI* = 0.993, *NNFI* = 0.942, *RMSEA* = 0.078 (0.073–0.083), and *SRMR* = 0.062].

Table 4. CFA measurement model: factors, estimates of factor loadings, standards errors, lower and upper 95% CI, and statistical significance.

							95% Confidence Interval	
Factor	**Indicator**	**Symbol**	**Estimate**	**Std. Error**	**z-Value**	***p***	**Lower**	**Upper**
Factor 1	01_CC_UnderstandAPSTarget	λ11	2.115	0.080	26.438	<0.001	1.958	2.272
	02_CC_UnderstandTeacherRole	λ12	2.160	0.081	26.511	<0.001	2.001	2.320
	03_CC_UndestandAPS	λ13	2.312	0.078	29.533	<0.001	2.158	2.465
	04_CC_UnderstandAPSDeveloped	λ14	2.314	0.077	29.892	<0.001	2.162	2.466
	05_CC_UnderstandPlannedScope	λ15	2.302	0.081	28.334	<0.001	2.143	2.462
Factor 2	06_AC_EnjoyImplementingSTEM	λ21	2.341	0.089	26.297	<0.001	2.167	2.516
	07_AC_StudentStrengths	λ22	2.378	0.085	27.845	<0.001	2.211	2.545
	08_AC_StudentWeaknesses	λ23	2.303	0.083	27.793	<0.001	2.140	2.465
	09_AC_TwoWayCommunication	λ24	2.393	0.087	27.368	<0.001	2.221	2.564
	10_AC_OrganizedAndSystematic	λ25	2.248	0.088	25.620	<0.001	2.076	2.420
	11_AC_GraspOfKnowledge	λ26	2.407	0.088	27.310	<0.001	2.234	2.579
Factor 3	12_SE_NotFeelBurdened	λ31	2.041	0.088	23.105	<0.001	1.868	2.214
	13_SE_StudentMastery	λ32	1.921	0.091	21.142	<0.001	1.743	2.099
	14_SE_NotDifficultImplementing	λ33	2.031	0.083	24.405	<0.001	1.868	2.195
	15_SE_WorkBurden	λ34	2.009	0.097	20.676	<0.001	1.819	2.200
	16_SE_NotDifficultControlST	λ35	1.811	0.087	20.911	<0.001	1.641	1.980
	17_SE_EnoughTime	λ36	1.725	0.088	19.605	<0.001	1.552	1.897
	18_SE_ConfidentImplementing	λ37	2.148	0.090	23.924	<0.001	1.972	2.324
Factor 4	19_SC_DiscussWithTeachers	λ41	1.589	0.092	17.213	<0.001	1.408	1.770
	20_SC_MeaningfulLE	λ42	2.266	0.078	28.888	<0.001	2.112	2.420
	21_SC_FunLE	λ43	2.186	0.078	28.013	<0.001	2.033	2.339
	22_SC_EffectiveIdeas	λ44	1.263	0.089	14.165	<0.001	1.088	1.438
	23_SC_RequirementsMOE	λ45	1.549	0.089	17.380	<0.001	1.374	1.724
	24_SC_KnowledgeEnhanceCourses	λ46	1.353	0.102	13.215	<0.001	1.152	1.554

CC = cognitive conditions, AC = affective conditions, SE = self-efficacy, SC = STEM commitment.

3.4. Measurement Invariance for Individual Characteristics

The measurement invariance is carried out in four steps: The first step is the test of *configural invariance*, which is the least restrictive model used as the baseline. The following step is testing the *metric invariance* that concerns the factor loadings in the groups. The metric invariance denotes that the meaning of the construct is the same across groups and factor variances and covariance. Next is the test of *scalar invariance* that inspects whether the item intercepts are equivalent across groups. A lack of this invariance means that a bias effect may exist and there are essential differences between the groups in the way they perceive the essence of the construct. The last is the *strict invariance*, the less restrictive model. More about measurement invariance could be found elsewhere [41–43].

The comparison between measurement invariance models is carried out via the χ^2 difference test, in tandem with the suggestive values of ΔCFI: 0.01 and ΔRMSEA: 0.015, for rejecting the null hypothesis of invariance [43,44].

3.4.1. Measurement Invariance for Gender

The first measurement invariance test was carried out for gender, summarized in Table 5. The chi-square difference ($\Delta\chi^2$) and the differences in CFI and TLI were used to conclude for each of the models. Comparing the *configural invariance model* with the restrictive *metric invariance* model, the difference is a statistically insignificant *p*-value ($p = 0.473$). Thus, the meaning of the construct is the same for males and females, and the factor variances and covariances are likewise certain. The *scalar invariance* shows that the *p*-value was statistically significant; the item intercepts are probably not equivalent between groups, and thus a bias exists in perceiving the essence of readiness. For the *strict invariance*, the difference is also statistically significant, denoting that the residual variances are not equal across groups. Nevertheless, examining the differences of the other fit indices [$\Delta CFI < 0.01$ and $\Delta RMSEA < 0.015$], it can be concluded that even though there is a lack of invariance for some parameters, the overall model fit is not practically affected regarding the two genders [45]. The limitation here is that the two groups are not numerically equal, so the finding is cautiously reported.

Table 5. Measurement invariance for gender.

Invariance Model	χ^2	*df*	CFI	TLT	RMSEA	SRMR	$\Delta\chi^2$	Δdf	*p*-Value
	0	0							
Configural	1376.49	492	0.939	0.931	0.085	0.063	1376.5	492	
Metric	1404.04	512	0.938	0.933	0.084	0.068	27.548	20	0.473
Scalar	1440.76	532	0.937	0.934	0.083	0.066	36.72	20	<0.05
Strict	1515.26	556	0.933	0.934	0.084	0.068	74.499	24	<0.001

3.4.2. Measurement Invariance for Age and Years of Service

The measurement invariance for age and years of service are shown in Tables 6 and 7, respectively. The two scale variables (age and years of service) were converted to two-point ordinal variables using the two-step cluster method and restricted to two hierarchical categories each. Table 5 shows that the *metric invariance* has a statistically insignificant *p*-value ($p = 0.47$) and the same holds for *scalar invariance* ($p = 0.16$), while for the *strict invariance* model, the *p*-value is significant ($p < 0.001$). These indicate that the factor loadings, the item intercepts, and residual variances are equivalent across age groups, and the meaning of the construct is the same. The same can be stated for the variable years-of-service (Table 7), since the two variables are highly correlated ($r = 0.817$, $p < 0.001$). The significant *p*-value for the *strict invariance* model can be neglected when considering the differences in the other model fit indexes ($\Delta CFI < 0.01$; $\Delta TLI < 0.01$; $\Delta RMSEA < 0.015$; and $\Delta SRMR < 0.015$), and the null hypothesis of invariance for age and years-of-service cannot be rejecting the [43,44].

Table 6. Measurement invariance for age.

Invariance Model	χ^2	*df*	CFI	TLT	RMSEA	SRMR	$\Delta\chi^2$	Δdf	*p*-Value
	0	0							
Configural	1339.459	492	0.941	0.933	0.084	0.067	1339.5	492	
Metric	1352.458	512	0.941	0.936	0.082	0.069	12.999	20	0.87
Scalar	1378.57	532	0.941	0.938	0.080	0.067	26.112	20	0.16
Strict	1458.749	556	0.937	0.937	0.081	0.067	80.179	24	<0.001

Table 7. Measurement invariance for years of service.

Invariance Model	χ^2	*df*	CFI	TLT	RMSEA	SRMR	$\Delta\chi^2$	Δdf	*p*-Value
	0	0							
Configural	1427.199	492	0.934	0.926	0.088	0.069	1427.2	492	
Metric	1448.387	512	0.934	0.929	0.061	0.071	21.188	20	0.36
Scalar	1477.999	532	0.934	0.931	0.085	0.067	29.612	20	0.08
Strict	1546.632	556	0.931	0.931	0.085	0.067	68.633	24	<0.001

3.4.3. Measurement Invariance for School Level

Table 8 summarizes the measurement invariance model for the school level (primary vs. secondary education). The metric and scalar models are statistically insignificant, while the model fit *indices* (ΔCFI < 0.01; ΔTLI < 0.01; $\Delta RMSEA$ < 0.015; and $\Delta SRMR$ < 0.015) are very small. Based on the same argument as above, it is concluded that the measurement invariance is supported. Therefore, teachers in primary and secondary education perceive the notion of the readiness construct likewise.

Table 8. Measurement invariance for school level.

Invariance Model	χ^2	*df*	CFI	TLT	RMSEA	SRMR	$\Delta\chi^2$	Δdf	*p*-Value
	0	0							
Configural	1404.73	492	0.936	0.929	0.087	0.065	1404.7	492	
Metric	1419.71	512	0.937	0.932	0.085	0.067	14.982	20	0.77
Scalar	1437.27	532	0.973	0.973	0.083	0.065	17.559	20	0.61
Strict	1502.79	556	0.974	0.979	0.083	0.065	65.513	24	<0.001

3.4.4. Measurement Invariance for Teachers' Educational Level

This analysis examined two groups of participants, those holding merely bachelor's degrees and those with postgraduate studies (MSc/Ph.D.). Table 9 summarizes the measurement invariance models for teachers' educational levels. The metric model is the only statistically insignificant model, while the others are not. Nevertheless, given the stability in the rest of the fit indices (ΔCFI < 0.01; ΔTLI < 0.01; $\Delta RMSEA$ < 0.015; and $\Delta SRMR$ < 0.015), the potential bias would not, practically, affect the overall model fit; thus, the measurement invariance is supported for teachers' educational level.

Table 9. Measurement invariance for teachers' educational level.

Invariance Model	χ^2	*df*	CFI	TLT	RMSEA	SRMR	$\Delta\chi^2$	Δdf	*p*-Value
	0	0							
Configural	1356.25	492	0.939	0.932	0.084	0.066	1356.2	492	
Metric	1379.07	512	0.939	0.934	0.083	0.071	22.822	20	0.29
Scalar	1412.05	532	0.939	0.936	0.082	0.068	32.984	20	0.03
Strict	1502.77	556	0.933	0.934	0.083	0.067	90.72	24	<0.001

4. Discussion

Teachers are the most significant determinants of the educational process and their responsibilities in the classroom include acting as mentors, motivators, role models, and organizers of effective teaching [46]. Particularly in STEM education, their role is associated with facilitating learning strategies and supporting students in the development of concepts and abstractions, as well as in the de-contextualization of ideas for use in a range of authentic contexts in various real-world situations [47]. Teachers' knowledge and attitude are two crucial areas for the successful implementation and sustainability of STEM education [48]. Knowledge and pedagogical expertise influence affective conditions and the behavioral intentions and attitudes towards STEM education [49–51], along with a variety of individual differences [48,52–54], such as self-efficacy and the associated affective states. Teaching scientific and technological content might be perceived negatively by instructors who tended to feel bored, anxious, and worried. Emotions have a crucial role because are linked [55] and correlated with their self-efficacy views. Moreover, educators' self-efficacy and cognition are correlated with their commitment. A teacher who has greater self-efficacy beliefs is more invested in their work, emotionally, physically, and cognitively. Teachers that are highly involved exhibit tenacity, professionalism, and dedication [56]. To ensure that students are acquiring valuable knowledge, teaching is a profession that necessitates total commitment and enduring innovation. Instructors require thorough subject knowledge as well as pedagogical content expertise in one or more of the STEM disciplines in order to effectively construct learning activities that combine different information [55].

The above comprise a theoretical description of the dimensions of readiness for STEM education, comprising affective conditions, cognitive conditions, self-efficacy, and STEM commitment. The proposed scale is theory-laden and the measurement validity of the degree of readiness and preparedness for STEM education is crucial in research, when a firm theoretical perspective is pursued.

4.1. Limitations and Future Research

This study has some limitations despite its importance and usability. This is one of the first works aiming to satisfy measurement presumptions for valid research, and, as such, further support is needed with additional samples and replication studies. Limitations also originate from the cross-sectional data collection through a self-reported instrument and the specificity of the sample. For gauging educators' attitudes toward practices in STEM education, scenario-based assessments can be employed in addition to teacher-report questionnaires. To further understand how and why educators may exhibit varying degrees of self-efficacy and competence in teaching STEM or putting an integrated STEM curriculum into practice, in-depth qualitative studies such as teacher interviews and classroom observations can be conducted. For a wider acceptance, to better promote cross-cultural comparison, future study needs to investigate the reliability of this scale in various cultural contexts, and the measurement invariance could be extended to additional individual differences. Furthermore, the proposed factor structure should not be viewed as complete; rather, it could be expanded to incorporate more dimensions that are directed by different theoretical presumptions and to improve the portrayal of the latent attribute of readiness.

4.2. Conclusions

In this study, the TRi-STEM, a research tool for measuring teachers' readiness for STEM teaching, was developed and validated. Exploratory and confirmatory procedures demonstrated satisfactory psychometric properties along with high reliability coefficients. The instrument appeals to the Greek population and includes 24 items, and comprises four dimensions: affective, cognitive, self-efficacy, and commitment. The factorial validity and the high values of internal consistency measures along with the measurement invariance denote that the psychometric properties of the proposed scale secure its implementation in research. TRi-STEM can safely be used to validly measure teachers' readiness, empower research exploring the factors affecting them, and facilitate intervention programs aiming to realize educational reforms regarding the integration of technology into new curricula. In addition, this instrument may serve as a template for the creation of other instruments that may differ in certain ways depending on the developmental goals and the environment in which they would be utilized. Finally, the TRi-STEM questioners' utilization in educational research can contribute to predicting the degree of the success of STEM educational reform and support further studies aiming to reveal the profiles and the needs of teachers regarding STEM implementation, so that appropriate training programs and interventions can be organized.

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Data Availability Statement: The data presented in this study are available upon request from the corresponding author.

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Appendix A

Table A1. Tri-STEM full questionnaire.

Cognitive Conditions	01_CC	I understand the objectives of implementing STEM education drawn up in the curriculum by the Ministry of Education.
	02_CC	I understand the teachers' role in implementing STEM education at school.
	03_CC	I understand the planned STEM education curriculum.
	04_CC	I understand the STEM education curriculum that is being developed.
	05_CC	I understand the scope of the planned STEM education curriculum.
Affective Conditions	06_AC	I enjoy implementing the STEM education approach in T&L in the classroom.
	07_AC	I am happy with the implementation of the STEM education approach as it can help me identify students' strengths.
	08_AC	I am happy with the implementation of the STEM education approach as it can help me identify students' weaknesses.
	09_AC	I am satisfied with the implementation of the STEM education approach as it can increase my two-way communication with students.
	10_AC	I feel at ease with being able to implement the STEM education approach in a way that is systematic and organized.
	11_AC	I am excited about the implementation of the STEM education approach in classrooms as it enables me to understand students' grasp of knowledge.
Self-efficacy	12_SE	I do not feel burdened by the many elements contained in STEM education that need to be related to the real-world context.
	13_SE	The differences in students' level of mastery do not make it difficult for me to implement the STEM education approach in the classroom.
	14_SE	I do not find difficulties in implementing STEM education.
	15_SE	I do not feel pressured by the increased work burden.
	16_SE	I do not find difficulties in controlling students during the T&L of STEM education in the classroom.
	17_SE	I have enough time to implement STEM education although I need to cover many syllabuses.
	18_SE	I am confident in implementing the STEM education approach in the classroom.
STEM commitment	19_SC	I need to discuss with other mathematics teachers to further improve my teaching quality of STEM education using multimodal learning.
	20_SC	I am responsible for ensuring that the process of T&L STEM education that is student-centered can produce meaningful learning experiences.
	21_SC	I am responsible for ensuring that the process of T&L STEM education that is student-centered can produce a fun learning experience.
	22_SC	I need to spend a lot of time searching for effective ideas before implementing the T&L of STEM education integration in the classroom.
	23_SC	I refer to the STEM education module to ensure that I have a clear understanding of the implementation of this approach according to the procedures and requirements of the MOE.
	24_SC	I am prepared to attend STEM education enhancement courses to enhance my knowledge.

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