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Article

The Development and Validation of an Instrument for Assessing Science Teacher Competency to Teach ESD

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Abstract: Promoting the implementation of education for sustainable development (ESD) in schools is necessary to educate future generations about sustainability. In cases where ESD is integrated into science lessons or ESD has to be taught by science teachers, science teachers have to integrate ESD teaching competencies with their science teaching competencies. The absence of an instrument to assess science teacher competencies to teach ESD makes it difficult for schools to assign the right science teacher to teach ESD or to support science teachers to integrate ESD into their lessons. This study aims to develop an instrument for measuring science teacher competencies to teach ESD. The instrument was developed by combining frameworks of science teacher competencies and ESD teacher competencies issued by several countries and ESD teacher competencies proposed by Okayama University ESD Promotion Center. A four-scale questionnaire comprising 96 statements was developed to assess seven competencies, i.e., content knowledge, content pedagogy, inquiry, professional practice, professional development, assessment and evaluation, and attitude. The instrument was tested on 234 science teachers nationwide, consisting of 166 females and 68 males from different schools, teaching years, and educational levels. The results show that the Cronbach's alpha of the instrument is 0.99 (very good category), person reliability 0.96 (good category), and item reliability 0.67 (fairly good category). Based on explanatory and confirmatory factor analysis, six competency dimensions are identified. The score of explanatory factor analysis based on Kaiser–Meyer–Olkin (KMO) was 0.966 and the significance on Bartlett's test of sphericity was 0.00. This means that there are significant correlations among the items. This suggests that the instrument is suitable to identify science teachers' competencies as indicators of their readiness to teach ESD.

Keywords: science teacher competencies; ESD teacher competencies; ESD; sustainability

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1. Introduction

The achievement of ASEAN countries in sustainability needs improvement [1]. Education can play a central role in achieving the Sustainable Development Goals (SDGs) as education is not only one of the 17 SDGs but also the way to achieve SDGs. ESD implies the need for everyone to promote sustainable development through education [2]. ESD provides opportunities to acquire knowledge, skills, values, and attitudes on sustainability to develop an equitable lifestyle and to achieve positive long-term social transformation [3]. ESD plays a central role in achieving SDGs by developing knowledge, attitudes, and values relevant to economic, social, and environmental life to create a prosperous society [4]. ESD can address sustainable development challenges [5] and contribute to present and future well-being [3,6].

In contrast to the previous finding that science teachers were less suitable to teach ESD [7], in the Indonesian context, science teachers are in a better position to teach ESD than teachers of other subjects. When the government introduced 'Environmental Education' as a school subject, science teachers were appointed to teach it. Indeed, there are challenges in incorporating ESD principles into science lessons. Firstly, science teachers view ESD as content. As a result, the essence of ESD as action-oriented and integrated subjects is not sufficiently implemented [8]. Analysis of student textbooks for environmental education also shows that the books are content-oriented [9]. Since school science is traditionally content-mastery-oriented, a shift in teachers' teaching paradigm is needed to teach ESD. Secondly, integrating the three dimensions of ESD into science lessons presents a unique challenge for science teachers [10,11]. Science teachers are "science-minded" and less pluralistic [7], which makes it difficult to relate the social and economic aspects of ESD to science content.

ESD must be comprehensively taught where school members see sustainable development as necessary [12–16]. Teachers' understanding of ESD is limited to only a part of sustainable development, i.e., the environmental dimension [17–20], but ignores the economic and social dimensions [21] and how they are interconnected [22]. A comprehensive framework of ESD should consist of holism, pluralism, and should be action-oriented [23]. A comprehensive framework of ESD should consist of holism, pluralism, and action.

In the science teacher education curriculum and teacher professional development program, there is need for a framework and an instrument to assess science teacher competencies to teach ESD. As a result, there is no information on science teachers' competencies to teach ESD. The absence of an instrument for assessing science teachers' competencies is the main motivation of this research, which develops such an instrument. It was performed in three steps. Firstly, it identified core science teacher competencies as formulated in the documents issued by several developed countries [24–31]. Secondly, it identified ESD teachers' competencies as formulated in the existing ESD teacher competencies [32]. ESD teacher competence consists of three domains: (1) Facilitation learning; (2) Connection, collaboration, and engagement; and (3) Continuing to learn and create. Thirdly, it proposed a framework of science teacher competencies to teach ESD based on science teacher competencies and ESD teacher competencies. Based on the proposed framework, an instrument for assessing science teacher competencies to teach ESD was developed and empirically tested.

2. Literature Review

2.1. The Need for ESD Teachers

ESD is an endeavor to inspire people to be constructive and innovative in the face of global issues [33]. ESD empowers people to gain the information, skills, attitudes, and values required to design a sustainable future [15]. ESD teaches pupils eco-friendly skills that will aid in conserving and restoring environmental quality and promote human well-being and social justice [34]. It encourages students to live a more sustainable lifestyle.

The acknowledgement of the importance of ESD has yet to be supported by the availability of teachers who are competent to teach ESD teachers. As the producers of teachers, teacher education institutions need to respond sufficiently to the demand for ESD teachers at schools [35]. The absence of teachers with ESD backgrounds can be a major hindrance in implementing ESD in schools. In this sense, teacher education institutions can deter the success of ESD in schools [36]. The absence of ESD teacher education forces schools to employ teachers with non-ESD education backgrounds. In recent decades, there have been initiatives in teacher education institutions to introduce ESD [37,38], but plenty still needs to be done. Teacher education is mostly subject-based. The graduates do not master comprehensive content knowledge on the environment, social aspects and the economy, nor the appropriate pedagogy for teaching ESD.

2.2. Science Teacher Competencies

Competence is the knowledge, skill, or attitude that enables one to effectively perform the activities of a particular occupation or role to the required standard [39]. Science teachers' competence is related to subject matter knowledge, understanding of learning processes and student learning analyses, knowledge of teaching methods, and classroom management [27]. These competencies are expected to result in effective teaching. Science teachers must recognize how students make sense of scientific ideas to provide effective science instructions [40]. Successful teaching can be achieved if the teacher can plan and implement instructions to assist students in achieving specific pedagogical goals and objectives and assess the teaching results to be used as learning reflection material [41].

Different countries may identify different science teacher competencies. As a result, there are variations of competencies of science teachers that must be cultivated [24–31]. In general, science teacher competencies are divided into two parts, namely cognitive abilities (subject knowledge, pedagogical content knowledge, and general pedagogical knowledge) and affective-motivational qualities (professional beliefs, motivation, and self-regulation) [42].

2.3. Science Teacher Competencies to Teach ESD

ESD is based on three pillars, i.e., social, environmental, and economic [43]. In the social dimension, ESD promotes social justice, gender equality, human rights, democratic and participatory systems, and healthcare by increasing awareness of social institutions and their role in change and development [44]. The goal of ESD in the environmental dimension aims to raise awareness of the physical environment's resources and fragility, the influence of human activities on the environment, climate change, environmental protection, and biodiversity [43]. Finally, ESD in the economic dimension focuses on fostering awareness of the possibilities and limits of economic progress, its effects on society and the environment, responsible and sustainable consumerism, and rural development [34].

There are several proposed frameworks for ESD teachers [45–47]. A framework that integrates the preceding ESD teacher competencies and is specifically designed for Asia and the Pacific context [32] is chosen as the main reference. The framework proposes three domains of ESD teacher competencies, i.e., facilitation of learning (culture, pedagogy, technology, and content), continuation of learning and creating (reflect, innovate, and transform), connection, collaboration, and engagement (collaborate, cooperate, participate, and engage). The first domain facilitates learning, which is the competency to generate and provide learning opportunities for students to increase their capacity for sustainability. The second category is 'connect, collaborate, and engage', which encourages collaboration and partnerships to support ESD policies and practices within and outside the surrounding community, including local and national authorities. Finally, the last area is to continue to learn and create, which is the ability to reflect, innovate, and convert ongoing knowledge as an ESD practitioner. ESD teacher competencies can shape sustainable development's learning process, including knowledge, systems thinking, emotions, values and ethics, and actions [34]. These competencies are essential for long-term sustainability, and each has unique qualities and areas of relevance. The interdependence of these competencies impacts personal behavior [34].

To teach science that integrates ESD, a science teacher needs to have science teaching competencies [24–31] and ESD teaching competencies [32]. A mapping of science teacher competency and ESD teacher competency shows the possible infusion of ESD teacher competencies into science teacher competencies (Table 1). Since the existing teachers are science teachers, science teacher competency is used as the backbone of the framework. The number of checks ($\surd$) indicates the number of ESD teacher competency indicators that can be integrated into the domain of science teacher competency. For example, one of the indicators for ESD teacher competencies in pedagogy is the 'ESD teaching repertoire'. This indicator fits science competency in the domain of 'content pedagogy' and 'professional practice'. As shown in Table 1, all ESD teacher competencies can be integrated into science teacher competencies.

Table 1. The integration of ESD teacher competency into science teacher competency.

		Science Teacher Competency						
		Content Knowledge	Content Pedagogy	Inquiry	Professional Practice	Assessment and Evaluation	Professional Development	Attitude
ESD Teacher Competency	A. Facilitate learning							
	1. Culture						√√	√√√
	2. Pedagogy		√√√		√√√	√	√	√
	3. Technology		√√		√√			
	4. Content	√√	√	√√				
	B. Continue to learn and create							
	1. Reflect				√	√√√	√	
	2. Innovate	√		√√	√√	√	√	
	3. Transform				√√√		√√	
	C. Connect, collaborate, and engage							
	1. Collaborate				√		√	
	2. Cooperate	√					√√	
	3. Participate and Engage						√√	√

3. Method

3.1. Research Design

Key science teachers' competencies were summarized based on standards issued in eight countries [24–31]. Meanwhile, the ESD teacher competencies were taken from the Asia Pacific ESD teacher competencies [32]. Combining science teachers' key competencies and ESD teacher competencies resulted in a new competency framework: science teachers' competencies to teach ESD. The instrument was distributed via Google Forms. The invitation to participate in the survey was sent to teacher associations and shared on social media. Participation in the survey was entirely voluntary and anonymous.

3.2. The Context and the Participants

Environment education is one of the compulsory local subjects taught in Indonesian schools. Since the environmental education content is closely related to science, the subject is taught by science teachers. The recognition of the importance of ESD receives its place in the school curriculum. Currently, ESD is integrated into the science curriculum, but there is a movement to replace 'environment education' with ESD. In either case, science teachers were appointed to teach it.

Participants of the study were science teachers from major islands in Indonesia. In total, 234 science teachers participated in the survey, 166 females and 68 males. One hundred and seventy of the science teachers who participated in the survey work in public schools, while 64 work in private schools. The educational level of the teacher respondents ranged from a four-year college to a master's degree and a doctoral degree.

3.3. Instrument

The instrument consisted of seven domains of science teacher competencies to teach ESD, i.e., content knowledge, content pedagogy, inquiry, professional practice, professional development, assessment and evaluation, and attitude. This instrument was a questionnaire using a Likert scale of 1–4 with a description of the scale ranging from 'strongly disagree' to 'strongly agree'. The total number of questionnaire items was 96, with 12 items on content knowledge (CK), 13 items on content pedagogy (CP), 14 items on inquiry (I), 25 items on professional practice (PP), 12 items on assessment and evaluation (EA), ten items of professional development (PD), and ten items of attitudes (A). These items were developed based on the 56 indicators of science teacher competency to teach ESD.

3.4. Data Analysis

Data analysis was carried out in several stages. In the first stage, reliability and validity tests were conducted using the Rasch model analysis. The reliability test consists of person and item reliability. Person reliability states that if a group is given a package of identical objects, the outcomes will be consistent [48]. On the other hand, item reliability emphasizes that if this item package is disseminated to different samples, the results will be consistent based on item criteria [48]. The standard values for person and item reliability are as follows: poor (<0.67), fair (0.67–0.80), good (0.81–0.91), very good (0.91–0.94), and excellent (>0.94) [48]. The standard of Cronbach's alpha [49] consists of 0.6 (unacceptable), 0.60–0.69 (undesirable to minimally acceptable), 0.70–0.80 (respectable), and above 0.80 (very good). The item test's validation is also measured using Rasch analysis by considering the value of the item fit (infit–outfit MNSQ). The infit–outfit MNSQ should be between 0.5 and 1.5 (valid).

The MNSQ, outfit ZSTD, and PT-Corr outfits for each item are calculated in the following analysis to establish the validity of the test items. The outfit MNSQ should be in the 0.5 to 1.5 range. Another criterion is that the outfit ZSTD should be between −2 and +2. The last criterion is PT-Corr, which ranges from 0.4 to 0.85. The item test is only valid if it meets all the criteria. The valid item test must meet at least one criterion.

The second stage calculated the explanatory factor analysis and confirmatory factor. The explanatory factor analysis tested the KMO (Kaiser–Meyer–Olkin) and Bartlett's. The rotated factor matrix with the commonalities was determined to know the loading factor of each item. Finally, the analysis was continued by confirmatory factor analysis. This analysis aims to select the model that fits with the instrument made. The confirmatory factor analysis consists of χ^2, DF, $\chi^2/$DF, RMSEA, GFI, AFGI, RFI, TLI, and CFI. The last stage calculated the mean and deviation standard of each indicator of science teacher competencies as ESD teachers to know the initial science teacher competence in teaching ESD.

4. Result

4.1. Substantive Validity

The substantive validity analysis was carried out using the Rasch model analysis. The results of the Rasch analysis on the item fit, person reliability, item reliability, and Cronbach's alpha are presented in Table 2.

Table 2. Item fit, person reliability, item reliability, and Cronbach's alpha of the questionnaire.

Domain	**Item Fit**		**Person Reliability**	**Item Reliability**	**Cronbach's Alpha**
	Infit MNSQ	**Outfit MNSQ**			
All domains (general)	0.99	0.95	0.96	0.67	0.99
Content Knowledge	1.00	0.91	0.94	0.72	0.97
Content Pedagogy	0.97	0.77	0.95	0.68	0.98
Inquiry	0.99	0.72	0.96	0.63	0.98
Professional Practice	0.98	0.90	0.97	0.80	0.99
Assessment and Evaluation	0.97	0.80	0.95	0.79	0.98
Professional Development	0.95	0.92	0.93	0.88	0.97
Attitude	0.98	0.78	0.92	0.67	0.97

The value of person reliability was higher than 0.9 (Table 2) for all domains. The general score of person reliability was 0.96, which means that all instruments can produce consistent responses. The identification is continued by analyzing person reliability for each domain. The highest score of person reliability was the 'professional practice' domain (0.97), while the lowest score of person reliability was the domain' attitude' (0.92). In subsequent analysis, we identified the items' reliability. Each domain had a different value of item reliability (Table 2). In general, the value of item reliability shows a reasonably good category (0.67). The highest score of item reliability was the domain 'professional development' (0.88), which means it fell under the 'good category'.

Meanwhile, the lowest score of item reliability was inquiry (0.62), which means it fell under the poor category. Then, Cronbach's alpha value was considered to determine whether the instrument of science teacher competencies as ESD teachers can be used for research. The Cronbach's alpha value for all domains (general) was 0.99 (Table 2), indicating a very good category. The Cronbach's alpha of each domain also shows a very good category because the value is more than 0.9. The item test's validation can be seen in the item fit's value (infit–outfit MNSQ). The range of item fit (infit–outfit MNSQ) should be 0.5–1.5, indicating that the items fit the domain (valid). Based on Table 1, all domains have an infit–outfit MNSQ value in the range of 0.5–1.5.

In general, the test items that were created are valid. However, we need to calculate the validity of each test item. A Rasch analysis was performed by calculating the output table's item column (fit order). Based on the analysis result, there are several invalid item tests. The determination of the invalid item test was based on the value of outfit MNSQ, outfit ZSTD, and PT-Corr. The invalid item tests were CK6, CK10, CP6, PP2, PP3, PP11, PD5, and A4. The invalid item tests were removed as the instruments for measuring science teacher competencies as ESD teachers. Therefore, invalid questions will not be used for further analysis.

4.2. Structural Validity

The structural validity is identified by exploratory factor analysis and confirmatory factor analysis of the valid item tests. The purpose of structural validity is to examine the instrument's construction. Each item will correlate with the other, which is the basic assumption of the exploratory factor. This analysis aims to show the adequacy of the sample and reveal the correlation between items. The sufficiency of the sample can be determined from the value of KMO (Kaiser–Meyer–Olkin). If the KMO value is above 0.5, it indicates enough samples. The correlation value between items can be determined by Bartlett's test of sphericity. The factor analysis can continue if the significance value ($sig < 0.05$). The KMO and Bartlett's test results are presented in Table 3.

Table 3. KMO and Bartlett's test.

KMO and Bartlett's Test		
Kaiser–Meyer–Olkin Measure of Sampling Adequacy.		0.966
Bartlett's Test of Sphericity	Approx. Chi-Square	26,865.869
	df	3828
	Sig.	0.000

Table 3 shows that the KMO value is high, and Bartlett's test of sphericity is significant. The two values are prerequisites for the factor analysis to find out the output of the rotated component matrix. The matrix shows the loading factor for each item. Each item can be correlated with all factors. A good item is an item that has the highest loading factor on a particular factor. In the initial design, seven domains were identified. Based on the rotated component matrix results, it turns out that there are only six domains (Table 4).

Based on the results of the maximum likelihood method, six domains were identified: i.e., (1) Inquiry; (2) Pedagogical content knowledge; (3) Attitude, (4) Professional practice; (5) Assessment and evaluation; and (6) Professional development. The items of content knowledge and content pedagogy were combined to become the items of pedagogical content knowledge.

Table 4. Rotated factor matrix.

		Domain					
	Communalities	**1**	**2**	**3**	**4**	**5**	**6**
CK1	0.681	0.175	0.757	0.099	0.181	0.083	0.165
CK2	0.733	0.211	0.748	0.135	0.167	0.175	0.23
CK3	0.738	0.174	0.777	0.166	0.131	0.119	0.212
CK4	0.779	0.222	0.779	0.172	0.129	0.154	0.23
CK5	0.701	0.235	0.731	0.06	0.159	0.062	0.28
CK7	0.69	0.306	0.693	0.163	0.104	0.201	0.199
CK8	0.669	0.261	0.711	0.099	0.143	0.144	0.21
CK9	0.684	0.257	0.717	0.145	0.156	0.196	0.142
CK11	0.703	0.336	0.733	0.128	0.151	0.093	0.071
CK12	0.683	0.289	0.742	0.096	0.149	0.103	0.082
CP1	0.663	0.324	0.562	0.307	0.252	0.277	0.092
CP2	0.691	0.349	0.563	0.307	0.27	0.281	0.07
CP3	0.69	0.472	0.568	0.216	0.215	0.222	0.053
CP4	0.749	0.486	0.627	0.226	0.18	0.188	0.024
CP5	0.66	0.461	0.519	0.245	0.269	0.209	0.043
CP7	0.671	0.408	0.575	0.212	0.158	0.283	0.154
CP8	0.665	0.45	0.507	0.279	0.253	0.236	0.089
CP9	0.652	0.466	0.483	0.236	0.266	0.27	0.049
CP10	0.669	0.448	0.518	0.226	0.294	0.244	0.054
CP11	0.7	0.436	0.576	0.22	0.24	0.262	0.059
CP12	0.713	0.416	0.545	0.22	0.258	0.35	0.069
CP13	0.692	0.508	0.546	0.189	0.209	0.229	0.063
I1	0.632	0.493	0.451	0.208	0.199	0.222	0.231
I2	0.711	0.629	0.322	0.23	0.252	0.221	0.215
I3	0.664	0.582	0.359	0.243	0.231	0.183	0.225
I4	0.767	0.741	0.251	0.199	0.188	0.202	0.195
I5	0.763	0.734	0.276	0.171	0.17	0.222	0.199
I6	0.739	0.684	0.325	0.217	0.21	0.183	0.204
I7	0.674	0.686	0.378	0.043	0.138	0.179	0.085
I8	0.777	0.708	0.371	0.209	0.246	0.154	0.102
I9	0.786	0.69	0.398	0.23	0.257	0.133	0.121
I10	0.742	0.728	0.355	0.193	0.129	0.13	0.125
I11	0.719	0.647	0.4	0.143	0.242	0.18	0.166
I12	0.716	0.654	0.315	0.189	0.265	0.195	0.212
I13	0.741	0.683	0.345	0.188	0.263	0.158	0.161
I14	0.751	0.664	0.358	0.185	0.207	0.227	0.233
PP1	0.659	0.48	0.472	0.245	0.267	0.268	0.047
PP4	0.647	0.523	0.361	0.171	0.35	0.238	0.187
PP5	0.607	0.491	0.205	0.235	0.388	0.286	0.189
PP6	0.579	0.531	0.216	0.146	0.332	0.282	0.2
PP7	0.68	0.541	0.334	0.238	0.345	0.249	0.195
PP8	0.688	0.464	0.333	0.289	0.424	0.284	0.135
PP9	0.679	0.535	0.241	0.26	0.414	0.255	0.177
PP10	0.727	0.522	0.237	0.215	0.475	0.273	0.227
PP12	0.755	0.564	0.291	0.229	0.442	0.257	0.199
PP13	0.767	0.485	0.304	0.307	0.445	0.32	0.211
PP14	0.756	0.487	0.296	0.239	0.514	0.231	0.238
PP15	0.716	0.427	0.305	0.203	0.506	0.278	0.258
PP16	0.753	0.417	0.341	0.232	0.525	0.258	0.259
PP17	0.742	0.456	0.336	0.284	0.495	0.233	0.2
PP18	0.711	0.441	0.254	0.239	0.529	0.253	0.225
PP19	0.737	0.495	0.269	0.146	0.512	0.258	0.262
PP20	0.735	0.542	0.286	0.198	0.446	0.267	0.224
PP21	0.701	0.294	0.138	0.322	0.628	0.274	0.148
PP22	0.632	0.307	0.169	0.273	0.609	0.181	0.178
PP23	0.724	0.334	0.267	0.254	0.641	0.149	0.207
PP24	0.708	0.303	0.322	0.269	0.638	0.166	0.069
PP25	0.734	0.346	0.347	0.204	0.615	0.237	0.133

Table 4. *Cont.*

		Domain					
	Communalities	**1**	**2**	**3**	**4**	**5**	**6**
EA1	0.76	0.404	0.399	0.264	0.22	0.52	0.22
EA2	0.718	0.36	0.441	0.294	0.156	0.518	0.123
EA3	0.747	0.468	0.268	0.307	0.243	0.528	0.156
EA4	0.756	0.431	0.254	0.251	0.206	0.598	0.207
EA5	0.744	0.416	0.324	0.223	0.221	0.573	0.198
EA6	0.817	0.304	0.283	0.231	0.303	0.657	0.261
EA7	0.846	0.316	0.223	0.242	0.312	0.7	0.224
EA8	0.815	0.312	0.281	0.318	0.349	0.568	0.305
EA9	0.691	0.295	0.331	0.262	0.394	0.486	0.186
EA10	0.724	0.36	0.42	0.209	0.29	0.528	0.11
EA11	0.7	0.284	0.334	0.27	0.402	0.503	0.139
EA12	0.797	0.389	0.315	0.292	0.316	0.575	0.175
PD1	0.647	0.196	0.333	0.359	0.195	0.271	0.507
PD2	0.697	0.189	0.185	0.403	0.145	0.253	0.616
PD3	0.629	0.315	0.191	0.324	0.185	0.158	0.574
PD4	0.643	0.348	0.246	0.301	0.167	0.143	0.568
PD6	0.759	0.213	0.248	0.49	0.183	0.12	0.603
PD7	0.79	0.19	0.285	0.518	0.232	0.131	0.578
PD8	0.806	0.164	0.261	0.493	0.236	0.144	0.626
PD9	0.786	0.25	0.271	0.427	0.231	0.22	0.605
PD10	0.752	0.273	0.257	0.443	0.214	0.202	0.573
A1	0.675	0.225	0.169	0.683	0.095	0.17	0.303
A2	0.754	0.186	0.238	0.695	0.235	0.175	0.307
A3	0.783	0.124	0.148	0.793	0.146	0.177	0.253
A5	0.824	0.184	0.148	0.821	0.186	0.153	0.191
A6	0.806	0.166	0.156	0.816	0.243	0.12	0.122
A7	0.838	0.202	0.149	0.836	0.2	0.12	0.149
A8	0.766	0.091	0.166	0.807	0.185	0.168	0.129
A9	0.722	0.217	0.132	0.788	0.106	0.126	0.102
A10	0.71	0.234	0.129	0.773	0.097	0.126	0.128

The items PP1, PP4, PP5, PP6, PP7, PP8, PP9, PP10, PP12, and PP13 were removed from the structure of the research instrument. These items were not categorized into groups because these items were outside the specified factor analysis category. Instead, the structure of these items will be examined more clearly through additional analysis, namely confirmatory factor analysis. This analysis is a method to check whether the measurement structure of the test instrument that was made falls under the actual student responses. The goal is to determine the model that fits the instrument that was made. Model I is a model which, according to the initial design, consists of seven domains, namely: (1) Content knowledge; (2) Content pedagogy; (3) Inquiry; (4) Professional practice; (5) Assessment and evaluation; (6) Professional development; and (7) Attitude. Model II is a model that follows the design of the results of the explanatory factor analysis, which consists of six domains, namely measuring all instrument items with the design of: (1) Inquiry; (2) Pedagogical content knowledge; (3) Attitude; (4) Professional practice; (5) Assessment and evaluation; and (6) Professional development. In Model II, all items are measured regardless of the type of item. Model III is a model that is almost the same as Model II, but in this model, items outside the relevant factors are removed so that the number of items is smaller than the items in Model II. The model fits indices for Measurement Model I, Model II, and Model III are presented in Table 5.

Model III is the fit model for measuring science teacher competencies as ESD teachers (Table 4). The RMSEA value is the index value used to correct the chi-square statistic in a large sample. Therefore, the index value categorized as an acceptable value is less than 0.8. Models I and III have an RMSEA of less than 0.8. Each model has a good precision value and can be categorized as a fit model. Another consideration is the value of GFI, AFGI, RFI, TLI, and CFI. Model III is a better model than Model I. One of the reasons is that the CFI value of Model III is higher than the CFI of Model I. The CFI value is used to determine the suitability of the model. Based on the analysis, the TLI value of Model III is 0.815, and the CFI value is 0.809. The GFI and RFI values of Model III also have large values compared to other models and are close to the model fit value. This result indicates that Model III has a better fitted category than other models. The confirmatory factor analysis in detail is presented in Figure 1.

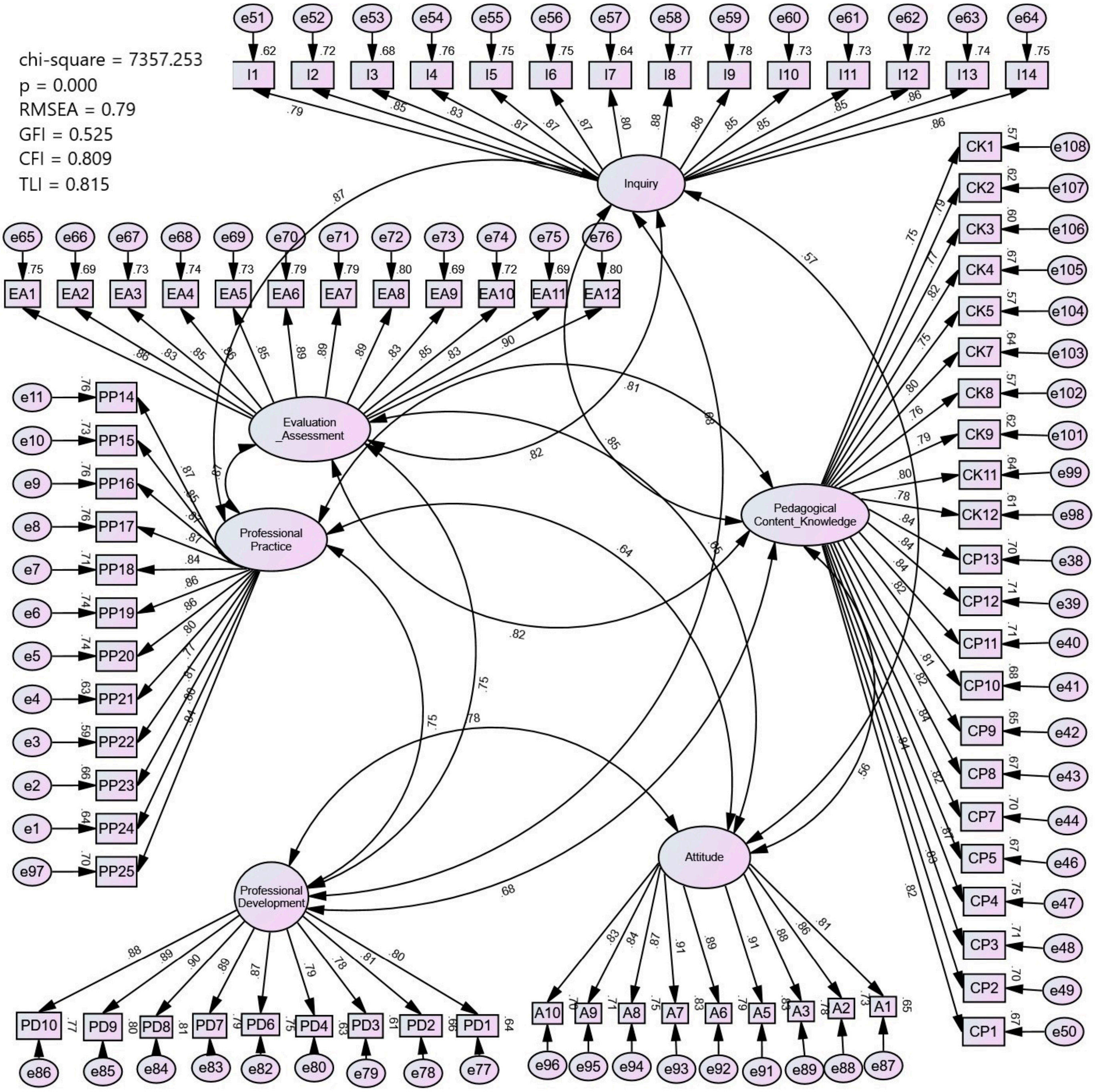

Figure 1. Confirmatory factor analysis.

Table 5. The model fits indices for Measurement Model I and II.

	χ^2	DF	χ^2/DF	RMSEA	GFI	AFGI	RFI	TLI	CFI
Model I	10,423.707	4443	2.346	0.76	0.521	0.498	0.694	0.804	0.798
Model II	10,295.538	4079	2.524	0.81	0.487	0.462	0.710	0.783	0.777
Model III	7357.253	2984	2.463	0.79	0.525	0.497	0.716	0.815	0.809

The correlation between the domains and each item is more than 0.5 (Figure 1). It means that all items have a good correlation with the domain. Each item is categorized as very fit with their respective domain. All items fit the domain. This result proves that the items are very compatible with the predetermined domains. Analysis of the correlation among the domains results in a correlation score higher than 0.5. These results can be defined as a significant correlation amongst the domains (detailed information about the domains of the framework, the indicators, the questionnaire, and the scores of the loading factors are available in the Supplementary Material).

5. Discussion

This study aims to develop an instrument for measuring science teacher competencies to teach ESD [24–31]. Initially, seven domains of science teacher competencies to teach ESD were proposed: (1) Content knowledge; (2) Content pedagogy; (3) Inquiry; (4) Professional practice; (5) Assessment and evaluation; (6) Professional development; and (7) Attitude. Based on these domains, a total of 96 statements were formulated. The instrument was tested for readability by three science teachers. Based on the feedback, several sentences were revised.

Rasch model analysis was performed to check the validity and reliability of the instrument. It was found that the value of person reliability was higher than 0.9 (Table 2) for all domains, which means that the instrument can produce a consistent response. In general, the scores of item reliability are either good or very good (Table 2). These scores suggest that the instrument can assess science teacher competencies to teach ESD.

Based on the confirmatory factor analysis results, Model III is chosen as the suitable framework for science teacher competencies to teach ESD. There are six domains with 79 test items that match those domains. The correlation scores among the domains and each item are higher than 0.5. It means that all items have a strong correlation with the domains. The RMSEA value is used to correct the chi-square statistic in a large sample. The data results of Model III showed an RMSEA value of 0.79, so it can be concluded that the framework has a good precision value and it fits the framework. The GFI value of 0.525 indicates that the framework has a relatively good level of accuracy. The CFI value is used to determine the suitability of the framework. Based on the analysis, the TLI value shows 0.815, which means that the framework is the best model.

The final framework of science teacher competencies to teach ESD consists of six domains. The first domain is pedagogical content knowledge. This domain consist of 15 indicators; (1) Understanding the ESD content in the science curriculum; (2) Understanding science concepts and the application of sustainability; (3) Applying science concepts to solve problems related to sustainability issues; (4) Developing ESD-enriched science content by considering the science curriculum; (5) Explaining science knowledge systematically and understanding its implication on ESD by considering the level of students' abilities and competencies; (6) Demonstrating a critical understanding of ESD developments in the science curriculum; (7) Demonstrating science knowledge to creatively and innovatively presents ESD content; (8) Setting learning objectives for science learning towards sustainability; (9) Planning appropriate science teaching strategies and applications on sustainability; (10) Planning ESD-enriched science lessons by considering the level of students' abilities and competencies; (11) Planning well-structured activities for exploring science concepts and their application to sustainability; (12) Aligning the learning objectives and assessment type to evaluate ESD-enriched science lessons; (13) Integrating specific technologies in ESD-enriched science learning to support students' conceptual understanding; (14) Understanding the student's background and characteristics to teach meaningful science lessons in the context of ESD; and (15) Modifying science lessons for sustainability when faced with unexpected conditions (see Supplementary Material for statements for each indicators of the domains).

The second domain is inquiry. The inquiry adopted is the same as the inquiry in science learning [24], such as asking questions, designing research investigations, conducting experiments, collecting data, and making conclusions [50]. This domain consists of eight indicators: (1) Provoking students' curiosity related to sustainability issues and engaging students to solve them by performing scientific investigations; (2) Stimulating students' thinking to formulate hypotheses based on scientific questions in ESD-enriched science learning; (3) Guiding students to plan and conduct scientific investigations to solve ESD problems; (4) Promoting engineering practices to support scientific investigations in solving ESD problems; (5) Developing students' scientific thinking competence and students' scientific problem-solving competence for lifelong learning; (6) Leading students in making evidence-based scientific explanations; (7) Managing class discussions to draw conclusions from the investigation; and (8) Guiding students in making reports of their scientific investigations conditions.

The third domain is the 'professional practice' related to technical learning. This domain focuses on some technicalities in the classroom [24,26,29,31]. The domain consists of six indicators; (1) Encouraging students to take responsibility for maintaining ways to solve ESD problems in science learning; (2) Practicing a sustainable way of life by managing behavior effectively in science lessons; (3) Paying attention to all learners in learning science by embedding ESD; (4) Challenging students to optimize the strategy for maintaining sustainability in science learning; (5) Facilitating students to demonstrate safe techniques, ethics, and safety; and (6) Cultivating students' critical awareness about social changes.

The fourth domain is 'assessment and evaluation'. This domain focuses on teachers' competencies in assessing and evaluating students' learning, as well as the effectiveness of the teaching. There are nine indicators; (1) Developing assessments appropriate for science lessons that integrate ESD; (2) Monitoring students' understanding of ESD-enriched science lessons by using different types of assessments; (3) Implementing various types of assessment based on learning objectives in ESD-enriched science lessons; (4) Using formative and summative assessments to evaluate student's progress in science learning and its implications on sustainability; (5) Assessing students' prior knowledge according to ESD issues in science lessons; (6) Engaging in continuous critical reflection to improve ESD-enriched science teaching and learning; (7) Analyzing and evaluating the practice of integrating ESD in science learning; (8) Providing feedback to help students understand ESD-enriched science learning; and (9) Analyzing and evaluating the results of the ESD-enriched science learning assessment to plan a follow-up to the next lesson.

The fifth domain is professional development. Indicators mainly focus on teachers' participation in professional development to become agents of change in promoting ESD-based science learning. This domain consists of six indicators; (1) Participation in professional development to deepen and expand science content knowledge and ESD practices; (2) Becoming an agent of change by promoting ESD-based science learning; (3) Collaborating with peers and stakeholders to improve the quality of ESD-based science learning; (4) Collecting student feedback on ESD-enriched science teaching and learning to improve and follow up on future lessons; (5) Developing action plans for the continuous improvement in the integration of ESD in science learning; and (6) Communicating effectively with stakeholders to support ESD-based science teaching and learning.

The sixth domain is 'attitude'. This domain describes how a science teacher responds to social, economic, and environmental changes to realize ESD learning in a community. This domain consists of five indicators; (1) Responding to social, economic, and environmental changes by being involved in communities and society; (2) Having tolerance for students; (3) Demonstrating a consistent and positive attitude and lifestyle; (4) Cooperating with students and communities across different cultures; and (5) Having work discipline in achieving personal and family well-being.

6. Conclusions

A synthesis of frameworks on science teacher competencies and ESD teacher competencies resulted in seven domains of science teacher competencies to teach ESD. Based on the framework, an instrument was developed and validated. Analysis of substantive and structural validity resulted in six valid domains of competencies. The scores on Cronbach alpha (0.99), person reliability (0.96), and item reliability (0.67) indicate that the instrument is valid. The analysis of the explanatory factor and confirmatory factor suggests that there are six valid domains. The KMO value of 0.966 and the Bartlett's test of sphericity of 0.00 means that the items significantly correlate. The means scores of science teacher competencies to teach ESD were 2.78 for pedagogical content knowledge, 2.77 for inquiry, 2.90 for professional practice, 2.82 for evaluation and assessment, 2.94 for professional development, and 3.15 for attitude. These scores indicate that the instrument can be used to assess science teacher competence in teaching ESD.

The availability of this instrument is useful for pre-service teacher education, as well as for in-service teacher education. Pre-service education institutions can design their curriculum toward the domains described in the instrument and assess the pre-service teachers' attainment of the domains. Meanwhile, the organizers of TPD can use the instrument to identify teachers' competencies in each domain and develop the appropriate program.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15043276/s1, Supplementary Materials File S1: Detailed information about the domains, the indicators, the questionnaire, and scores of the loading factor.

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