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Scaling of sustainable development goals in science education using Thurstone's pairwise comparison–based scaling technique

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ABSTRACT

A lack of evidence-based guidelines on which sustainable development goals (SDGs) need to be focused on in educational settings can be regarded as the key deficiency that leads to an inefficient sustainability learning process. As sustainability-related issues become ever more acute, there is a necessity to determine which SDGs should be prioritized pedagogically. Thus, the current study aims at examining how future teachers evaluate the significance of selected SDGs in relation to environmental learning. Applying the paired comparison methodology, the authors gathered data from 129 third- and fourth-year prospective teachers concerning their perceptions of 11 SDGs (SDG 1, 2, 3, 4, 5, 6, 7, 12, 13, 14, and 15). According to the results, SDG 3, SDG 6, and SDG 2 seem to be the most important goals, while SDG 15, SDG 5, and SDG 14 appear less critical. Thus, one may hypothesize about hierarchy within SDGs based on their importance as prerequisites for environmental problems solving. In terms of practical application, this paper offers a definite methodology that instructors can apply to rank and arrange SDGs for teaching purposes, as well as useful tips for curriculum designers and policymakers who seek to develop sustainability education programs.

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1. INTRODUCTION

Sustainable education has been put across as an important element of educational policy globally; yet its implementation in classrooms has remained problematic all along. In science education, educators are supposed to fit issues related to sustainability in what is already an overloaded curriculum while at the same time trying to meet other learning outcomes [1], [2]. The problem here lies in the very practical challenges of having little time, dealing with an overloaded curriculum, and aligning sustainability-related themes with the curriculum. While the sustainable development goals (SDGs) are clear and globally known, the wide range and interconnectivity of the goals make it difficult for teachers to know how to address them in teaching [3]–[5]. In this case, SDGs become addressed in a shallow manner in many cases, while in others, only those that the teacher feels like covering or can cover due to various reasons are taken into account.

Though the field of research of sustainability in education continues to expand considerably, the majority of current research papers focus on the examination of particular issues such as the awareness of the environment, students' attitudes towards various topics or processes, climate literacy, or sustainable consumption behaviors. While all the research is important and relevant in terms of its results, it relies heavily on qualitative research methodology and does not attempt to explore how the various aspects of sustainability must be incorporated into teaching strategies [6], [7]. In addition, there has been little attention paid to the empirical study and development of the hierarchy for the SDGs in the context of education [8]. Namely, no one has conducted any research on the relative significance, priority, or prerequisites of different SDGs. This issue can hardly be attributed merely to the lack of a particular methodology that might help address the problem since it reveals the insufficiency of knowledge regarding the cognitive hierarchy of sustainability goals formed by different stakeholders [9]–[11]. This problem is especially pertinent if one considers the position of prospective teachers, who will eventually be entrusted with the task of implementing sustainable development education in classrooms. The perceptions of the significance of each of the SDGs among prospective teachers have a direct bearing on how they can implement sustainable development education. It is necessary to know these perceptions in order to design a more structured approach to sustainable development education [12], [13].

The novelty and main contribution of this study in filling this gap can be found in both its methodological and conceptual aspects of the hierarchy building of SDGs in science education. Applying Thurstone's pairwise comparison method, the research goes further from merely describing and ranking SDGs into developing a quantitative scale of their importance with taking into account the distances among them as well. It helps to discover cognitive structures behind judgment of the respondents concerning SDGs and the way different goals relate to each other. Thus, this research creates an empirically based and theory-informed tool for prioritizing SDGs. This tool has two advantages. Firstly, in conceptual terms, it is represented by hierarchy, which has rarely been mentioned in existing studies. Secondly, in practical sense, it may help teachers to build content of their lessons, provide curricula designers with a better framework for structuring sustainability topics and policymakers with useful information when making educational decisions [14]–[16]. Thurstone's pairwise comparison method used in the research not only provides a simple ranking but also transforms the psychological distances between complex concepts (SDGs) into an objective mathematical scale. In this way, the study reveals the perceived weights and distances between SDGs in science education in a data-driven manner, providing a unique theoretical basis for the educational prioritization of sustainability goals [17], [18]. The findings of this hierarchical model have critical implications for real classroom environments, curriculum design, and educational policies [19], [20]. At the teacher level, this study will provide a concrete, evidence-based prioritization map that they can use when integrating complex SDGs into their lesson plans. Curriculum developers can optimize content density according to this hierarchy, giving more strategic space to core and priority SDGs in textbooks. Policymakers can leverage these findings to develop more effective macro-education strategies by determining which goals to allocate resources to when designing teacher training and professional development programs [21]–[23].

In light of the all over these, the aim of the current study is to scale the SDGs in the context of science education through the application of Thurstone's pairwise comparison scaling method [24]. Specifically, the dimensions of the SDGs included in the scaling process are based on a consideration of both the global SDGs and the structures of science education curricula. By so doing, the current study aims to develop a scientifically derived hierarchy based on prospective science teachers' comparative evaluation of SDGs related themes in science education. Although the SDGs are a comprehensive global sustainability framework increasingly included in science education curricula, there is a lack of sufficient empirical research on prospective science teachers' comparative evaluation of SDGs related themes in science education, and none of the studies has applied a pairwise comparison-based scaling method for establishing a hierarchical ordering of the priorities for these themes. The findings of the study are also likely to offer evidence-based suggestions for curriculum developers and policymakers on how best they can enhance the incorporation of SDGs in science education by showing how the dimensions of SDGs are positioned relative to each other in a statistically derived scale. In this context, the current study aims to examine the following research question: how can the SDGs be hierarchically scaled within the context of science education according to prospective teachers' perceived importance using Thurstone's pairwise comparison–based scaling technique?

2. METHOD

2.1. Research design

This study employed a quantitative cross-sectional survey design. It aims to examine prospective teachers' perceived prioritization of SDGs in the context of science education. The study was non-experimental and aimed to capture participants' existing judgments without any intervention.

2.2. Study group

The participants for this study comprised of 129 prospective science teachers who were undergoing their teacher training in their third and fourth undergraduate years. Purposive sampling was applied to choose prospective science teachers who have taken courses on environmental education and sustainability.

This sampling procedure is based on the assumption that these prospective science teachers will possess adequate knowledge about the SDGs, which they are expected to incorporate in their future pedagogical practices.

2.3. Data collection tools

The questionnaire used to collect data involved the application of a form for conducting pairwise comparisons involving 11 SDGs selected from the 17 goals of the United Nations' sustainable development agenda: SDG 1, 2, 3, 4, 5, 6, 7, 12, 13, 14, and 15. The choice of only 11 goals as the focus of the study was based on both methodological considerations and conceptual representativeness. As regards methodology, the greater number of objects under comparison implies the exponential increase in the number of comparisons needed, thus making the method of pairwise comparison increasingly complicated. Consequently, if all 17 SDGs had been used as objects of judgment, it would have created unnecessary difficulties for the participants involved in this part of the research process.

Conceptually, the chosen 11 SDGs were selected specifically to ensure the representation and balance of SDG criteria from all three aspects of sustainability: social development (SDG 1, 2, 3, 4, 5); environmental sustainability (SDG 6, 7, 13, 14, 15); and economic sustainability (SDG 12). By including only these particular SDGs in the process, it is possible to cover the key features of the entire list of SDGs, providing a manageable but still representative set of objects under comparison. Content validity was established through the selection of SDGs based on their applicability to science education and coverage of key sustainability concepts.

2.4. Data collection process

For the purpose of data collection in this research, a survey form was first developed, and assistance was sought from candidates in the teaching profession through their academic programs. The participants were made aware of the content and purpose of the survey, and the survey form was thus administered. At the start of the survey, an informed consent part was included to ensure that the participants were aware of the details of the study and gave their voluntary consent to participate. To ensure that the participants gave their honest and sincere responses, no personal identifying information was collected. Participants who were unwilling to participate in the study or who provided a substantial portion of the survey form incomplete were not included in the study. Data collection was done over a period of three months, and once a sufficient number of data was collected for the application of the scaling method, the data was processed and prepared for analysis.

2.5. Data analysis

The data collected were analyzed using case III of Thurstone's Law of Comparative Judgment. First, the answers obtained from the respondents were recorded in frequency and proportion matrices that were further transformed to standard scores. From these scores, scale scores were obtained for each goal and ranked according to their importance. IBM SPSS Statistics 20 software was used to analyze the collected data. Internal consistency of judgment was assessed by examining the patterns and cohesiveness of the responses provided. The reliability of the scale was established on the basis of consistency of judgments, while the validity was achieved by means of an expert analysis of SDGs in light of scientific literacy goals.

3. RESULTS

The main findings of the study indicate a clear hierarchical structure among the selected SDGs. Overall, SDG 3 (good health and well-being), SDG 6 (clean water and sanitation), and SDG 2 (zero hunger) emerged as the most highly prioritized goals by prospective teachers. In contrast, SDG 15 (life on land), SDG 14 (life below water), and SDG 5 (gender equality) were ranked among the least prioritized. The remaining SDGs formed intermediate clusters, suggesting a perceived gradation in importance rather than a random distribution of priorities. Table 1 shows the frequency matrix "F" considering the comparison of two stimulants, which represents the SDGs.

In the F matrix of Table 1, each cell indicates the frequency of preference of the SDGs with respect to the other one. For example, 35, which is in the second row of the first column, shows the frequency of the preference of SDG 1 with respect to SDG 2. In the same way, 94, which is in the second column of the first row, shows the frequency of the preference of SDG 2 with respect to SDG 1. After completing the frequency F matrix, each value in each of the cells was divided into total number of participants (n=129). In this way, ratio matrix, P matrix was constructed and indicated in Table 2.

Table 1. Frequency matrix (F)

Stimulant	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 12	SDG 13	SDG 14	SDG 15
SDG 1	-	94	82	70	52	85	57	56	56	55	52
SDG 2	35	-	59	56	34	67	41	48	38	41	41
SDG 3	47	70	-	47	27	58	41	35	44	38	32
SDG 4	58	73	82	-	46	69	53	40	47	55	44
SDG 5	76	95	102	83	-	96	91	77	81	68	64
SDG 6	43	62	71	60	33	-	57	44	53	35	31
SDG 7	72	88	88	76	38	72	-	54	59	56	56
SDG 12	73	81	94	89	52	85	75	-	60	54	55
SDG 13	73	91	85	82	48	76	70	69	-	53	42
SDG 14	74	88	91	74	61	94	73	75	76	-	44
SDG 15	77	88	97	85	65	98	73	74	87	85	-

Table 2. Ratio matrix (P)

Stimulant	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 12	SDG 13	SDG 14	SDG15
SDG 1	–	0.729	0.636	0.543	0.403	0.659	0.442	0.434	0.434	0.426	0.403
SDG 2	0.271	–	0.457	0.434	0.264	0.519	0.318	0.372	0.295	0.318	0.318
SDG 3	0.364	0.543	–	0.364	0.209	0.450	0.318	0.271	0.341	0.295	0.248
SDG 4	0.450	0.566	0.636	–	0.357	0.535	0.411	0.310	0.364	0.426	0.341
SDG 5	0.589	0.736	0.791	0.643	–	0.744	0.705	0.597	0.628	0.527	0.496
SDG 6	0.333	0.481	0.550	0.465	0.256	–	0.442	0.341	0.411	0.271	0.240
SDG 7	0.558	0.682	0.682	0.589	0.295	0.558	–	0.419	0.457	0.434	0.434
SDG 12	0.566	0.628	0.729	0.690	0.403	0.659	0.581	–	0.465	0.419	0.426
SDG 13	0.566	0.705	0.659	0.636	0.372	0.589	0.543	0.535	–	0.411	0.326
SDG 14	0.574	0.682	0.705	0.574	0.473	0.729	0.566	0.581	0.589	–	0.341
SDG 15	0.597	0.682	0.752	0.659	0.504	0.760	0.566	0.574	0.674	0.659	–

In the P matrix of Table 2, in the first line of second column, value of 0.729 shows the result of the division of 94, which is in the second column of the first row of F matrix, into the total number of participants (n=129). Similarly, first column of the second row, 0.271 shows the result of the division of 35, which is in the second row of the first column of F matrix, into the total number of participants (n=129). Since these cell values are symmetrical to each other along the main diagonal, sum of the 0.729 and 0.271 is equal to 1. In this way, it was observed that the sum of all the symmetrical values on the main diagonal is equal to 1. The Z matrix, which was obtained from the P matrix, was presented in Table 3.

Z values were calculated depending on the values in the P matrix of Table 3. The Z matrix was obtained by taking the inverse of the standard normal cumulative distribution of the P matrix. In this type of distribution, the mean is 0 and the standard deviation is 1. The sum of the values of cells that are symmetrical to each other on the main diagonal is equal to 0. For example, the value -0.609 in the second row of the first column and the value 0.609 in the first row of the second column are symmetrical to each other and their sum is equal to zero. It was observed that the sum of all values that are symmetrical to each other on the main diagonal in the Z matrix is equal to 0. After that, discrimination variances were calculated from the values of Z matrix, and each step was displayed in Table 4.

According to Table 4, the discrimination variances (σj^2) were calculated from the Z matrix using the sum of columns ($\sum Zj$) and sum of squares of columns ($\sum Zj^2$). The variances of SDGs were estimated using the usual variance calculation method under Thurstone's scaling model. Afterward, the scaling constant (K.C=1.721) was determined. By using this constant, the discrimination parameters were calculated for all SDGs, and their squares were taken as variance estimates. Table 5 shows the total variance matrix that was calculated for scaling purposes.

Table 3. Unit standard deviations matrix (Z)

Stimulant	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 12	SDG 13	SDG 14	SDG 15
SDG 1	0.000	0.609	0.347	0.107	-0.245	0.410	-0.146	-0.166	-0.166	-0.186	-0.245
SDG 2	-0.609	0.000	-0.107	-0.166	-0.632	0.049	-0.474	-0.326	-0.540	-0.474	-0.474
SDG 3	-0.347	0.107	0.000	-0.347	-0.809	-0.127	-0.474	-0.609	-0.410	-0.540	-0.681
SDG 4	-0.127	0.166	0.347	0.000	-0.368	0.088	-0.225	-0.496	-0.347	-0.186	-0.410
SDG 5	0.225	0.632	0.809	0.368	0.000	0.656	0.540	0.245	0.326	0.068	-0.010
SDG 6	-0.431	-0.049	0.127	-0.088	-0.656	0.000	-0.146	-0.410	-0.225	-0.609	-0.705
SDG 7	0.146	0.474	0.474	0.225	-0.540	0.146	0.000	-0.205	-0.107	-0.166	-0.166
SDG 12	0.166	0.326	0.609	0.496	-0.245	0.410	0.205	0.000	-0.088	-0.205	-0.186
SDG 13	0.166	0.540	0.410	0.347	-0.326	0.225	0.107	0.088	0.000	-0.225	-0.452
SDG 14	0.186	0.474	0.540	0.186	-0.068	0.609	0.166	0.205	0.225	0.000	-0.410
SDG 15	0.245	0.474	0.681	0.410	0.010	0.705	0.166	0.186	0.452	0.410	0.000

Table 4. Discriminant variances

Stimulant	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG12	SDG13	SDG14	SDG15
∑Zj	-0.379	3.753	4.235	1.537	-3.881	3.171	-0.281	-1.488	-0.879	-2.113	-3.737
∑Zj2	0.914	1.884	2.440	0.921	2.143	1.732	0.943	1.105	1.039	1.249	1.847
K∑Zj2	10.059	20.719	26.841	10.131	23.576	19.057	10.372	12.153	11.427	13.735	20.320
(∑Zj)2	0.143	14.088	17.935	2.363	15.058	10.052	0.079	2.213	0.772	4.465	13.969
KVj	0.992	0.663	0.891	0.777	0.852	0.900	1.029	0.994	1.066	0.927	0.635
1/KVj	1.009	1.508	1.123	1.287	1.174	1.111	0.972	1.006	0.938	1.079	1.575
∑1/KVj	12.78076184										
K.C	1.721337138								K.C = 2*K/∑(1/KVj)		
σj*	0.736	1.596	0.933	1.216	1.021	0.912	0.672	0.732	0.615	0.857	1.710
σj2	0.542	2.547	0.870	1.479	1.042	0.831	0.452	0.536	0.379	0.735	2.925

*σj=(KC/KVj)-1

Table 5. Total variance matrix

σj2		0.542	2.547	0.870	1.479	1.042	0.831	0.452	0.536	0.379	0.735	2.925
		A	B	C	D	E	F	G	H	I	J	K
0.542	A	1.083	3.089	1.412	2.020	1.584	1.373	0.994	1.077	0.920	1.276	3.467
2.547	B	3.089	5.094	3.417	4.025	3.589	3.378	2.999	3.082	2.926	3.281	5.472
0.870	C	1.412	3.417	1.740	2.348	1.912	1.701	1.322	1.405	1.249	1.604	3.795
1.479	D	2.020	4.025	2.348	2.957	2.521	2.309	1.931	2.014	1.857	2.213	4.404
1.042	E	1.584	3.589	1.912	2.521	2.085	1.873	1.494	1.578	1.421	1.777	3.968
0.831	F	1.373	3.378	1.701	2.309	1.873	1.662	1.283	1.366	1.210	1.565	3.756
0.452	G	0.994	2.999	1.322	1.931	1.494	1.283	0.904	0.988	0.831	1.187	3.377
0.536	H	1.077	3.082	1.405	2.014	1.578	1.366	0.988	1.071	0.914	1.270	3.461
0.379	I	0.920	2.926	1.249	1.857	1.421	1.210	0.831	0.914	0.758	1.113	3.304
0.735	J	1.276	3.281	1.604	2.213	1.777	1.565	1.187	1.270	1.113	1.469	3.660
2.925	K	3.467	5.472	3.795	4.404	3.968	3.756	3.377	3.461	3.304	3.660	5.850

Table 5 represents the sum of variances matrix. This table constructed by calculating sum of the row and column sums of the discrimination variance values (σj2). For example, to obtain the variance in the first row of the first column, the variance of A and the variance of A are summed to get a sum of variances of 1.083. Table 6 presents the square root of total variance matrix.

The square root of the total variance matrix resulting from Table 5 is shown in Table 6, after the application of the square root transformation on the calculated total variances. The square root transformation was essential to make the variance pattern consistent and to ready the data for further scaling procedures within Thurstone's model. From the information, the S matrix is presented in Table 7.

Table 6. Square root of total variance matrix

Stimulant	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 12	SDG 13	SDG 14	SDG15
SDG 1	1.041	1.757	1.188	1.421	1.259	1.172	0.997	1.038	0.959	1.130	1.862
SDG 2	1.757	2.257	1.848	2.006	1.895	1.838	1.732	1.756	1.710	1.811	2.339
SDG 3	1.188	1.848	1.319	1.532	1.383	1.304	1.150	1.186	1.117	1.267	1.948
SDG 4	1.421	2.006	1.532	1.720	1.588	1.520	1.389	1.419	1.363	1.488	2.099
SDG 5	1.259	1.895	1.383	1.588	1.444	1.369	1.222	1.256	1.192	1.333	1.992
SDG 6	1.172	1.838	1.304	1.520	1.369	1.289	1.133	1.169	1.100	1.251	1.938
SDG 7	0.997	1.732	1.150	1.389	1.222	1.133	0.951	0.994	0.911	1.089	1.838
SDG 12	1.038	1.756	1.186	1.419	1.256	1.169	0.994	1.035	0.956	1.127	1.860
SDG 13	0.959	1.710	1.117	1.363	1.192	1.100	0.911	0.956	0.870	1.055	1.818
SDG 14	1.130	1.811	1.267	1.488	1.333	1.251	1.089	1.127	1.055	1.212	1.913
SDG 15	1.862	2.339	1.948	2.099	1.992	1.938	1.838	1.860	1.818	1.913	2.419

Table 7. S matrix (Z matrix * square root of total variance matrix)

Stimulant	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG12	SDG13	SDG14	SDG15
SDG 1	0.000	1.070	0.412	0.152	-0.309	0.480	-0.146	-0.172	-0.159	-0.210	-0.457
SDG 2	-1.070	0.000	-0.198	-0.333	-1.198	0.089	-0.820	-0.573	-0.924	-0.858	-1.108
SDG 3	-0.412	0.198	0.000	-0.532	-1.119	-0.165	-0.545	-0.722	-0.458	-0.684	-1.326
SDG 4	-0.180	0.333	0.532	0.000	-0.584	0.133	-0.313	-0.703	-0.473	-0.276	-0.859
SDG 5	0.284	1.198	1.119	0.584	0.000	0.898	0.660	0.308	0.389	0.091	-0.019
SDG 6	-0.505	-0.089	0.165	-0.133	-0.898	0.000	-0.166	-0.479	-0.248	-0.762	-1.367
SDG 7	0.146	0.820	0.545	0.313	-0.660	0.166	0.000	-0.204	-0.098	-0.181	-0.305
SDG 12	0.172	0.573	0.722	0.703	-0.308	0.479	0.204	0.000	-0.084	-0.232	-0.345
SDG 13	0.159	0.924	0.458	0.473	-0.389	0.248	0.098	0.084	0.000	-0.238	-0.822
SDG 14	0.210	0.858	0.684	0.276	-0.091	0.762	0.181	0.232	0.238	0.000	-0.783
SDG 15	0.457	1.108	1.326	0.859	0.019	1.367	0.305	0.345	0.822	0.783	0.000

The results of the S matrix have been shown in Table 7, where each corresponding element of the Z matrix in Table 3, is multiplied by the results obtained from the square root of the total variance matrix as shown in Table 6. This process incorporates standardized results along with variance modifications to further develop the comparative judgment system under the Thurstone scale method. The scale values for each SDG are shown in Table 8, based on the results of the S matrix (Table 7).

Table 8. Scale values

	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 12	SDG 13	SDG 14	SDG 15
Sj	-0.067	0.636	0.524	0.215	-0.503	0.405	-0.049	-0.171	-0.090	-0.233	-0.672
Sc	0.605	1.308	1.196	0.887	0.169	1.077	0.623	0.501	0.582	0.439	0.000

To construct Table 8, firstly, each column was summed in Table 7. Then, the column totals obtained from the S matrix were divided by the number of stimuli (K=11). In this way, the raw scale values were obtained (Sj). After that, to shift the starting point of these values to the "zero", the absolute value (+0.636) of the smallest value (-0.672) was added to all values. Thus, finally, Sc values were obtained. Figure 1 shows the scale values of the SDGs in science education, depending on their importance level on the metric.

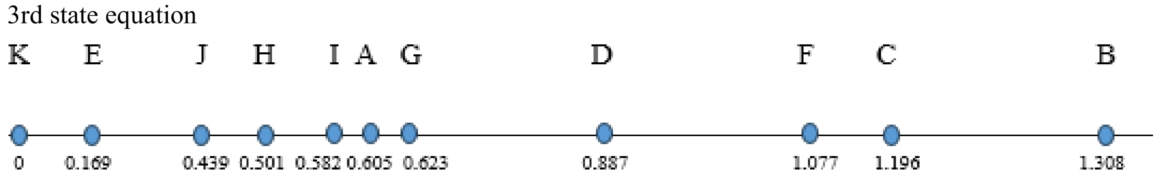

Figure 1. Scale values on the metric

According to Figure 1, the SDGs in environmental education have been listed on a number line based on their Thurstone scale values from the least important to the most important. In this regard, SDG 15 (Life on Land) has been determined as the least important goal since it is associated with the lowest scale value, 0.000, being placed first on the number line. The SDG 5 (gender equality) with a scale value of 0.169 ranks second, whereas the SDG 14 (life below water) with a scale value of 0.439 is placed third. The SDG 12 (responsible consumption and production) ranks fourth (0.501), SDG 13 (climate action) ranks fifth (0.582), SDG 1 (no poverty) ranks sixth (0.605), and SDG 7 (affordable and clean energy) ranks seventh (0.623). As can be seen, these SDGs are relatively close to each other on the scale which shows that they have similar levels of importance. SDG 4 (quality education) ranks eighth (0.887), whereas SDG 6 (clean water and sanitation) ranks ninth (1.077). SDG 3 (good health and well-being) ranks tenth with a scale value of 1.196, whereas SDG 2 (zero hunger) ranks eleventh and is the most important SDG with the highest scale value of 1.308. Overall, the results indicate that SDG 15 was perceived as the least important, whereas SDG 2 was perceived as the most important among the SDGs included in the scaling procedure. The ranked scale values are presented in Table 9, from the least important to the most important SDG.

Table 9. Ranking of scale values

Codes	Stimulant	Sc
K	SDG 15: life on land	0.000
E	SDG 5: gender equality	0.169
J	SDG 14: life below water	0.439
H	SDG 12: responsible consumption and production	0.501
I	SDG 13: climate action	0.582
A	SDG 1: no poverty	0.605
G	SDG 7: affordable and clean energy	0.623
D	SDG 4: quality education	0.887
F	SDG 6: clean water and sanitation	1.077
C	SDG 3: good health and well-being	1.196
B	SDG 2: zero hunger	1.308

As a result of the scaling procedure, a hierarchical structure of selected SDGs was clearly distinguished. Overall, SDG 3, SDG 6, and SDG 2 were found to be the most significant SDGs by future teachers. In turn, SDG 15, SDG 14, and SDG 5 were defined as the least relevant SDGs. Other SDGs were located in an intermediate position within a hierarchy without evident separation from one another. As the analysis was performed according to Thurstone's Law of Comparative Judgment (case III), pairwise comparison values were firstly collected in a frequency matrix, next converted into proportions and further standardized in order to acquire scales values. In the end, the relative significance score of each goal was estimated in relation to a common scale. Consequently, the key conclusion that can be made based on the study findings is that the hierarchy of priorities in SDGs is consistent among future teachers and shows their preferences for basic welfare SDGs (health, water, and hunger) above others.

4. DISCUSSION

The research used Thurstone's pairwise comparison technique to investigate the cognitive orderings of the SDGs among prospective science teachers. It turns out that the SDGs are not equally valued; rather, they have created a hierarchy. In general, the SDGs associated with human needs, like health, water, and hunger, received more weight compared to environmental and social/structural SDGs [25]. This shows that the participants conceptualize sustainability not as an interconnected set of equal objectives but rather in terms of a hierarchically structured set. Unlike other related works that have been published before, these results are mostly in line with existing research indicating that preservice teachers prefer to address practical sustainability problems as opposed to abstract and systemic ones. As was established earlier, topics such as climate change, the disappearance of biological diversity, or ecology as a whole were seen as complex and far-reaching subjects. Meanwhile, health and resource-oriented issues were deemed more concrete and understandable from the standpoint of education [26], [27].

Nevertheless, in contrast to prior research, the current study offers a hierarchically structured analysis of several SDGs rather than sustainability issues in isolation. It can be argued that the higher order of SDGs 2 (zero hunger), SDGs 3 (good health and well-being), and SDGs 6 (clean water and sanitation) can be attributed to the high importance of human biology and life support systems in science education. Still, such an assumption needs to be made with caution, as the observed order may be due to the fact that participants had more experience with these SDGs during their curricula [28], [29]. Hence, the findings cannot be considered as evidence of cognitive schemes, but rather as perceptions affected by the specific framework of science education. In turn, SDGs 14 (life below water), SDGs 15 (life on land), and SDGs 5 (gender equality) were found to have lower positions. These findings resonate with previous research on the fact that socio-ecological and equity aspects of sustainable development are not always viewed as topics directly related to the science subject matter by prospective teachers [30], [31]. This should not be taken as evidence of their low priority, but only indicate that these goals are harder to connect to science education than those focused on biological or resource-related topics [32], [33].

In light of pedagogy, these observations reveal a possible disbalance in the way that sustainability is theoretically framed in teachers' mental models. In other words, SDGs do not constitute a cohesive body of knowledge by themselves; instead, they represent selective priorities of certain domains. These findings have practical significance for the development of science curricula since they require the adoption of specific learning formats which would focus on SDG interdependence rather than isolated aspects of sustainability [34].

From an instructional standpoint, science educators may benefit from the assistance in drawing links between human-centric aspects of sustainable development and larger ecological and sociological systems. Thus, combining health and water-related targets with biodiversity, climate regimes, and consumption patterns may prove fruitful in terms of building a holistic vision of sustainability among learners [35]. Moreover, professional development courses in science may be enhanced with respect to socio-scientific aspects of sustainability. Policy-wise, the implications indicate that merely incorporating the SDGs in the curriculum is insufficient. More importantly, emphasis must be placed on their organization and prioritization in order to facilitate effective educational practice. The creation of a pedagogical framework that would allow educators to arrange and incorporate the SDGs may prove beneficial [36]. In conclusion, this study reveals that future science teachers generally perceive SDGs in a hierarchical manner wherein human needs serve as a guiding principle. It further emphasizes the necessity of curriculum, teacher education, and policies in facilitating an interdisciplinary approach to sustainability education.

5. CONCLUSION

The current research created a scientifically supported prioritization of SDGs within science education, which is based on the views of future teachers. Employing Thurstone's pairwise comparison method, the current study shows that SDGs are not considered equal and that they form a hierarchy in the minds of respondents. In turn, the primary novelty of this research consists in the fact that the list of SDGs is transformed into a ranked educational system.

The results show that there are priorities in SDGs among future teachers. Thus, the goals associated with human needs, such as SDG 2 (zero hunger), SDG 3 (good health and well-being), and SDG 6 (clean water and sanitation), are considered more basic as opposed to those that are related to ecology and sociostatics. Such results are vital in terms of practical application of these findings. First, SDGs in curriculum development may have to be arranged in a systematic, spiral way by considering needs-related SDGs first and then extending towards environmental and social SDGs gradually. Moreover, from the perspective of educators, there is a scientifically-backed approach of prioritizing SDGs in order to assist their instruction in class under time and curriculum restrictions. At the level of policymakers, there is a possibility to take into account this approach while implementing sustainability education policy.

This study also includes certain limitations. In particular, the small sample size, which only consisted of prospective science teachers, is a restriction regarding the generalization of results to other disciplines and educational levels. Also, the purely quantitative aspect of the study makes it incapable of explaining the cognitive basis of the hierarchy found by researchers. Thus, further research is expected to integrate both quantitative and qualitative methods like interviews to uncover the thinking process behind SDG prioritization.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies and has been approved by the authors' institutional review board or equivalent committee.

DATA AVAILABILITY

Derived data supporting the findings of this study are available from the corresponding author, [AVY], on request.

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