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Education for Sustainable Development (ESD): Analysis of System Thinking Competencies of Primary School Learners

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ABSTRACT

Objective: Sustainable Development Goals (SDGs) is a 2030 agenda comprised of 17 goals. One of these goals, the fourth, pertains to Quality Education and includes indicator 4.7, Education for Sustainable Development (ESD), as one of its achievements. The implementation of ESD in education targets the instillation of systems thinking competencies within learning objectives. Consequently, students are expected to possess systems thinking competencies as a direct outcome of the learning process. The purpose of the research is to find out how good the system thinking competence of students in elementary schools is. **Method:** This study employs descriptive quantitative methods, analyzing 15 tested items to assess system thinking competencies. The analysis of competency in system thinking involved 65 sixth-grade students at Elementary School 1 Sukaraja. Data collected was analyzed using the Rasch model via the Winstep application. **Results:** The analysis of the data obtained revealed a notably low interaction between the items and the student's responses, with Cronbach Alpha producing a logit of 0.34. This suggests that students have limited ability to engage with complex systems, as evidenced by the logit number of -0.8. **Novelty:** The development of systems thinking competency in elementary school students must be continually monitored and fostered as an essential aspect of applying ESD principles to real-life issues to ensure a sustainable future. This is based on an analysis of the data obtained regarding the long-term impact of such an approach on the students' problem-solving abilities.

INTRODUCTION

Sustainable Development Goals (SDGs) were declared by the United Nations (UN) as a follow-up to the conclusion of the Millennium Development Goals (MDGs) (UNESCO, 2017). The goals provide a comprehensive framework for sustainable development efforts worldwide, with a focus on generating positive social, economic, and environmental outcomes for present and future generations (Shulla et al., 2020), and designate UNESCO as the primary organization responsible for overseeing the implementation of Chapter 36 of Agenda 21 (UNESCO, 2019). The 17 goals of the SDGs are transformative, inclusive, and universal, aimed at addressing the challenges that hinder sustainable development (UNESCO, 2018). This objective aims to tackle a worldwide issue that is paramount to human existence to ensure the long-term habitability of the planet (UNESCO, 2018).

The SDGs adhere to the principle of inclusivity, ensuring that all members of society, both in developed and developing countries, have a crucial role in realizing global goals. No individual or group must be left behind in this pursuit (Glavic, 2020). The goals of the SDGs are inseparable from the world of education, and this is evidenced in the fourth goal, "Quality Education," which contains indicator 4.7 on Education for Sustainable Development (ESD) (UNESCO, 2019). ESD is a crucial metric for achieving the SDG objectives since education can aid in all aspects. It is attaining and improving the quality of human life. This is because education can act as a support system to progress and enhance various aspects of life.

ESD, proposed by the United Nations Economic Commission for Europe (UNECE), is an outcome of reflective thinking and actions aimed at promoting sustainable lifestyles. Through ESD, learners can make self-determined decisions that have long-term impacts on the environment (Hoffmann & Pengepungan, 2018; UNESCO, 2019). ESD-based education is made relevant to learners' school environment (Japan National Commission for UNESCO, 2016), with the assumption that quality education should provide knowledge, skills, competencies, and values for sustainable living and community participation for decent work. So, through this program, students are expected to be able to have the expected competencies in ESD (UNESCO, 2016).

ESD can be a reality when the competence of educators and learners can be well under control (UNESCO, 2017a; Rrustemi & Kurtheshi, 2023). When viewed from a teacher competence lens, the level of implementation of ESD-based teacher competencies is 1) facilitate learning, 2) connect, collaborate, and engage, 3) continue to learn and create. Although socialization has not been explicitly linked to technical implementation in the field, it remains a necessary factor (Azzahra & Hamdu, 2021; Purwadi & Hamdu, 2021; Fauzi & Hamdu, 2021). In the same way, students need to be able to master ESD-based competencies (UNESCO, 2017a).

UNESCO (2017b) has formulated eight competencies in ESD that can achieve global goals, including (1) systems thinking competency, (2) anticipatory competency, (3) normative competency, (4) strategic competency, (5) collaborative competency, (6) critical thinking competency, (7) self-awareness competency, and (8) integrated problem-solving competency. Indonesia contributes to ensuring that learners can acquire knowledge and skills through ESD to meet the country's needs (Kemendikbud, 2019). In reality, however, it is still difficult for students to master ESD competencies, especially in the area of systems thinking competencies of students in primary school (Haniyah & Hamdu, 2022). Schuler et al. (2018) found that students need help to analyze and make decisions about their learning material. This finding is consistent with previous research showing that students are unable to understand learning materials and make sustainable decisions (Funa et al., 2022).

Research on students' systems thinking competencies is still rare despite the long-standing presence of these competencies, as articulated by Peter Senge in his publication, The Fifth Discipline: The Art and Practice of the Learning Organization. Senge's framework outlines a logical approach and formal language for creating interpretive and operational models that simulate diverse phenomena' dynamics. To date, the systems thinking competency has been one of the main competencies initiated in ESD to achieve the SDGs. Systems thinking competencies focus on processes and wholes, not parts or details (Ramírez-Montoya et al., 2022). System dynamics and systems thinking can be taught without including sustainability, but sustainability cannot be taught without including systems thinking (Palmberg et al., 2017; Unsal, 2017). Systems thinking has been defined as a type of problem-solving reasoning that uses a non-reductionist approach to consider how cause and effect interact. Thus, the purpose of this article is to analyze the systems thinking competencies of ESD-based learners in primary schools.

RESEARCH METHOD

This research is descriptive quantitative research because, in this study, researchers are not comparing or looking for relationships between one variable and another (Creswell & Creswell, 2018). The researcher analyzed system thinking competencies objectively. Sixty-five Elementary School 1 Sukaraja students participated in the data collection by answering 15 questions. The questions encompassed three dimensions of ESD (environmental, social, and economic) integrated with relevant materials. Technical term abbreviations were explained upon first use, and a logical flow of information was followed. The study adhered to conventional formatting structures and used precise word choices with grammatical correctness throughout. Clear, objective language with a formal register was utilized, and filler words were avoided. The research found the questions to be valid (Haniyah & Hamdu, 2022).

Furthermore, A Rounder Sense of Purpose (RSP) outlines markers of systems thinking skills that are interlinked with the 17 Sustainable Development Goals (SDGs) (Vare et al., 2022). The system thinking competency falls under the "thinking holistically" category. Table 1 provides a mapping of questions based on system thinking indicators.

Table 1. System thinking indicator-based question mapping.

No Item	System Thinking Indicator
1 – 5	1.1 Understand the root causes of unsustainable development and that sustainable development is an evolving concept
6 – 10	1.2 Understand critical characteristics of complex systems such as living environments, human communities, and economic systems, including concepts such as interdependencies, non-linearity, self-organization, and emergence
11 - 15	1.3 Apply different viewpoints and frames when looking at systems, e.g., different scales, boundaries, perspectives, and connections

To evaluate the attainment of system thinking skills, we utilized the Rasch model to analyze responses given by 65 sixth-grade pupils at Elementary School 1 Sukaraja (Saffanah & Hamdu, 2022). However, the validation of the 15 tested items is explained in Table 2.

Table 2. Item validity using the Rasch model.

Item	Output MNSQ	Output ZSTD	Pt Measure Corr	Status
Q1	1.07	0.41	0.28	*Valid*
Q2	0.65	-1.07	0.46	*Valid*
Q3	0.73	-2.57	0.61	*Valid*
Q4	1.04	0.41	0.32	*Valid*
Q5	0.94	-0.51	0.40	*Valid*
Q6	1.25	1.96	0.06	*Valid*
Q7	1.39	1.14	0.06	*Valid*
Q8	1.05	0.32	0.24	*Valid*
Q9	0.68	-0.69	0.37	*Valid*
Q10	1.26	1.08	0.08	*Valid*
Q11	1.17	0.58	0.15	*Valid*
Q12	1.09	0.69	0.35	*Valid*
Q13	0.95	-0.38	0.38	*Valid*
Q14	0.89	-0.81	0.54	*Valid*
Q15	1.07	0.41	0.28	*Valid*

Table 2 shows that all items are valid based on Rasch model criteria, if the instrument is valid, at least one of the three criteria is met, namely Outfit MNSQ (0.5 < MNSQ < 1.5), Outfit ZSTD (-0.2 < ZSTD <, 2.0), Pt Measure Corr (0.4 < Pt Measure Corr < 0.85) (Abdul et al., 2020). Based on Table 2, the 15 tested items have achieved a "Valid" status and meet the Rasch model's criteria. Following the validity test, it is necessary to determine the reliability or consistency in responses to a question. The reliability results are displayed in Figure 1 (Sumintono & Widhiarsono, 2015).

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	22.5	65.0	.00	.30	.99	-.09	1.02	.07
SEM	2.8	.0	.23	.01	.03	.31	.06	.28
P.SD	10.5	.0	.88	.04	.12	1.15	.21	1.07
S.SD	10.8	.0	.91	.05	.13	1.19	.22	1.10
MAX.	41.0	65.0	1.51	.41	1.24	2.52	1.39	1.96
MIN.	7.0	65.0	-1.43	.27	.78	-2.79	.65	-2.57

REAL RMSE .31	TRUE SD .82	SEPARATION 2.64	ITEM	RELIABILITY .87	
MODEL RMSE .30	TRUE SD .82	SEPARATION 2.70	ITEM	RELIABILITY .88	
S.E. OF ITEM MEAN = .23					

Figure 1. Item reliability (summary of 15 measured items).

For item reliability values, there are five categories determined by a set range: <0.67 (weak), 0.67-0.80 (fair), 0.81-0.90 (good), 0.91-0.94 (very good), and >0.94 (excellent). Based on Figure 1, item reliability indicates a value of 0.87, which falls under the excellent category. Therefore, according to the Rasch model's results, the items formulated from ESD-based thinking system competencies are valid and reliable. Figure 2 further illustrates the research flow.

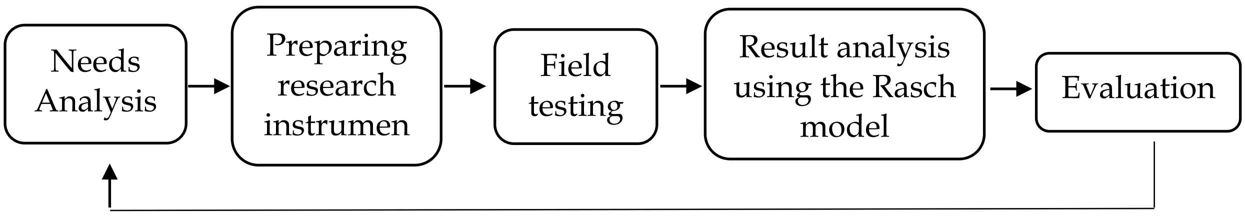

Figure 2. Flowchart of research.

RESULTS AND DISCUSSION

The level of stability of the items, the abilities of the students as respondents, and the results of interaction between items and respondents are explained in this section.

Results

Analysis of Question Item Suitability

This study employs items to evaluate the competencies of students' systems thinking. Therefore, adherence to the Rasch model's criteria is essential when designing items. The Rasch model has three acceptable criteria, including MNSQ OUTFIT (mean square) value: 0.50 < MNSQ < 1.50, OUTFIT ZSTD (standardized fit statistic) value: -2.00 < ZSTD < +2.00, and Pt Mean Corr value (point measure correlation): 0.40 < Pt Mean Corr < 0.85. Figure 3 explains that all items utilized for assessing students' system thinking competencies follow the Rasch model criteria, and at least one acceptable criterion is met, indicating that the items are suitable for measurements (Cebrian et al., 2018).

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	JMLE MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	ITEM
7	10	65	1.07	.36	1.12	.57	1.39	1.14	A .06	.25	83.1	84.6	Q7
10	15	65	.53	.31	1.16	1.03	1.26	1.08	B .08	.29	73.8	77.6	Q10
6	27	65	-.43	.27	1.24	2.52	1.25	1.96	C .06	.34	47.7	65.4	Q6
11	10	65	1.07	.36	1.04	.26	1.17	.58	D .15	.25	86.2	84.6	Q11
12	26	65	-.36	.27	.97	-.29	1.09	.69	E .35	.34	70.8	65.9	Q12
1	19	65	.18	.29	1.01	.10	1.07	.41	F .28	.31	73.8	71.9	Q1
15	24	65	-.21	.27	.99	-.05	1.07	.53	G .32	.33	70.8	67.0	Q15
8	18	65	.26	.29	1.06	.48	1.05	.32	H .24	.31	72.3	73.3	Q8
4	28	65	-.50	.27	1.01	.16	1.04	.41	g .32	.34	66.2	64.9	Q4
13	38	65	-1.21	.27	.98	-.17	.95	-.38	f .38	.35	61.5	66.6	Q13
5	35	65	-.99	.27	.97	-.34	.94	-.51	e .40	.35	63.1	65.3	Q5
14	41	65	-1.43	.27	.81	-1.86	.89	-.81	d .54	.35	84.6	68.7	Q14
9	7	65	1.51	.41	.88	-.31	.68	-.69	c .37	.22	89.2	89.2	Q9
2	10	65	1.07	.36	.84	-.65	.65	-1.07	b .46	.25	86.2	84.6	Q2
3	29	65	-.57	.27	.78	-2.79	.73	-2.57	a .61	.34	76.9	64.8	Q3
MEAN	22.5	65.0	.00	.30	.99	-.09	1.02	.07			73.7	73.0	
P.SD	10.5	.0	.88	.04	.12	1.15	.21	1.07			10.9	8.5	

Figure 3. Level of item (item statistics: misfit order).

According to Figure 3, item Q3 was deemed unsuitable based on three predetermined criteria. An Outfit ZSTD value of -2.57 was recorded. When considering the ZSTD criteria, a value range of < -2.00 suggests that the data is overly easy to predict (Sumintono & Widhiarsono, 2015). Thus, the question item with code Q3 ranks the lowest in difficulty despite meeting the other two criteria. Therefore, question item Q3 can still be utilized to evaluate the competency of students in systems thinking (Abdul et al., 2020).

Analysis Based on Class Bias

Researchers must prioritize objectivity and exclude subjective evaluations unless they are marked as such. In addition to the suitability of the items, researchers must ensure that the items used are unbiased, meaning that the items used can be used fairly by all respondents (Fitri, 2017; Nurhudaya et al., 2019). The Rasch model uses Differential Item Functioning (DIF) to detect bias, provided that the probability value is > 5.00% or > 0.05 (Sumintono & Widhiarsono, 2015).

PERSON CLASSES	SUMMARY DIF CHI-SQUARED	D.F.	PROB.	BETWEEN-CLASS/GROUP UNWTD MNSQ	ZSTD	ITEM Number	Name
3	.2363	2	.8900	.1217	-1.18	1	Q1
3	2.0531	2	.3546	1.1008	.43	2	Q2
3	1.5027	2	.4683	.7941	.11	3	Q3
3	5.1579	2	.0743	2.9185	1.62	4	Q4
3	3.7165	2	.1534	2.0471	1.14	5	Q5
3	.7805	2	.6753	.4051	-.45	6	Q6
3	1.4422	2	.4829	.7676	.08	7	Q7
3	4.0091	2	.1324	2.2402	1.26	8	Q8
3	1.4275	2	.4865	.7816	.10	9	Q9
3	3.4758	2	.1731	1.9299	1.07	10	Q10
3	.1985	2	.9072	.1027	-1.26	11	Q11
3	3.5004	2	.1710	1.9438	1.08	12	Q12
3	.1206	2	.9433	.0615	-1.48	13	Q13
3	.1064	2	.9501	.0544	-1.53	14	Q14
3	3.1312	2	.2059	1.7039	.92	15	Q15

Figure 4. DIF (bias of class).

Researchers utilized class codes (A, B, C, and D) to group classrooms and determine if the items were suitable for all classes or only specific ones. Figure 4 displays the absence of probability values less than 5.00%, indicating that no item is biased in assessing the system thinking competence of students in all classes.

Discussion

Analysis Question Item Interaction with Respondents

Rasch model can describe the interaction of item and person (respondents) from some aspect, like in Table 3.

Table 3. Item validity using the Rasch model.

Aspect	Aspects	Person	Item
Mean MNSQ	INFIT	1.00	0.99
	OUTFITS	1.02	1.02
ZSTD mean	INFIT	-0.01	-0.09
	OUTFITS	0.01	0.07
Mean Measure		-0.83	0.00
Standard Deviation (SD)		0.79	0.88
Reliability		0.31	0.87
Cronbach Alpha		0.34	

Table 3 demonstrates that the average MNSQ for INFIT and OUTFIT of both respondents and items falls within the range of 0.50-1.50. These results suggest that students, as both respondents and items, are in satisfactory condition to be tested, as the items are capable of measuring students' systems thinking skills, and the students themselves are suitable for being tested for their systems thinking competencies. For the average ZSTD INFIT and OUTFIT of both individuals and items, the range falls between -1.90 and -1.90, indicating a logical prediction for the data. This suggests that the tested items are deemed logically acceptable and that the students can effectively demonstrate their system thinking competencies. While the reliability of students is 0.31, indicating weak consistency of their answers, the reliability of the items is 0.87, categorized as good (Saffanah & Hamdu, 2022). This verifies that the questions are of good quality, but the consistency of the answers provided by the students could be more vital. Thus, the Cronbach Alpha value of 0.34 suggests a weak relationship between students and items.

Analysis of Respondent Distribution

The Rasch model displays the distribution of individuals based on their abilities utilizing the Wight Map, developed by Benjamin Wright (Sumintono & Widhiarsono, 2015). Wright's map presents the distribution of student abilities and the level of statement difficulty with the same scale (Hamdu et al., 2020; Soeharto & Csapó, 2022). The data collected by researchers using the Wright map is displayed in Figure 4. The measurement column displays item and person logits, with a distance of 1 between each logit. Learners are distributed based on their respective logit values and for each item. Wright's map can accurately demonstrate the systems thinking competencies of learners ranging from good to poor, as well as the difficulty level of the items.

On Wright's map, the right side displays the distribution of item difficulty or question items. Q9 represents the most challenging question for learners, while Q14 is the easiest. The left side of the Item Measure demonstrates the difficulty level of the questions, as the distribution of learners' abilities appears in the Person Measure.

Learners who have code 04AP occupy the highest position, with serial number 04 or Jasmine Caroline, studying in class VIA and identifying as female. The detailed data obtained by researchers through the Wright map can be seen in Figure 3.

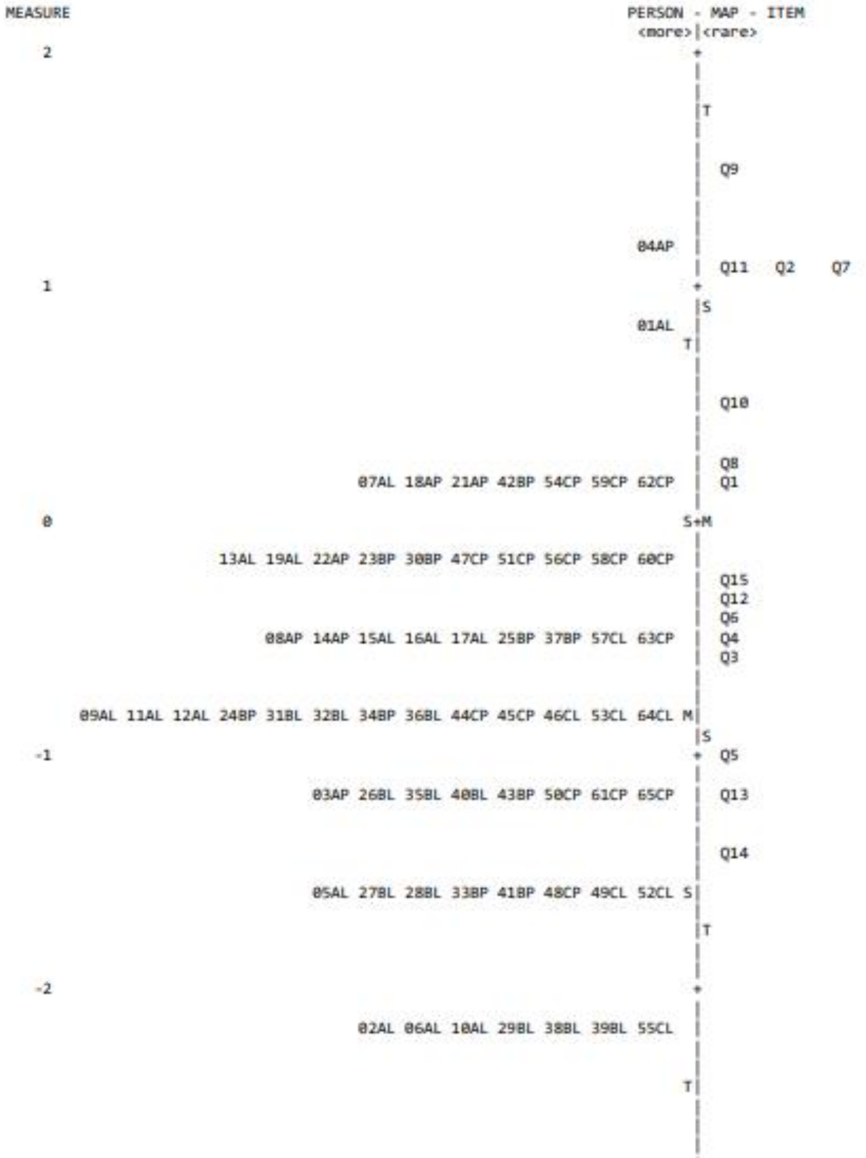

Figure 3. Distribution is based on students' system thinking competencies and item difficulty.

Analysis of Students' System Thinking Ability

Education for Sustainable Development (ESD) aims to ensure that all levels of society can contribute to preserving the environment, advancing the economy, and maintaining social relations, with the hope that each individual will be able to face the challenges of the future (Situmeang et al., 2021). Public attention on Education for Sustainable Development (ESD) is increasing. UNESCO has stated that several competencies are necessary to implement ESD, one of which is the ability to think systematically. This makes ESD an exciting topic for discussion (Prabawani et al., 2022).

Systems thinking is defined as the process of gathering, analyzing, and understanding the response of a system to complex interactions. Systems thinking involves an objective analysis of the interconnectedness of components, tracing changes in the system over time. This approach emphasizes the whole process rather than isolating individual parts (Prabawani et al., 2022; Shidiq et al., 2018). Systems thinking represents a significant breakthrough in comprehending reality, as it allows for the prevention of catastrophes and the cultivation of a more favorable future. Sustainability can only be effectively taught to students with the application of systems thinking skills (Palmberg et al., 2017).

The achievement of system thinking competency indicators can be seen in Table 3, which shows that the standard deviation value is at logit 0.79; from this value, we can determine the distribution of groups of students based on their achievements by looking at Figure 4 (Wright Map) which explains the distribution of students' abilities based on their logit value (Hamdu et al., 2020).

Table 3. System thinking ability of students (n=65).

Level	Login	Respondent
High	0.79 – 1.58	04AP, 01AL
Medium	0.00 – 0.79	07AL, 18AP, 21AP, 42BP, 54CP, 59CP, 6ACP
Low	-0.79 – 0.00	03AP, 26BL, 35BL, 40BL, 43BP, 50CP, 61CP, 65CP, 05AL, 27BL, 28BL, 33BP, 41BP, 48CP, 49CL, 52CL
Very Low	> -0.79	02AL, 06AL, 10AL, 29BL, 39BL, 55CL, 20AP

Table 3 reveals that the mean person size has a logit of -0.83, which places it in the "deficient" category when categorized by student ability. This indicates that, on average, learners have low systems thinking competencies. Therefore, students need to meet the indicators of systems thinking competence in RSP-based ESD, as depicted in Table 1. However, students identified with the code 04AP have a logit value greater than 1.00, indicating their categorization in the high systems thinking competence group. Based on Table 1, which presents indicators for systems thinking competence, this study concludes that students need to possess the desired competence in systems thinking (Miller et al., 2023). Learners failed to meet indicator 1.1, as tested through questions 1-5, with results indicating a lack of understanding of both the concept of sustainability and development problems. Indicator 1.2 tested students' comprehension of the characteristics of a complex system, including the environment, human interaction, and self-organization, through questions 6-10. Results indicate that understanding in this area needs improvement. Additionally, results from indicator 1.3, assessed through questions 11-12, show that students needed help to apply different points of view when analyzing a system. Therefore, educators should guide in incorporating system-thinking indicators into education, thereby promoting system-thinking solid skills among students (Holman & Svejdarova, 2023).

CONCLUSION

Fundamental Finding: The system thinking competency indicator for ESD (refer to Table 1) reveals that research among grade VI students at Elementary School 1 Sukaraja indicates a shallow average ability level. This is confirmed by the logit value of -0.83. Nonetheless, one student with code 04AP possesses a logit value exceeding 1.00, thereby placing them in the high system thinking ability category. Overall, the research indicates that students need help to meet the criteria for systems thinking. Specifically, learners experience difficulties comprehending the notion of sustainability and complicated systems within their respective environments, as well as employing diverse perspectives when analyzing a system. **Implication:** However, this problem must still be addressed by various parties, particularly educators who guide students. It is essential to be aware of the significance of ongoing learning. The competencies that students require must be adapted to current needs in order to support their future lives. **Future Research:** Educators must integrate indicators of systems thinking into the learning process. It is imperative to create tools for research, instructional modules, or learning materials to enhance learners' proficiency in system thinking skills or other ESD competencies. **Limitation:** The limited literature on developing systems thinking is concerning, given its identification as a crucial competency in sustainable learner development.

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