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ESD Biodiversity and Systems Thinking Context in PISA and End-Semester Exams

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Abstract

PISA becomes a benchmark for the quality of a country's education. The research was to compare the theme of biodiversity and the system of thinking on the 2018 PISA questions with end-semester exam questions for the 2020/2021 school year in elementary schools. This study used qualitative research with an analysis method for 4-unit PISA questions, 3 sets of end-semester exam questions for grade 5, and 6 questions for elementary school teachers. The results showed that the content related to plants, animals, and microorganisms in the PISA questions was the highest, with a presentation of 95.83%. For the end-semester exam questions, the animal content was the highest percentage of 43.802%. The PISA questions are created thematically, while end-semester exam questions are mostly created per subject. In addition, the content of the structure domain is the highest competency in the system of thinking on PISA questions and end-semester exam questions with presentations of 53.57% and 55.22%, respectively. Students were asked more questions about interconnection analysis. Of course, this content can be learned more by elementary school students. So, that students can have global competence from an early age.

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INTRODUCTION

An end-semester exam is arranged thematically or in a subject matter. The end-semester exam contains indicators that reflect all competencies in the one-semester exam to determine the completeness of student learning outcomes. In addition, the data will be processed, analyzed, and utilized to complete the report (Ditjen Dikdasmen, 2016). Meanwhile, PISA (Program for International Student Assessment) is an ongoing program from the OECD (Organization for Economic Co-Operation and Development), that aims to determine the average reading, math, and scientific literacy skills of 15-year-old students from each country (Khurniawan & Erda, 2019). However, the 2018 PISA Indonesia results show that the learning achievement of Indonesian students is lower than the OECD average (OECD, 2018b). Likewise, with the average score of all OECD countries, efforts still need to improve students' abilities to realize quality education as agreed in the 2030 SDGs (Sustainable Development Goals) (OECD, 2019b). Students in each country that is a member of the OECD are required to have global competence, including (1) the ability to research problems that occur at the local, intercultural, and global levels; (2) the ability to understand the world from multiple perspectives; (3) the ability to engage openly; (4) the ability to communicate with people from different cultures effectively; and (5) the ability to collaborate to achieve SDGs goals (OECD, 2018a).

ESD (Education for Sustainable Development) is the main driver for achieving SDGs in 2030 (UNESCO, 2015). Generally, ESD includes various types, steps, and educational processes aimed at achieving the SDGs by promoting and integrating collaborative concepts that encourage student contributions (Hoffmann & Siege, 2018). In its implementation, ESD is not a new curriculum but integrated with the existing educational curriculum (UNESCO, 2017). Three methods are used in Indonesia to incorporate ESD into the curriculum: creating a contextual framework for already-existing content, incorporating a small amount of ESD content, and creating a unique curriculum (Hariyono et al., 2024). However, sustainability in natural science, social science, geography, and biology is usually done in several schools to teach students to overcome problems arising from human interaction with the environment and encourage environmental (Hawa et al., 2021; Parker, 2017).

One of the ESD themes set by UNESCO is biodiversity (Filho et al., 2016; Pretorius et al., 2016; Suryani & Hamdu, 2021; Shabrina et al., 2024). The significance of biodiversity has been highlighted since the Rio Earth Summit to enhance public awareness about the necessity of safeguarding our natural resources (Díaz & Malhi, 2022). This theme of biodiversity includes the diversity of all species living on earth, all types of animals, plants, fungi, and microorganisms, and the ecological balance that is very important for maintaining the continuity of life (Bruno, 2023; Gómez-Márquez, 2023).

Systems thinking is one of the cross-sectoral competencies in ESD (UNESCO, 2017; Vilmala et al., 2022). Systems thinking increases the ability to help humans understand a system, predict human behavior, and design and develop something (Arnold & Wade, 2015). Students can understand the dynamics of living systems that will grow through systems thinking (Schuler et al., 2018). By applying systems thinking, students' employability is improved, interdisciplinary learning is promoted, and higher-order thinking skills (HOTS) are developed (Jackson & Hurst, 2021; York et al., 2019). Thinking is a key competency that spans various sectors in ESD and is one of the global competencies that should be taught and assessed starting from elementary school. According to Paragraph (1) of National Education System Law No. 20 of 2003, "basic education serves as the foundation for secondary education."

Questions related to the theme of biodiversity, especially environmental awareness, and optimism toward species extinction and deforestation, have been tested in the 2015 PISA test (Niankara, 2019). Similarly, the 2018 PISA assessment included questions about "Global Competencies" that dealt with sustainable development and global citizenship awareness (Chandir & Gorur, 2021). Even for the upcoming PISA 2025, environmental science education experts are asked to assess students' abilities in overcoming significant socio-ecological challenges (Kurdiati & Apriana, 2025).

Through the 2013 Indonesian curriculum, the themes of biodiversity and systems thinking have been implicitly included, such as ecosystem and food web materials for elementary school students (Hamdu et al., 2021; Salam & Hamdu, 2022). Additionally, the Merdeka curriculum teaches this ecosystem (Erlinawati et al., 2024; Noviani et al., 2023). Both the 2013 curriculum and the Merdeka curriculum educate high school students on biodiversity material (Mei & Suryadarma, 2023; Purwaningsih et al., 2024).

Numerous studies are currently available

on the analysis of student test questions. Suryani & Hamdu (2021) showed that the content of the theme of biodiversity and the ability to analyze something complex has a higher percentage in the national science examination questions. The study analyzing the content of the ESD theme and systems thinking competencies in the 2016-2018 elementary school science national examination questions. Nevertheless, they did not address the implications for science education that teachers can implement in their research. Oliver et al. (2021) explored the influence of the inquiry approach on science learning and students' science literacy based on PISA 2015 data. Their study does a good job of comparing PISA data from six different countries. However, the characteristics schools that influence students' science literacy abilities are not discussed specifically.

Nurjanah et al. (2022) investigated HOTS content in thematic end-semester exams in elementary schools, which showed that the quantity of HOTS questions was still low. The investigation was effective as it thoroughly examined five themes from the odd semesters of grade 5 during the 2020–2021 academic years. However, this investigation did not provide a detailed explanation of the percentage of each HOST content indicator. Accordingly, no study has compared the end-semester exam with the PISA 2018 questions. An analysis is necessary to compare the content of the biodiversity theme and systems thinking competencies in the end-semester exam questions for elementary schools with those in the PISA questions. This comparison will serve as a foundation for developing innovative science learning strategies, enabling teachers to design lessons that foster competencies evaluated by PISA.

METHOD

This study is qualitative by analytical methods. The data used in this study are documents of 4 units of PISA questions in 2018, 3 sets of end-semester exam questions for class 5 2020/2021 academic year from three elementary schools in Tasikmalaya, various coverage of biodiversity according to Bruno (2023) and Gómez-Márquez (2023), Competency Standard document Permendikbud No. 37 of 2018, the domain of systems thinking competency descriptions according to Arnold & Wade (2017), description of systems thinking indicators according to Karaarslan Semiz & Teksöz (2019), and the results of interviews from 6 elementary school teachers in Tasikmalaya.

End-semester exam questions for grade 5 for the 2020/2021 academic year consist of 1 set end-semester exam questions arranged thematically from an elementary school in Tasikmalaya Regency, 2 set end-semester exam questions compiled subject from elementary schools in Tasikmalaya Regency and Tasikmalaya City. In this study, analysis was carried out by reading questions, reviewing questions, calculating and recording the percentage of item content based on the theme of biodiversity and systems thinking competencies using the following formula.

$$Persentase = \frac{Total\ of\ Content}{Total\ Amount\ of\ Content\ in\ Theme} x\ 100\%$$

The analysis instruments for PISA and end-semester exam questions based on the theme of biodiversity are shown in Table 1.

Table 1. Biodiversity Themes Analysis Instruments on PISA Questions and End-Semester Exam

Types of Biodiversity (Bruno, 2023; Gómez-Márquez, 2023)	**Indicators** (Kemendikbud, 2018; Kemendikbud, 2022)
Plants	The form and function of the parts of plants in plants; and How to propagate plants
Animals	The shape of the animal's body parts and their functions; Types of animals; Tools for movement in animals and their functions; Respiratory in animals; Digestive organs in animals and their functions; Circulatory organs in animals and their functions; and How to reproduce animals
Microorganisms	Types of microorganisms
The Ecological Balance	The form of interaction between living things and their surroundings; The life cycle of living things; Ecosystem components; Neighborhood food webs; The way living things adapt to their environment; and Natural resources

Beside that, analysis instruments for PISA questions and end-semester exam based on systems thinking competencies are shown in Table 2.

Table 2. Systems Thinking Analysis Instruments on PISA Questions and End-Semester Exam

The Domain of Systems Thinking (Arnold & Wade, 2017)	**Indicators** (Karaarslan Semiz & Teksöz, 2019)
Mindset	Describing a place from multiple perspectives; Adjusting the perspective of systems thinking with personal life; and Acknowledging one's responsibility in the system.
Content	Observing nature as a system; and Analyzing the components of a system
Structure	Analyzing the interconnection or linkages between aspects; Identifying relationships between environments; Recognizing the hidden dimensions in the system; and Identifying the cyclical nature of the system
Behavior	Consider the relationship between the past, present, and future actions; Develop empathy for humans; and Develop empathy for living things other than humans

The data collection instrument in this study used a data recording sheet containing a distribution analysis table. The content of the theme of biodiversity and systems thinking in PISA questions and end-semester exam questions is reviewed based on the data analysis procedure adopted from Creswell (2019) shown in Figure 1.

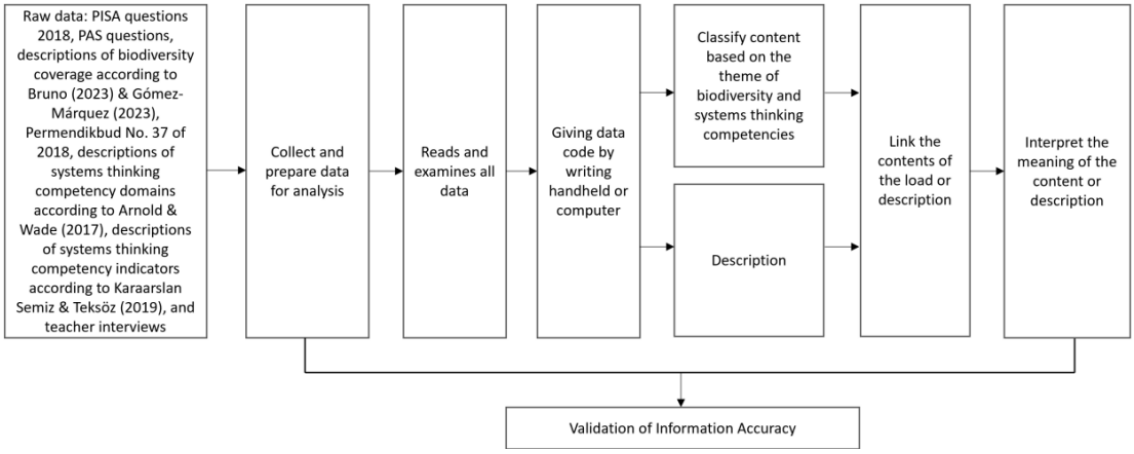

Figure 1. Analysis Procedure

After preparing and compiling the three sets of raw data, they are read and examined together. The analysis is conducted by coding each question based on various criteria, including Exam Type Coding, Biodiversity Type Coding, Systems Thinking Competency Coding, Exam Unit Coding, and Question Number Coding. The content of each exam type is categorized according to the themes of biodiversity and systems thinking competency. This ensures that each column related to these themes is populated with the appropriate indicators, allowing for the calculation of percentages. The text also includes a narrative presentation of the teacher interview transcripts, highlighting the percentage related to each theme. Following this, an interpretation of the significance of each theme is provided to validate the accuracy of the information.

RESULT AND DISCUSSION

Contents on Biodiversity Themes in PISA Questions and End-Semester Exam Questions

The theme of biodiversity generally focuses on the diversity of life forms on earth, such as genetic differences within species, diversity between species, and the diversity of ecosystems formed by various species (Gómez-Márquez, 2023; Ram, 2021). Students should be taught about biodiversity, which includes all kinds of animals, plants, fungi, microorganisms, and ecological balance, all of which are critical to preserving the continuation of life (Bruno, 2023; Gómez-Márquez, 2023). This relates to the ESD concept, which combines the social, economic, and environmental pillars of sustainability (UNESCO, 2018; Glavi, 2020). At the elementary school level, students

should first learn about biodiversity before engaging with various environmental issues related to biodiversity conservation. The following is the percentage of the results of the analysis of PISA questions and sample end-semester exam questions in Tasikmalaya based on the theme of biodiversity presented in Table 3.

Table 3. Presentation of Content on Biodiversity Themes on PISA and End-Semester Exam

The Domain of Systems Thinking	PISA Questions (%)	Tasikmalaya Regency		Tasikmalaya City	Average End-Semester Exam Questions (%)
		Thematic End-Semester Exam Questions (%)	End-Semester Exam Questions Per Subject (%)	End-Semester Exam Questions Per Subject (%)	
Mindset	17.86	60	4.35	10	24.78
Content	25	0	0	60	20
Structure	53.57	40	95.65	30	55.22
Behavior	3.57	0	0	0	0

Based on the table above, the highest presentation containing the competency of thinking systems in the 2018 PISA questions and 2020/2021 academic year end-semester exam questions in Tasikmalaya lies in the domain structure with presentations of 53.57% and 55.22%, respectively. In PISA questions, indicators analyzing interconnections or relationships between aspects and recognizing hidden dimensions in the system are indicators of systems thinking that are more often tested on students. The majority of Indonesian students, however, are thought to be incapable of mastering the system's indicator of multiplying hidden dimensions. This is because students still make mistakes in understanding the problems in PISA questions (Fazzilah et al., 2020). For this reason, the ability of Indonesian students in reading literacy skills is ranked 74th out of 79 countries that participated in PISA (OECD, 2019b).

Students are given more questions containing indicators of analyzing interconnections or related aspects and recognizing the cyclical nature of the system in PAS questions. In line with that, the ability to analyze something complicated is a presentation of the content of the thinking system that is more tested in the National Examination questions in elementary schools in 2016-2018 (Suryani & Hamdu, 2021). Metacognitive skills, crucial for effective thinking systems, are closely linked to HOTS. These skills enable students to plan, monitor, and manage their learning processes, allowing them to tackle complex scientific problems (Hamzah et al., 2022).

The indicators of systems thinking in end-semester exam questions are not explained clearly, because elementary school teachers who are also the makers of end-semester exam questions are not yet familiar with the term systems thinking itself. Although not present in every question, end-semester exam questions implicitly show the need to examine the relationship in the thinking system. This is because questions that stimulate students to analyze high-level thinking questions are still limited (Mariani et al., 2021; Sari et al., 2023). In addition, not all questions used in the assessment in grade 5 are high-level thinking questions (Kholiq et al., 2019). The difficulty level of the questions on the national exam remains at levels C1, C2, and C3 (Asiasi & Ridlo, 2018). Creating thought-provoking questions that cater to students with varying skill levels and low literacy interests has proven to be a challenge for five out of the six elementary school teachers surveyed. Consequently, students struggle to process the information provided by the PAS questions. The implementation of systems thinking questions in elementary schools also presents significant challenges for teachers (Azzahra et al., 2023).

Improving the PISA results of Indonesian students requires optimizing the implementation of ESD learning innovations, specifically by developing students' systems thinking competencies through various topics, such as biodiversity. By implementing ESD innovations in schools, students can improve their skills, knowledge, and environmental awareness in the 21st century (Mardian, 2023). Students have demonstrated improved systems thinking abilities when participating in elementary school STEL (System Thinking and ESD Learning) instruction (Mulyadiprana et al., 2024). In addition, experts from OECD member countries emphasize that cognitive knowledge test questions for students should cover the following areas: (1) global issues that are central to ESD; (2) intercultural knowledge and understanding; and (3) analytical and critical thinking skills (UNESCO, 2017). The emphasis

on socio-ecological issues will be highlighted in the upcoming 2025 PISA to evaluate students' abilities to address these challenges (Kurdiati & Apriana, 2025). Relevance between competencies and mastery of the material tested in the PISA assessment and science learning in schools is essential. To promote systems thinking skills, including HOTS, teachers must develop and implement innovative teaching strategies that encourage students to think critically and solve complex problems (Ab Halim et al., 2021; Hamzah et al., 2022). Moreover, the implementation of ESD in elementary schools currently tends to be minimal (Gunansyah et al., 2021; Supriatna et al., 2018; Suwarto et al., 2021).

Teachers can improve each indicator of systems thinking in science learning in elementary schools based on the scope of material on basic competencies or science learning achievements with issues raised in ESD. In addition to biodiversity, there are other ESD issues, namely climate change, disaster risk reduction, health improvement, sustainable lifestyles, and air (Suryani & Hamdu, 2021). Material on the impact of human activities on the environment and various environmental problems due to human actions can be used to develop the four aspects of systems thinking (Mulyadiprana et al., 2024). Science learning material on the air cycle can also improve indicators of students' systems thinking abilities in observing nature as a system, analyzing the components of a system, analyzing interconnections or relationships between aspects, and identifying relationships between environments. In addition, giving performance assignments to create concept maps can also help students organize their thoughts and understand relationships in the system (Schumacher, 2023).

Teachers should focus on systems thinking and ESD issues when creating end-semester exam questions to help improve PISA test results. The formulation of final exam questions should be under the PISA framework, which focuses on relevant content and context that students can understand, such as the local context (Rizal et al., 2021; Susanta et al., 2023). The inclusion of questions that promote higher-order thinking skills in preparing final exam questions is essential for meeting PISA standards (Budiarti et al., 2023). Therefore, incorporating HOTS questions that address real-world problems can serve as valuable material for creating final semester exam questions, helping to familiarize students with the types of questions they will encounter in PISA assessments. In addition, students' abilities in analyzing, rotating, and creating, which are HOTS processes, intersect with systems thinking competencies. Thus, utilizing HOTS questions can help students understand and engage with complex scientific concepts (Khaeruddin et al., 2023; Seher Budak & Defne Ceyhan, 2024).

Follow-up actions in education are vital for teachers to grasp and implement ESD learning innovations and systems thinking competencies. This requires support from various stakeholders and effective institutional policies (Mulà et al., 2017). Organizations like Smart Classes can provide training programs to integrate ESD methodologies, such as project-based learning (Cebrián et al., 2020). Outdoor ESD courses can be an alternative follow-up for teachers and prospective teachers (Karaarslan Semiz & Teksöz, 2019). Moreover, universities in Indonesia have included ESD principles (Tristananda, 2018) and the implementation of ESD is in line with the "Merdeka Belajar" curriculum, which encourages a more relevant learning process that supports sustainable development (Ama longgo et al., 2023). Additionally, teachers can engage in learning communities to collaborate and share innovative practices (Labudasari et al., 2024). The limitation of this study is that it does not analyze the effectiveness and depth of content regarding biodiversity and systems thinking competency between PISA and end-semester exam questions.

CONCLUSION

The results showed that the relationship between plants, animals, and microorganisms was the highest percentage in the content of the theme of biodiversity, namely 95.83%. Meanwhile, in the end-semester exam questions in Tasikmalaya, the animal load was the highest percentage, namely 43.802%. In the PISA and end-semester exam questions, the highest systems thinking competency content presentation was in the structure domain, namely 53.57% and 55.22%. Students tested more questions that contained indicators of analyzing interconnections and recognizing hidden dimensions in the system in the PISA questions. Meanwhile, in the end-semester exam, students are given more questions which are indicators to analyze the relationship and identify the nature of the system cycle. Further researchers are expected to be able to develop ESD learning and test questions with the theme of biodiversity and can bring up system thinking competencies in 5th-grade elementary school considering that the theme of biodiversity and system thinking competence has entered the learning flow although not implicitly.

REFERENCES

Ab Halim, A. S., Osman, K., Aziz, M. S. A. M., Ibrahim, M. F., & Ahmad, A. A. K. (2021). The Competency of Science Teachers in Integrating Higher Order Thinking Skills in Teaching and Learning. *Journal of Physics: Conference Series*, 1793(1). https://doi.org/10.1088/1742-6596/1793/1/012005

Ama longgo, D. H., Adiatma, T., & Siamsa, S. (2023). Integrating Education for Sustainable Development (ESD) in Higher Education Institutions To Reduce the Impact of Climate Change on Agricultural Industries. *AGROLAND The Agricultural Sciences Journal (e-Journal)*, 10(2), 94–102. https://doi.org/10.22487/agroland.v0i0.1936

Arnold, R. D., & Wade, J. P. (2015). A Definition of Systems Thinking: A Systems Approach. *Procedia Computer Science*, 44(C), 669–678. https://doi.org/10.1016/j.procs.2015.03.050

Arnold, R. D., & Wade, J. P. (2017). A Complete Set of Systems Thinking Skills. *Insight*, 20(3), 9–17. https://doi.org/10.1002/inst.12159

Asiasi, M. F., & Ridlo, R. Z. (2018). Analisis Komparasi Soal Ujian Sekolah Dasar (2011-2017) Terhadap Soal Olimpiade (IMSO) Tahun 2006-2017. *Prosiding FKIP Universitas Jember*, 1, 121–130.

Azzahra, M., Pramudiyanti, P., Rohman, F., & Nurwahidin, M. (2023). Education for Sustainable Development (ESD): Analysis of System Thinking Competencies of Primary School Learners. *IJORER : International Journal of Recent Educational Research*, 4(6), 689–699. https://doi.org/10.46245/ijorer.v4i6.403

Bruno, M. (2023). Remarks on the Misunderstood Use of the Term Biodiversity. *International Journal of Zoology and Animal Biology*, 6(6), 1–7. https://doi.org/10.23880/izab-16000537

Budiarti, M. I. E., Musa'ad, F., & Supriadi. (2023). Analisis Proses Pemecahan Masalah Peserta Didik dalam Menyelesaikan Soal Berorientasi PISA. *Prima Magistra: Jurnal Ilmiah Kependidikan*, 4(4), 533–539.

Cebrián, G., Palau, R., & Mogas, J. (2020). The Smart Classroom as a Means to the Development of ESD Methodologies. *Sustainability*, 12(3010), 1–18.

Chandir, H., & Gorur, R. (2021). Unsustainable Measures? Assessing Global Competence in PISA 2018. *Education Policy Analysis Archives*, 29. https://doi.org/10.14507/epaa.29.4716

Creswell, J. W. (2019). *Research Design, Qualitative, Quantitative, and Mixed Methods Approaches Fourth Edition*. Yogyakarta: Pustaka Pelajar.

Cross, S., Aristeidou, M., Rossade, K. D., Wood, C., & Brasher, A. (2023). The Impact of Online Exams on the Quality of Distance Learners' Exam and Exam Revision Experience: Perspectives from the Open University UK. *Online Learning Journal*, 27(2), 27–45. https://doi.org/10.24059/olj.v27i2.3761

Departemen Pendidikan Nasional. (2003). *Undang-undang Republik Indonesia Nomor 20 Tahun 2003 Tentang Sistem Pendidikan Nasional*. Jakarta: Depdiknas.

Direktorat Jenderal Pendidikan Dasar dan Menengah Kementrian Pendidikan dan Kebudayaan. (2016). *Juknis Panduan Penilaian K13 Permendikbud No. 23 Tahun 2016 Revisi 2017*. Jakarta: Ditjen Dikdasmen.

Díaz, S., & Malhi, Y. (2022). Biodiversity : Concepts , Patterns , Trends , and Perspectives. *Annual Review of Environment and Resources*, 31–63. https://doi.org/https://doi.org/10.1146/annurev-environ-120120-054300

Erlinawati, B., Roshayanti, F., & Nugroho, A. S. (2024). Profil Pembelajaran Berdeferensiasi Berorientasi ESD pada Materi Ekologi dan Keanekaragaman Hayati di SMP N 1 Wirosari Kabupaten Grobogan. *Jurnal Inovasi Pembelajaran Di Sekolah*, 5(1), 071–076. https://doi.org/10.51874/jips.v5i1.207

Fazzilah, E., Effendi, K. N. S., & Marlina, R. (2020). Analisis Kesalahan Siswa Dalam Menyelesaikan Soal PISA Konten Uncertainty dan Data. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, 4(2), 1034–1043. https://doi.org/10.31004/cendekia.v4i2.306

Filho, W. L., Castro, P., Bacelar-Nicolau, P., Azul, A. M., & Azeiteiro, U. M. (2016). Biodiversity and Education for Sustainable Development (ESD): Tendencies and Perspectives. In P. Castro, U. M. Azeiteiro, P. Bacelar-Nicolau, W. Leal Filho, & A. M. Azul (Eds.), *Biodiversity and Education for Sustainable Development: World Sustainability Series* (pp. 1–10). Springer International Publishing. https://doi.org/10.1007/978-3-319-32318-3_1

Glavi , P. (2020). Identifying Key Issues of Education for Sustainable Development. *Sustainability (Switzerland)*, 12(16). https://doi.org/10.3390/su12166500

Gómez-Márquez, J. (2023). The Life Tree of Ecosystems and Living Worlds. *Biodiversity*, 24(3), 114–116. https://doi.org/10.1080/14888386.2023.2212641

Green, C., Molloy, O., & Duggan, J. (2022). An Empirical Study of The Impact of Systems Thinking and Simulation on Sustainability Education. *Sustainability (Switzerland)*, 14(1). https://doi.org/10.3390/su14010394

Gunansyah, G., Zuhdi, U., Suprayitno, S., & Aisy, M. R. (2021). Sustainable Development Education Practices in Elementary Schools. *Journal of Education and Learning (EduLearn)*, 15(2), 178–187. https://doi.org/10.11591/edulearn.v15i2.17091

Hamdu, G., Suryani, L., & Prana, A. M. (2021). Tingkat Kesulitan Soal Tes Berpikir Sistem pada Implementasi Pembelajaran Education for Sustainable Development di Sekolah Dasar. *Prosiding Seminar Nasional MIPATI*, 1, 142–147. https://www.stkipbjm.ac.id/mathdidactic/index.php/mipati/article/view/1538

Hamzah, H., Hamzah, M. I., & Zulkifli, H. (2022).

Systematic Literature Review on the Elements of Metacognition-Based Higher Order Thinking Skills (HOTS) Teaching and Learning Modules. *Sustainability (Switzerland)*, 14(2), 1–15. https://www.mdpi.com/2071-1050/14/2/813

Hariyono, E., Wijaya, A. F. C., & Rusdiana, D. (2024). Infusing Education for Sustainable Development into the Curriculum: Best Practice from Indonesia's Science Curriculum Implementation BT - Science Education for Sustainable Development in Asia. In H. Fujii & S.-K. Lee (Eds.), Science Education for Sustaineble Development in Asia (pp. 141–157). Springer Nature Singapore. https://doi.org/10.1007/978-981-99-8711-5_9

Hawa, N. N., Zakaria, S. Z. S., Razman, M. R., & Majid, N. A. (2021). Geography education for promoting sustainability in Indonesia. *Sustainability (Switzerland)*, 13(8), 1–15. https://doi.org/10.3390/su13084340

Heidarzadeh, A., Zehtab Hashemi, H., Parvasideh, P., Hasan Larijani, Z., Baghdadi, P., Fakhraee, M., Mousavi, M. M., Mahmoodi, D., & Dehghan, H. (2021). Opportunities and Challenges of Online Take-Home Exams in Medical Education. *Journal of Medical Education*, 20(1), 1–8. https://doi.org/10.5812/jme.112512

Hirschprung, R. S., Kordova, S., Klein, M., & Maimon, O. (2023). Representation and Assessment of Systems Thinking Competencies Through Soft Logic. *IEEE Access*, 11(November), 141547–141558. https://doi.org/10.1109/ACCESS.2023.3342131

Hoffmann, T., & Siege, H. (2018). What is Education for Sustainable Development (ESD)? *In ESD Expert Net* (Vol. 21, Issue 2, pp. 1–6). https://doi.org/10.1080/0958517022000014673

Ilgaz, H., & Afacan Adanır, G. (2020). Providing online exams for online learners: Does it really matter for them? *Education and Information Technologies*, 25(2), 1255–1269. https://doi.org/10.1007/s10639-019-10020-6

Jackson, A., & Hurst, G. A. (2021). Faculty Perspectives Regarding The Integration of Systems Thinking Into Chemistry Education. *Chemistry Education Research and Practice*, 22(4), 855–865. https://doi.org/10.1039/d1rp00078k

Jaradat, R. M., Keating, C. B., & Bradley, J. M. (2018). Individual Capacity and Organizational Competency for Systems Thinking. *IEEE Systems Journal*, 12(2), 1203–1210. https://doi.org/10.1109/JSYST.2017.2652218

Karaarslan Semiz, G., & Teksöz, G. (2019). Developing The Systems Thinking Skills of Pre-Service Science Teachers Through An Outdoor ESD Course. *Journal of Adventure Education and Outdoor Learning*, 00(00), 1–20. https://doi.org/10.1080/14729679.2019.1686038

Kementrian Pendidikan dan Kebudayaan. (2018). Peraturan Menteri Pendidikan dan Kebudayaan Nomor 37 Tahun 2018 Tentang Perubahan Atas Peraturan Menteri Pendidikan dan Kebudayaan Nomor 24 Tahun 2016 Tentang Kompetensi Inti dan Kompetensi Dasar Pelajaran pada Kurikulum 2013 pada Pendidikan Dasar dan Pendidikan Menengah. Jakarta: Kermendikbud.

Kementerian Pendidikan dan Kebudayaan. (2022). Capaian Pembelajaran Mata Pelajaran Ilmu Pengetahuan Alam dan Sosial (IPAS) Fase A -Fase C untuk SD/MI/Program Paket A. Jakarta: Kemendikbud. https://guru.kemdikbud.go.id/kurikulum/referensi-penerapan/capaian-pembelajaran/sd-sma/ilmu-pengetahuan-alam-dan-sosial-ipas/

Khaeruddin, K., Indarwati, S., Sukmawati, S., Hasriana, H., & Afifah, F. (2023). An Analysis of Students' Higher Order Thinking Skills Through the Project-Based Learning Model on Science Subject. *Jurnal Pendidikan Fisika Indonesia*, 19(1), 47–54. https://doi.org/10.15294/jpfi.v19i1.34259

Kholiq, H. A., Artharina, F. P., & Arisyanto, P. (2019). *Analisis Penilaian Berorientasi Higher Order Thinking Skills Siswa Kelas V*. 2(September).

Khurniawan, A. W., & Erda, G. (2019). Evaluasi Pisa 2018: Indonesia Perlu Segera Berbenah. *Vocational Education Policy, White Paper*, 1(21), 1–10.

Kurdiati, L. A., & Apriana, R. (2025). Transformation of Sustainability Science Education : PISA 2025 Science Framework and ESD on E-Worksheets Science in the Context of the Role of Peatland in Global Warming Phenomenon. *Kasuari: Physic Education Journal (KPEJ)*, 7(2), 431–445.

Labudasari, E., Rochmah, E., & Rohana, S. (2024). Empowering Learning Communities to Enhance Assessment Utilization on Merdeka Curriculum's PMM Platform. *Community Empowerment*, 9(10), 1524–1533.

Mardian, V. (2023). How is ESD (Education for Sustainble Development) Implemented After Covid-19 in Indonesia to Realize SGD's? *Physics and Science Education Journal (PSEJ)*, 3, 126–133. https://doi.org/10.30631/psej.v3i3.2116

Mariani, R., Ansori, H., & Mawaddah, S. (2021). Kemampuan Berpikir Tingkat Tinggi Menurut Teori Anderson dan Krathwohl pada Siswa SMP Kelas IX. *Jurmadikta*, 1(1), 49–55. https://doi.org/10.20527/jurmadikta.v1i1.729

Mei, O. Z., & Suryadarma, I. (2023). Utilization of Traditional Conservation of Sumatran Tiger as a Potential Development of Biology Teaching Materials. *Jurnal Penelitian Pendidikan IPA*. https://doi.org/10.29303/jppipa.v9i12.5565

Mulà, I., Tilbury, D., Ryan, A., Mader, M., Dlouhá, J., Mader, C., Benayas, J., Dlouhý, J., & Alba, D. (2017). Catalysing Change in Higher Education for Sustainable Development: A Review of Professional Development Initiatives for University Educators. *International Journal of Sustainability in Higher Education*, 18(5), 798–820. https://doi.org/10.1108/IJSHE-03-2017-0043

Mulyadi, D., Ali, M., Ropo, E., & Dewi, L. (2023).

Correlational Study: Teacher Perceptions and The Implementation of Education for Sustainable Development Competency for Junior High School Teachers. *Journal of Education Technology*, 7(2), 299–307. https://doi.org/10.23887/jet.v7i2.62728

Mulyadiprana, A., Hamdu, G., & Yulianto, A. (2024). STEL (System Thinking and ESD Learning) Model: Developing Elementary School Students' System Thinking Skills. *Jurnal Kependidikan: Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran Dan Pembelajaran*, 10(4), 1665–1674.

Munkebye, E., Scheie, E., Gabrielsen, A., Jordet, A., Misund, S., Nergård, T., & Øyehaug, A. B. (2020). Interdisciplinary Primary School Curriculum Units for Sustainable Development. *Environmental Education Research*, 26(6), 795–811. https://doi.org/10.1080/13504622.2020.1750568

Niankara, I. (2019). Cross-national Data Sample on The Environmental Affection And Cognition of Adolescent Students of Varying Interests in Ecosystem Services And Sustainability. *Data in Brief*, 22, 312–318. https://doi.org/https://doi.org/10.1016/j.dib.2018.12.019

Noviani, E. T., Ismaya, E. A., & Khamdun. (2023). Development of IPAS Learning Modules Based on Problem-Based Learning on Ecosystem Material for Elementary School Students. *Asian Journal of Assessment in Teaching and Learning*, 13(1), 71–81. https://ojs.upsi.edu.my/index.php/AJATeL/article/view/9872%0Ahttps://ojs.upsi.edu.my/index.php/AJATeL/article/download/9872/5116

Nurjanah, E., Mas Ramadhan, G., & Lesti, D. (2022). Analisis Soal Tipe High Order Thinking Skill (HOTS) pada Soal Penilaian Akhir Semester (PAS) Tematik Ganjil Kelas V SDN Selakaso Tahun Ajaran 2020/2021. *Journal of Elementary Educatio,* 05(02), 308–315. https://www.journal.ikipsiliwangi.ac.id/index.php/collase/article/view/10590%0Ahttps://www.journal.ikipsiliwangi.ac.id/index.php/collase/article/download/10590/3291

OECD. (2018a). *PISA Preparing Our Youth for An Inclusive and Sustainable World The OECD PISA Global Competence Framewor*. https://www.oecd.org/education/Global-competency-for-an-inclusive-world.pdf

OECD. (2018b). What 15-year-old Students in Indonesia Know and Can Do. *Programme for International Student Assessment (PISA) Result from PISA 2018*, 1–10.

OECD. (2019a). *PISA 2018 Released Field Trial and Main Survey New Reading Items (Issue October)*. https://www.oecd.org/pisa/test/PISA2018_Released_REA_Items_12112019.pdf

OECD. (2019b). PISA 2018 Results Combined Executive Summaries. *Journal of Chemical Information and Modeling*, 53(9), 1689–1699. www.oecd.org/about/publishing/corrigenda.htm.

Oliver, M., McConney, A., & Woods-McConney, A. (2021). The Efficacy of Inquiry-Based Instruction in Science: a Comparative Analysis of Six Countries Using PISA 2015. *Research in Science Education*, 51, 595–616. https://doi.org/10.1007/s11165-019-09901-0

Paramita, P. D. Y. (2023). Penggunaan Teknologi dalam Pembelajaran Bahasa Inggris: Studi Kasus Implementasi Aplikasi E-Learning. *EDUKASIA: Jurnal Pendidikan Dan Pembelajaran,* 4(2), 1799–1804. https://doi.org/10.62775/edukasia.v4i2.508

Parker, L. (2017). Religious Environmental Education? The New School Curriculum in Indonesia. *Environmental Education Research*, 23(9), 1249–1272. https://doi.org/10.1080/13504622.2016.1150425

Pauw, J. B. de, Gericke, N., Olsson, D., & Berglund, T. (2015). The Effectiveness of Education for Sustainable Development. *Sustainability (Switzerland)*, 7(11), 15693–15717. https://doi.org/10.3390/su71115693

Pretorius, R. W., Brand, M. E., & Brown, L. R. (2016). Engaging ODL Students with Biodiversity Issues: A South African Case Study on the Role of ESD. In P. Castro, U. M. Azeiteiro, P. Bacelar-Nicolau, W. Leal Filho, & A. M. Azul (Eds.), Biodiversity and Education for Sustainable Development: World Sustainability Series (pp. 289–304). *Springer International Publishing*. https://doi.org/10.1007/978-3-319-32318-3_18

Purwaningsih, I., Isnaeni, W., Marianti, A., & Ellianawati, E. (2024). Application-Assisted PBL-STEM Model Hinbiodiv to Improve Stu- dents ' Science Literacy in Biodiversity Material. *Unnes Science Education Journal*, 13(3), 155–164.

Rahman, A. A., Kaniawati, I., Riandi, R., & Hendayana, S. (2023). Secondary Science Teachers Perception on STEM Learning for Sustainable Development. *Jurnal Penelitian Pendidikan IPA*, 9(3), 1297–1303. https://doi.org/10.29303/jppipa.v9i3.2776

Ram, D. (2021). Biodiversity Loss with Habitat and Risk of New Diseases. *Proceedings of 1st International Electronic Conference on Biological Diversity, Ecology and Evolution,* 1. https://doi.org/10.3390/bdee2021-09427

Rizal, Y. A., Zubainur, C. M., & Yusrizal. (2021). The Validity of PISA Equivalent Mathematical Problems Based on Content Quantity. *AIP Conference Proceedings,* 2331(April). https://doi.org/10.1063/5.0045498

Salam, A., & Hamdu, G. (2022). Penerapan Education for Sustainable Development (ESD) dalam Media Pembelajaran Elektronik di Kelas V Sekolah Dasar: Perspektif Guru. *PEDADIDAKTIKA: Jurnal Ilmiah Pendidikan Guru Sekolah Dasar,* 9(1), 161–172. https://doi.org/10.17509/pedadidaktika.v9i1.53129

Saleem, A., Aslam, S., Sang, G., Dare, P. S., & Zhang, T. (2023). Education for Sustainable Devel-

opment and Sustainability Consciousness: Evidence from Malaysian Universities. *International Journal of Sustainability in Higher Education*, 24(1), 193–211. https://doi.org/10.1108/IJSHE-05-2021-0198

Sari, N., Ratu, T., Rittianti, R., Erfan, M., Kunci, K., & Poe, : (2023). Pengaruh Model Pembelajaran Poe (Predict-Observe-Explain) Terhadap Kemampuan Berpikir Tinggkat Tinggi (HOTS) Muatan Ipa Siswa Kelas V Disekolah Dasar. *BIOCHEPHY: Journal of Science Education*, 03(1), 83–88. http://journal.moripublishing.com/index.php/biochephy

Schuler, S., Fanta, D., Rosenkraenzer, F., & Riess, W. (2018). Systems Thinking Within The Scope of Education for Sustainable Development (ESD)–a Heuristic Competence Model As a Basis for (Science) Teacher Education. *Journal of Geography in Higher Education*, 42(2), 192–204. https://doi.org/10.1080/03098265.2017.1339264

Schumacher, M. T. G. (2023). Effects of Thinking Maps in the Development of Higher Order Thinking Skills among Elementary Science Students. *AIDE Interdisciplinary Research Journal*, 3(November), 130–138. https://doi.org/10.56648/aide-irj.v3i1.58

Seher Budak, U., & Defne Ceyhan, G. (2024). Research Trends on Systems Thinking Approach in Science Education. *International Journal of Science Education,* 46(5), 485–502. https://doi.org/10.1080/09500693.2023.2245106

Shabrina, A., Suhartini, S., & Huang, T. C. (2024). Problem-Based Learning Tool Integrated with Education for Sustainable Development on Biodiversity Topic to Improve Science Literacy. *Jurnal Pendidikan Sains Indonesia*. https://jurnal.usk.ac.id/JPSI/article/view/36218

Shraim, K. (2019). Online Examination Practices in Higher Education Institutions: Learners' Perspectives. *Turkish Online Journal of Distance Education*, 20(4), 185–196. https://doi.org/10.17718/TOJDE.640588

Sinakou, E., Donche, V., Pauw, J. B. De, & Van Petegem, P. (2019). Designing Powerful Learning Environments in Education for Sustainable Development: A Conceptual Framework. *Sustainability (Switzerland)*, 11(21). https://doi.org/10.3390/su11215994

Sopipare, R., Wasekar, S., Kadhikaye, P., Mule, R., Patil, S., & Shinde, A. (2022). Online Examination System. *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, 10(May), 1599–1605.

Sumaiya, A. S., Al-Majeed, S. S., & Karam. (2019). Online Exams For Better Students ' Performance A Case Study: General Foundation Program Students. *9th International Conference on Education, Teaching & Learning (ICE 19)*, 0–2.

Suprayitno, T. (2019). *Pendidikan di Indonesia: Belajar dari Hasil PISA 2018 Vol. 1 Isuue 2*. Jakarta: Badan Penelitian dan Pengembangan Kementrian Pendidikan dan Kebudayaan.

Supriatna, N., Romadona, N. F., Saputri, A. E., Darmayanti, M., & Indonesia, U. P. (2018). Implementasi Education for Sustainable Development (ESD) Melalui Ecopedagogy Dalam. *Primaria Educationem Journal*, 1(2), 80–86.

Suryani, L., & Hamdu, G. (2021). Education for Sustainable Development in Science National Exam Questions of Elementary School. *ASEAN Journal of Science and Engineering Education*, 1(1), 1–6. https://doi.org/10.17509/ajsee.v1i1.32396

Susanta, A., Koto, I., & Susanto, E. (2023). Mathematics PISA Problems Using Local Context for Elementary School Students. *Jurnal Gantang*, 8(1), 11–19. https://doi.org/10.31629/jg.v8i1.5604

Suwarto, R. S., Sanjaya, Y., & Solihat, R. (2021). Implementation of Education for Sustainable Development and Pupils' Sustainability Consciousness in Adiwiyata School and ESD-based School. *Journal of Physics: Conference Series*, 1806(1). https://doi.org/10.1088/1742-6596/1806/1/012153

Tristananda, P. W. (2018). Membumikan Education for Sustainable Development (ESD) di Indonesia dalam Mengahadapi Isu-Isu Global. *Purwadita: Jurnal Agama Dan Budaya*, 2(2), 42–49. http://stahnmpukuturan.ac.id/jurnal/index.php/Purwadita/article/download/86/79

UNESCO. (2015). *Education 2030 Incheon Declaration and Framework for Action for The Implementation of Sustainable Development Goal 4. Paris*: United Nations educational, Scientific and Cultural Organization.

UNESCO. (2017). *Education for Sustainable Development Goals Learning Objectives.* Paris: United Nations Educational, Scientific and Cultural Organization.

UNESCO. (2018). *Integrating Education for Sustainable Development (ESD) in Teacher Education in Sounth-East Asia A Guide for Teacher Educators*. Paris: United Nations Educational, Scientific and Cultural Organization.

Vilmala, B. K., Karniawati, I., Suhandi, A., Permanasari, A., & Khumalo, M. (2022). A Literature Review of Education for Sustainable Development (ESD) in Science Learning: What, Why, and How. *Journal of Natural Science and Integration*, 5(1), 35. https://doi.org/10.24014/jnsi.v5i1.15342

York, S., Lavi, R., Dori, Y. J., & Orgill, M. (2019). Applications of Systems Thinking in STEM Education. *Journal of Chemical Education*, 96(12), 2742–2751. https://doi.org/10.1021/acs.jchemed.9b00261

Yudhistira, J. (2024). Perancangan Sistem Informasi Ujian Online Menggunakan Metode Extreme Programming. *Journal of Artificial Intelligence and Technology Information*, 2(2), 87–95. https://ejournal.techcart-press.com/index.php/jaiti/article/view/122