RESEARCH ARTICLE

Holistic higher-order thinking in solving environmental problems: A profile of Indonesian undergraduate students

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Abstract: Holistic higher-order thinking (H-HOT) is needed by someone who lives in the 21st century to solve environmental problems. This study aims to determine the ability of H-HOT to solve environmental problems in undergraduate students of biology and biology education programs in Indonesia. The research used a survey method. The sample was taken using a purposive sampling technique, namely only undergraduate students from the biology and biology education program who had graduated from environmental theme lectures. The research instrument in the form of a H-HOT ability test in solving environmental problems is 10 numbers that have been validated by material and construction experts, and empirically validated given to 205 respondents online. Data in the form of H-HOT ability values in solving environmental problems were analyzed descriptively and quantitatively. The results showed that the ability of H-HOT to solve environmental problems in undergraduate students of the biology study program obtained an average score of 24.81, biology education study program is 27.48, and overall average score of all undergraduate students from both the Biology study program and the Biology Education study program are 26.23. The conclusion of this study is that the ability of H-HOT in solving environmental problems in undergraduate students of biology and biology education programs is in a very low category so that efforts need to be made to improve. The study implies a need for improved educational approaches to enhance students' higher-order thinking skills for effectively solving environmental problems.

Keywords: H-HOT; solving environmental problem; undergraduate students

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Introduction

Problem solving skills are needed by someone who lives in the 21st century (Retnawati et al., 2018; Saavedra & Opfer, 2012; Griffin & Care, 2015; Afandi et al., 2019). Problem solving ability can be used by a person to overcome problems in various fields of life, one of which is in the environmental field. Various Environmental problems that have continued to increase significantly in the last decade require a solution (Kalabokidis et al., 2019). Environmental problems such as water pollution, soil pollution, air pollution, climate change, deforestation, marine damage, ecological disasters, global warming, and other environmental problems have become unresolved problems until now (Blanco & Lozano, 2015; Gu et al., 2015; Karpudewan et al., 2015). A series of interrelated environmental problems, making the earth an increasingly less comfortable environment to live in. These various environmental problems need to be immediately resolved so that humans can live comfortably on earth.

The ability to solve problems in general or specifically on environmental problems needs to be supported by higher-order thinking skills (HOTS) (Purnamawati & Saliruddin, 2017; Chinedu & Kamin, 2015). Higher-order Thinking (HOT) is a person's ability to think at a higher level (Aisyah et al., 2018; Anderson & Krathwohl, 2001; Garcia, 2015). HOT in the revised Bloom's taxonomy by Anderson and Krathwohl (2001) includes the ability to analyze (C4), evaluate (C5), or create (C6) (Pecka, Kotcherlakota, & Berger, 2014). Analyze is the ability to divide material into its constituent parts and determine how these parts

relate to one another and relate to the overall structure or purpose. Evaluate is the ability to make judgments/ decisions/ considerations/ opinions/ assumptions based on criteria or standards. Create is the ability to unite elements to form a tangible/ visible/ coherent/ functional form/ configuration/ whole; rearrange elements into new patterns or structures (Soltis et al., 2015). The ability of HOT in analyzing, evaluating, or creating that is owned by a person should be a unified whole (unity) and not separated from one another which is called a holistic HOT (H-HOT) (Dettmer, 2015). A H-HOT needs to be owned by someone in order to be able to solve environmental problems in a more holistic and comprehensive manner.

The use of Holistic Higher-order Thinking (H-HOT) in this study is based on the understanding that environmental problems are complex and interrelated. Solving these problems requires not only the ability to analyze, evaluate, and create but also the capacity to integrate these skills into a cohesive approach. Regular HOT might lead to fragmented thinking, where individuals excel at analyzing or evaluating separately but struggle to apply all these skills together in a real-world context. H-HOT, therefore, offers a more comprehensive way to address multifaceted issues like environmental challenges.

H-HOT abilities in solving environmental problems need to be trained and taught to students at various levels of education (Palennari, 2016). All levels of education in principle require students to have H-HOT abilities (Baris, 2015; Copley, 2013; Heong et al., 2012; Lile & Bran, 2014; Saltan & Divarci, 2017). At the tertiary level, H-HOT abilities in solving environmental problems are very possible to be trained and taught through lecture activities that discuss environmental issues and problems such as in environmental science courses, environmental biology, environmental education, or other similar subjects. Biology undergraduate study programs and biology education should be more flexible in training and teaching H-HOT skills in solving environmental problems to students, considering that the topic or subject matter regarding the environment is one of the problems studied in lectures in the undergraduate biology study program and biology education.

This research is important because it provides insights into the current state of H-HOT abilities among undergraduate students, highlighting gaps in their capacity to address environmental issues effectively. Understanding these gaps is crucial for developing targeted educational strategies and interventions that can enhance problem-solving skills in environmental contexts, ultimately empowering future professionals to contribute to sustainable solutions

The issue is that there is no established profile of H-HOT abilities for solving environmental problems among undergraduate biology and biology education students. This lack of a profile makes it challenging to assess the effectiveness of various teaching methods and models used in environmental courses in Indonesia. This study aims to determine the H-HOT abilities of undergraduate students in biology and biology education in relation to solving environmental problems, presenting the findings in the form of an H-HOT ability profile.

Method

This research is a survey research that aims to determine the ability of H-HOT in solving environmental problems in undergraduate biology and biology education students in Indonesia. The population in this study consists of undergraduate students in biology and biology education programs throughout Indonesia. The research sample was determined using a purposive sampling technique by focusing on undergraduate students in biology and biology education who had taken environmental themes or topics such as environmental science, environmental biology, environmental education, or other similar subjects. A total of 205 undergraduate students from biology and biology education study programs from 13 universities in Indonesia, including: Yogyakarta State University, Ahmad Dahlan University Yogyakarta, Gajah Mada University, Sunan Kalijaga State Islamic University, Sebelas Maret University, Tidar Magelang University, Diponegoro University, Semarang State University, Kudus State Islamic Institute, University of Muhammadiyah Malang, North Sumatra State Islamic University, Metro Lampung State Islamic Institute, and the Ternate State Islamic Institute became respondents by filling out an instrument that was distributed online. The distribution of respondent characteristics in detail is presented in Table 1.

Table 1. Characteristics of research respondents

Characteristics	Type and Amount (Percentage)	
Study program	Biology= 96 people (47%)	Biology education= 109 people (53%)
College status	Country= 114 people (56%)	Private= 91 people (44%)
Gender	Male= 87 people (42%)	Female= 118 people (58%)
Types of lectures when obtaining environmental theme courses	Online= 119 people (58%)	Offline= 86 people (42%)

Data collection techniques were carried out by tests. A total 205 respondents participate in this research,

they filled out an instrument that was distributed online using Google Forms. The instrument used in this research is a H-HOT ability test in solving environmental problems. The instrument for the H-HOT ability test in solving environmental problems consists of 10 questions with each question number containing 1 environmental problem. Each question number contains 1 analysis question (C4), 1 evaluation question (C5), and 1 creative question (C6). The H- HOT ability test instrument in solving environmental problems has met content validity, construct validity, and empirical validity. Content validity was met through an assessment conducted by 3 lecturers of environmental science material experts. Construct validity was met through an assessment conducted by 3 expert lecturers on evaluation and assessment by looking at the suitability of the grid and the construction of the questions. Empirical validity was met through testing questions to respondents and analyzed using the Quest program involved 205 participants. The grid of H-HOT ability test questions are presented in Table 2, and the results of the empirical test of questions using the Quest program are presented in Figure 1.

Table 2. Grid of H-HOT ability test questions in solving environmental problems

Aspect	Indicator	Sub Indicator	Question Indicator	Item
Analyze	Differentiating	Select, Choosing, Discriminating, Focusing, Distinguishing	▪ Choose related disciplines to solve environmental problems in the Mount Merapi national area due to sand mining	1a
			▪ Choose wisely energy sources or fuels that are more environmentally friendly	10a
	Organizing	Arrange, Find, Structure, Organize	▪ Finding complex problems that will arise from a case of environmental problems caused by waste is studied from various fields of scientific study	3a
			▪ Finding possible causes of river pollution cases based on the indicators found	5a
			▪ Finding the impact of plastic waste pollutants on the damage to the marine environment	9a
	Attributing	Assign, Attributes	▪ Expressing the relationship between cases of forest environmental damage and other problems that will be caused	4a
			▪ Linking environmental damage to mangrove forests with their causes	8a
	Deconstructing	Deconstruct	▪ Describe the impact of pesticide contaminants in various fields of scientific study	2a
			▪ Describe the causes of pollution in an air pollution case	6a
			▪ Describe the causes of coral reef damage	7a
Evaluate	Checking	Check, Verify, Confirm, Monitor, Test	▪ Checking the effectiveness of solutions to the problem of solving environmental pollution problems caused by waste	3b
			▪ Determine the impact of river environmental pollution cases based on data	5b
			▪ Checking the effectiveness of air pollution solutions	6b
			▪ Determine the impact of coral reef damage cases	7b
			▪ Provide evidence that damage to mangrove forests will have an impact on other environmental damage	8b
	Critiquing	Evaluate, Comment on, Review, Appraise, Critique, Judge, Critically, Assess	▪ Provide an assessment of alternative solutions to environmental problems	1b
			▪ Critically review the impact of pesticide pollutants on environmental pollution	2b
			▪ Assessing the effectiveness of an effort to solve the problem of forest destruction	4b
			▪ Assess the effectiveness of a solution to overcome marine pollution that has been carried out	9b
			▪ Give a critique of the use of fossil fuels	10b
Create	Generating	Suggest, Produce, Hypothesis, Imagine	▪ Develop hypotheses for solving environmental damage cases	1c
			▪ Propose solutions to river pollution problems or cases	5c
			▪ Provide suggestions/proposals to repair damage to coral reefs holistically	7c
			▪ Formulate a solution hypothesis Overcoming marine pollution due to plastic waste	9c
	Planning	Plan, Design, Set-up	▪ Designing a solution to solve environmental problems	2c
			▪ Designing a holistic solution by involving various fields/sectors to overcome air pollution	6c
			▪ Designing research to produce environmentally friendly fuel	10c
	Produce	Produce, Make, Construct, Create	▪ Develop ideas for holistic solutions by involving various disciplines to overcome cases of environmental pollution caused by waste	3c
			▪ Generate holistic solution ideas by involving various disciplines to overcome forest damage cases	4c
			▪ Develop ideas for holistic solutions by involving various disciplines to overcome cases of damage to mangrove forests	8c

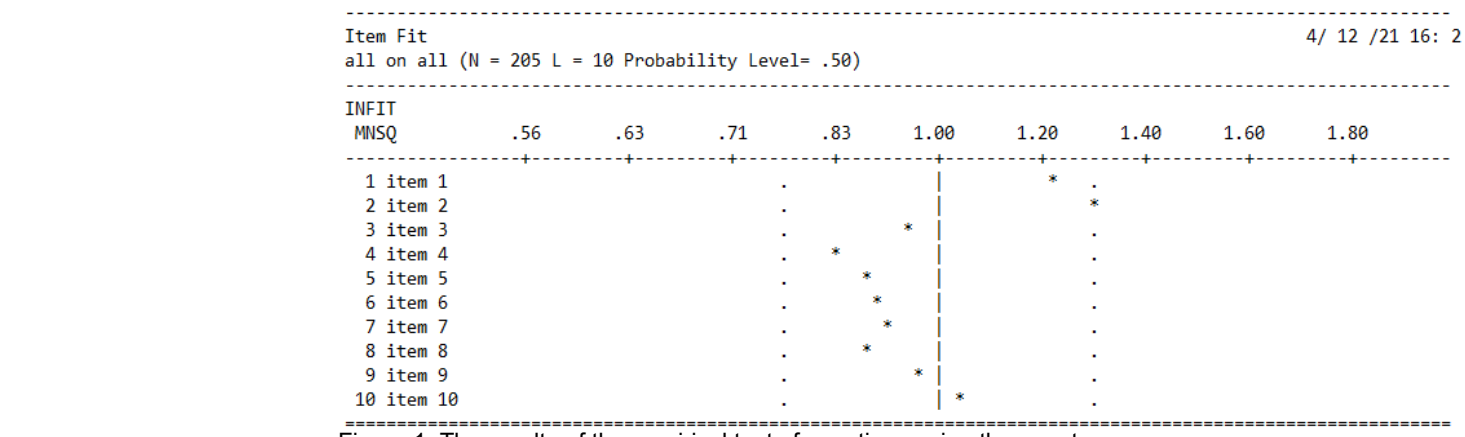

Figure 1. The results of the empirical test of questions using the quest program

Figure 1 shows the distribution of test items based on their compatibility with the Rasch model. The parameter used is INFIT MNSQ. The two vertical dots indicate the range of the MNSQ INFIT values obtained, which is between 0.77 and 1.30. Based on the data, it is clear that the 10 questions of the H-HOT test in solving environmental problems are valid/ fit according to the Rasch model, because they have an INFIT MNSQ value between 0.77 and 1.30.

The data obtained in this study were analyzed descriptively quantitatively, namely by assessing the average ability of H-HOT in solving environmental problems in students who became respondents and categorizing them according to level. In addition, the average score and the H-HOT ability level category per item, the question number and its constituent aspects/ dimensions are also displayed. The levels of the H-HOT ability category in solving environmental problems are presented in Table 3.

Table 3. Category levels of H-HOT ability in solving environmental problems

Value Range	Category
81.25 < x 100	Very high
71.5 < x 81.25	High
62.5 < x 71.5	Medium
43.75 < x 62.5	Low
0 < x 43.75	Very low

Source: Category and interval score adapted from Ichsan et al. (2019)

Results and Discussion

Data on the scores of H-HOT abilities in solving environmental problems in undergraduate students of biology and biology education programs were obtained from filling out the H-HOT ability test instrument in solving environmental problems by respondents online using google form. The results of the H-HOT ability test in solving environmental problems for undergraduate students in biology and biology education are presented in Table 4.

Table 4. Scores and categories of H-HOT ability in solving environmental problems

Study Program	N	Max. Score	Min. Score	Mean	SD
Biology	96	46.67 (Low)	4.44 (Very low)	24.81 (Very low)	12,34
Biology education	109	53.33 (Low)	3.33 (Very low)	27.48 (Very low)	13,21
All Students	205	53.33 (Low)	3.33 (Very low)	26.23 (Very low)	12,89

Note: Score in the range 0-100.

Table 4 shows that the H-HOT ability in solving environmental problems in undergraduate students of biology education study program is higher than students of biology undergraduate study program. The

H-HOT ability in solving environmental problems in the combination of undergraduate biology and biology education students is in the very low category with an average score of 26.23.
Data of H-HOT abilities in solving environmental problems in undergraduate students of biology and biology education programs are also classified based on the scores on each item presented in Table 5.

Table 5. H-HOT ability in solving environmental problems on each item

Item	Environmental Problems Studied	Biology Student	Biology Education Student	All Students
1	Damage to the mount Merapi area due to sand mining	25.46 (very low)	27.42 (very low)	26.50 (very low)
2	Environmental pollution due to synthetic chemical pesticides	37.50 (very low)	43.53 (very low)	40.70 (very low)
3	Environmental pollution due to garbage	38.43 (very low)	39.86 (very low)	39.19 (very low)
4	Tropical rainforest deforestation	14.24 (very low)	16.92 (very low)	15.66 (very low)
5	Citarum river pollution	12.50 (very low)	14.07 (very low)	13.33 (very low)
6	Air pollution or poor air quality in big cities	28.24 (very low)	27.12 (very low)	27.64 (very low)
7	Damage to coral reefs and marine ecosystems	27.43 (very low)	30.68 (very low)	29.16 (very low)
8	Damage to mangrove forest areas	30.90 (very low)	34.35 (very low)	32.74 (very low)
9	Pollution of marine areas due to plastic waste	22.57 (very low)	29.77 (very low)	26.40 (very low)
10	Environmental damage due to the use of fossil energy sources	10.88 (very low)	11.11 (very low)	11.00 (very low)

Note: Score in the range 0-100.

Table 5 shows that the highest H-HOT ability in solving environmental problems obtained by the combined undergraduate students of biology and biology education is in item number 2 with environmental problems in the form of environmental pollution due to synthetic chemical pesticides. The lowest H-HOT ability in solving environmental problems obtained by the combined undergraduate biology and biology education students is in item number 10 with environmental problems in the form of environmental damage due to the use of fossil energy sources.
The data on the H-HOT ability score in solving environmental problems for undergraduate biology and biology education study program students are also presented based on the dimensions or aspects of the H-HOT ability. The data are presented in Table 6. Table 6 shows that the analyze dimension/aspect has the highest average score of 31.43 in the very low category while the create dimension/aspect has the lowest average score of 19.15 in the very low category.

Table 6. H-HOT ability in solving environmental problems dimensions/ aspects

Dimensions/ Aspect	Biology Student	Biology Education Student	All Students
Analyze	30.17 (very low)	32.54 (very low)	31.43 (very low)
Evaluate	27.15 (very low)	28.96 (very low)	28.11 (very low)
Create	17.12 (very low)	20.95(very low)	19.15 (very low)
H-HOT	24.81 (very low)	27.48 (very low)	26.23 (very low)

Note: Score in the range 0-100.

The distribution of lecture types (58% online and 42% offline) provides context for understanding the learning environments in which students are assessed using the H-HOT ability test. This data indicates that a significant portion of students is engaged in online learning, which can influence how they develop and demonstrate their H-HOT skills in solving environmental problems. Different teaching modalities may affect the development of H-HOT abilities differently. Online lectures utilize interactive tools such as discussions, quizzes, and multimedia resources, which can enhance critical thinking and problem-solving skills. Conversely, offline lectures offer hands-on activities, group discussions, and real-world applications that foster holistic thinking. The instrument for the H-HOT ability test take these varying learning experiences to accurately assess students' skills.
This study reveals the H-HOT in solving environmental problems in undergraduate students of biology and biology education in Indonesia. H-HOT ability in solving environmental problems is measured using a H-HOT ability test instrument in solving environmental problems. The analysis of score data from the results of filling out the H- HOT ability test instrument in solving environmental problems shown in Table 4 shows that the H-HOT ability in solving environmental problems in undergraduate students of the

biology study program is in the very low category with an average value of 24.81. The H-HOT ability in solving environmental problems in undergraduate students of the biology education study program is also in the very low category with an average score of 27.48. H-HOT ability in solving environmental problems in all or a combination of undergraduate students of biology study program and biology education is in the very low category with an average score of 26.23.

The findings in this study are the ability of H-HOT in solving environmental problems in undergraduate students of biology study programs and biology education in Indonesia which is very low in line with research conducted by Ichsan et al. (2019) and Ichsan et al. (2021), which also revealed the very low HOT ability of Indonesian students at all levels of education from elementary school to university. H-HOT ability in solving environmental problems is a whole and a unified ability to analyze, evaluate, and create solutions to solve environmental problems. H-HOT capabilities have 3 dimensions or aspects, namely analyzing, evaluating, and creating (Pecka et al., 2014; Fanani & Kusmaharti, 2018; Julianingsih et al., 2017). These three dimensions of H-HOT capabilities are in a unified whole and are not separated from one another (Dettmer, 2015). This is thought to be one of the causes of the very low ability of H-HOT in solving environmental problems in this study when compared to measurements on each dimension/ aspect.

Several factors may explain these unsatisfactory results. One key factor is the instructional approach utilized in teaching environmental topics. The reliance on traditional lecture methods, which may not sufficiently engage students in active learning or critical thinking exercises, can impede the development of H-HOT ability. Additionally, the transition to online learning formats, particularly during the COVID-19 pandemic, may have negatively impacted student engagement and interaction, leading to lower H-HOT performance compared to face-to-face learning.

Moreover, students' prior experiences with problem-solving and critical thinking in their educational journey can influence their current capabilities. If previous curricula have not emphasized higher-order thinking skills, students may lack the necessary foundation to apply these skills effectively in new contexts. This is particularly relevant in the context of environmental education, where interdisciplinary approaches and real-world problem-solving are crucial.

Bloom's taxonomy revised by Anderson and Krathwohl divides the cognitive domain into 6 levels, namely the level of C1 remembering, C2 understanding, C3 applying, C4 analyzing, C5 evaluating, and C6 creating (Ganapathy et al., 2017). Level C4 analyzing to C6 creating is included in higher-order thinking skills (HOT) (Abosalem, 2016; Alias & Ibrahim, 2015). The findings in this study as shown in Table 6 regarding the H-HOT ability in solving environmental problems are described by dimension/ aspect. The highest average is the dimension or aspect of analyze both in undergraduate students in biology, biology education, or a combination of both. This result is in accordance with the level of thinking ability in Bloom's taxonomy revised by Anderson and Krathwohl (2001) where the ability to create is the highest level compared to evaluate and analyze. This suggests that while students may struggle with the more complex aspects of H-HOT, they can still perform relatively better in analysis, possibly due to familiarity with breakdown tasks from prior coursework.

H-HOT is a very important ability that needs to be possessed by students, especially in universities (Craig, 2011). H-HOT ability is the core that must be possessed by someone living in the 21st century (Riadi, 2016). A person who lives in the 21st century will be faced with complex problems, full of uncertainty and dilemmas (Hasan & Pardjono, 2019). If a person has a H-HOT ability, he or she will be able to be critical, logical, reflective, metacognitive and creative to solve complex problems holistically and comprehensively. Students who have H-HOT abilities are claimed to be more successful in the world of work than those who have Lower-Order Thinking Skills (LOTS) (Djami & Kuswandono, 2020).

Students need to have H-HOT abilities so that they are able to solve problems in various fields of life, including environmental problems around them. The findings in this study, which are shown in Table 5, show that students' H-HOT abilities are still very low in solving various cases of environmental problems. This finding indicates that the H-HOT ability in solving environmental problems has not been optimally trained and taught through environmental-themed lecture activities. H-HOT capabilities is not obtained automatically, but needs to be trained and taught regularly through learning (Cahyaningsih & Ghufron, 2016; Buku et al., 2015). An educator needs to design a curriculum and learning that can improve students' HOT (Fauzi, 2013; Azid et al., 2022). Learning design must integrate potential learning models that can empower student learning outcomes and thinking skills at the HOT level (Haryati et al., 2017; Husamah & Pantiwati, 2014; Khasanah & Astuti, 2018; Setiawati & Corebima, 2017; Ichsan et al., 2021). The use of learning models that involve the process of analyzing, evaluating, and creating can increase students' HOT (Nanda et al., 2023). This study provides a recommendation that learning in higher education, especially in environmental-themed courses in the undergraduate biology study program and biology education, is directed at the formation of H-HOT abilities in solving environmental problems.

Conclusion

In summary, this study reveals that undergraduate students in biology and biology education programs in Indonesia have very low holistic higher-order thinking (H-HOT) when it comes to solving environmental problems. To improve H-HOT capabilities, educators need to adopt interactive teaching strategies that engage students in real-world problem-solving, ultimately better preparing them to address environmental challenges and succeed in their careers.
The implications of this research highlight the urgent need to enhance holistic higher-order thinking (H-HOT) skills among undergraduate biology and biology education students, particularly in addressing environmental issues. Develop assessments that specifically evaluate H-HOT capabilities, encouraging students to engage in analysis, evaluation, and creation rather than rote memorization.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

M. Mualimin: writing original draft preparation and **R. Pamungkas:** review and editing.

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