JPPIPA 9(9) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

The Impact of Science Learning Materials Integrating Natural Disasters and Disaster Mitigation on Students' Learning Outcomes: A Meta Analysis

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Received: January 15, 2023
Revised: August 10, 2023
Accepted: September 25, 2023
Published: September 30, 2023

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DOI: 10.29303/jppipa.v9i9.2680

Abstract: This research is a meta-analysis to determine the impact of science teaching materials integrated with natural disasters and disaster mitigation on students' learning outcomes. The method used is meta-analysis with research samples, namely scientific articles that have been published through Google Scholar on a national and international scale in 2012-2022, which discuss integrated science teaching materials on natural disasters and disaster mitigation on student learning outcomes. The results of the study showed that science teaching materials integrated with natural disasters and disaster mitigation had a large effect on student learning outcomes. In the category of teaching materials, the science module, which integrates natural disasters and disaster mitigation materials, has the highest effect. In the category where natural disaster materials and disaster mitigation are integrated, disaster mitigation materials have the highest effect compared to natural disaster materials. And in the school level category, the application of integrated science teaching materials on natural disasters and disaster mitigation has a high effect when applied to the Junior and Senior High School Levels, with a higher impact on the Junior High School level.

Keywords: Disaster Mitigation; Learning Materials; Learning Outcomes; Meta-Analysis; Natural Disaster; Science.

Introduction

The 21st century is a period of rapid development both in terms of education, economy, and social life. Education is designed to be as complex as possible to meet the current conditions and situation of Indonesian society, so that the lessons learned can be applied in daily life. Education is a planned and structured activity for forming and enhancing a noble personality, mental agility, and knowledge competence. Therefore, education is a very influential factor in shaping a human person who has character and has intellectual, social, emotional, and spiritual intelligence so that he is able to compete in global life (Andira et al., 2017).

Indonesia is a country that has a high level of vulnerability to natural disasters (Hadi et al., 2019). Based on data from the 2018 World Risk Report, Indonesia ranks 36th with a risk index of 10.36 out of 172 countries most prone to natural disasters in the world. The potential for a tsunami disaster is higher than in Japan; Indonesia ranks first out of 256 countries in the world listed at the United Nations. In addition, Indonesia has a level of seismicity 10 times higher than the earthquake that occurred in the United States (Amri et al., 2016).

This condition is due to the geographical location of Indonesia, which is located between four tectonic plates, namely the Asian Continent, the Australian Continent, the Indian Ocean, and the Pacific Ocean. Indonesia is also surrounded by volcanic mountains that stretch from the south and east of the country, extending from the islands of Sumatra and Java to Nusa Tenggara and Sulawesi.

The real conditions in Indonesia can be integrated into the learning process. As research by (Sumarmi et al., 2021) explained that e-module teaching materials can

How to Cite:
Asrizal, A., Hikmah, N., Febriya, D., & Mawaddah, F. (2023). The Impact of Science Learning Materials Integrating Natural Disasters and Disaster Mitigation on Students' Learning Outcomes: A Meta Analysis. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 586–595. https://doi.org/10.29303/jppipa.v9i9.2680

increase disaster preparedness, student learning interest. and learning outcomes. The high and low learning outcomes of students can be influenced by learning devices. The availability of learning tools is one of the supporting factors in the learning process, so that it can improve students' abilities (Aulyana et al., 2017), both cognitively, affectively, and psychomotorically. One important element in the learning process is teaching materials. Teaching materials are materials or subject matter that are arranged systematically and used by educators and students in the learning process.

One of them is in science learning, especially physics, where choosing the right teaching materials can help achieve the goals of education itself. Physics is the study of phenomena or scientific processes in order to develop technology and other scientific works (Fauza et al., 2021). Often, learning physics at school is seen as less applicable in everyday life, so students feel less able to benefit from learning physics. Physics education is designed to help students master physics concepts and principles, as well as develop knowledge and self-confidence through experience in formulating problems, submitting and testing hypotheses through experiments, designing and assembling experimental instruments, and collecting, processing, interpreting, and communicating experimental data. Applicatively, physics is expected to be used to uncover natural secrets that commonly occur in everyday life, for example, natural disasters (Purwati & R, 2018). Integrated natural disaster mitigation learning is a plan that is used to design teaching patterns based on everyday life that are linked to or adapted to natural disaster management materials based on disaster risk reduction (Wedyawati et al., 2017).

There have been many studies conducted regarding the development or influence of integrated teaching materials for natural disasters or disaster mitigation materials on student learning outcomes. Based on the results of research conducted by Deby Putri Perwita and Ahmad Fauzi regarding the "Effectiveness of Integrated High School Physics E-Book Integrated Inquiry Based Learning Earthquake Material to Improve Student Learning Outcomes," the use of integrated physics e-book inquiry based earthquake material learning is declared effective for improving student learning outcomes (Perwita & Fauzi, 2022). In the research conducted by Yudha Azzahri, Akmam, and Asrizal on "The Influence of LKS ICT Integrating MSTDC (Mathematics, Science, Technology, Disaster, and Character) on Motion, Gravity, and Energy Material on Physics Competence of Class XI Students at SMAN 1 Padang," it was found that there were significant differences in physics competence between students who used the ICT student worksheet to integrate MSTDC and students who did not use the ICT student worksheet to integrate MSTDC in their physics learning. (Azzahri et al., 2015).

The results of previous studies have limitations, including the results described in the study do not explain the effect of similar studies regarding the integration of natural disaster and disaster mitigation materials in physics and science teaching materials on student learning outcomes, only applying one teaching material that integrated natural disaster and disaster mitigation material, and integrating natural disaster and disaster mitigation material into teaching materials only on certain topics. Based on these limitations, this research was conducted to integrate all similar studies to determine the magnitude of the influence of several similar studies regarding integrated physics and science teaching materials on natural disasters and disaster mitigation on student learning outcomes using the meta-analysis method.

Meta-analysis is research conducted to analyze empirical studies that have been carried out by previous researchers. This research was conducted by summarizing, integrating, combining, and interpreting the results of selected studies in certain fields of science (Retnawati et al., 2018). Meta-analytical research was chosen as a research method for several reasons, namely that there have been many studies discussing the effect of integrating natural disaster and disaster mitigation materials in science teaching materials on student learning outcomes, but there has been no research on the effect of several similar articles on the use of integrated science teaching materials. material on natural disasters and disaster mitigation on students' learning outcomes.

Based on the reasons above, this meta-analysis research was carried out to determine the effect of several similar articles on integrated science teaching materials on natural disasters and disaster mitigation on student learning outcomes, especially in the cognitive domain, based on the type of teaching materials as well as natural disasters and disaster mitigation materials that are integrated.

Method

This research is a meta-analysis with a quantitative approach. This study aims to analyze several national articles and articles in international proceedings on the same topic. The article criteria used were articles published in 2012-2022, had a DOI, samples were taken from junior high to high school, and had information that could support meta-analysis and descriptive statistical information to estimate effect size values.

The articles used in this research can be found on Google Scholar. The variables used are independent variables, dependent variables, and moderator variables. The independent variable in this study is science teaching material integrated with natural disaster and disaster mitigation material; the dependent variable is student learning outcomes; and the moderator variable used is the type of teaching material integrated with natural disaster material, natural disaster material, or integrated disaster mitigation, as well as educational level.

The research procedure was carried out based on the opinion of George A. Kalley, starting with determining the research topic, determining the period and criteria for articles to be analyzed, collecting relevant articles into one folder, writing research data, and then determining the effect size of each article (Asrizal et al., 2022). The articles that have been collected are then analyzed using analytical techniques in meta-analysis research, namely calculating or determining the value of the effect size using the Cohen's d equation and calculating the conclusions from the effect size using the random effect model and the fixed effect model. The effect size results are classified according to Table 1.

Table 1. Effect Size Category

Effect size	Category
$0 \leq ES \leq 0.2$	Low
$0.2 \leq ES \leq 0.8$	Medium
$ES \geq 0.8$	High

(Becker, 2000)

Result and Discussion

The analysis of integrated science teaching materials on natural disasters and disaster mitigation consists of books, student worksheets, and modules. The impact of integrated teaching materials on natural disasters and disaster mitigation in science learning on cognitive aspects of learning outcomes was investigated. The analysis was conducted using the categories of teaching materials with the highest to lowest effect-size values.

Based on the data gathered, only 22 of the 50 articles meet the criteria, and the magnitude of the effect can be calculated. The effect size in this study is used to see the strength of the relationship between variables in each study studied and is used to draw conclusions (Retnawati et al., 2018).

The limitation of the explanation in this meta-analysis article is that it uses stages to test the hypothesis. By calculating the effect size, you will get a p-value as the basis for rejecting or accepting H_O (Anwar, 2005). The assessment criterion from the results of the meta-analysis is that if the p value is less than the significance value (0.05), then the teaching material is said to have an effect on student learning outcomes. Following are the results of the analysis of the 22 articles.

Analysis of The Effect of Similar Research on Students' Learning Outcomes

Tabel 2. The Result of Calculating the Effect Size of a Number of Similar Articles on Students' Learning Outcomes

Source	Code	Y_i	V_{Yi}	T^2	$V_{Yi} + T^2$	W_i*	W_i*Y_i
(G. E. Putri & Fauzi, 2022)	A1	0.55	0.06	0.32	0.39	1.39	0.76
(Perwita & Fauzi, 2022)	A2	0.88	0.13	0.32	0.46	1.27	1.12
(Yanti & Fauzi, 2022)	A3	0.85	0.04	0.32	0.36	1.44	1.22
(Rustam et al., 2019)	A4	1.86	0.23	0.32	0.56	1.12	2.09
(Khair & Fauzi, 2022)	A5	0.70	0.04	0.32	0.37	1.43	1.00
(Trisnawati & Jumadi, 2018)	A6	0.30	0.01	0.32	0.34	1.49	0.44
(Akbari & Wiyatmo, 2018)	A7	0.37	0.06	0.32	0.39	1.39	0.51
(Zukir et al., 2013)	A8	0.55	0.07	0.32	0.40	1.37	0.75
(Mila et al., 2018)	A9	0.46	0.06	0.32	0.38	1.40	0.64
(T. A. Wahyuni et al., 2018)	A10	1.90	0.06	0.32	0.39	1.39	2.64
(Andira et al., 2017)	A11	0.66	0.06	0.32	0.39	1.39	0.92
(D. Putri et al., 2016)	A12	1.04	0.07	0.32	0.39	1.38	1.43
(Listia et al., 2016)	A13	0.56	0.06	0.32	0.39	1.39	0.78
(Azzahri et al., 2015)	A14	1.60	0.08	0.32	0.41	1.35	2.17
(Vasista et al., 2014)	A15	0.61	0.07	0.32	0.40	1.37	0.84
(Zulhendra et al., 2016)	A16	0.76	0.06	0.32	0.39	1.39	1.06
(Rustam et al., 2016)	A17	3.81	0.17	0.32	0.50	1.20	4.60
(Pebrika et al., 2015)	A18	0.61	0.06	0.32	0.38	1.40	0.85
(Akbari & Wiyatmo, 2018)	A19	1.34	0.42	0.32	0.74	0.93	1.24
(Agustia & Fauzi, 2020)	A20	0.75	0.05	0.32	0.38	1.40	1.05
(Asi et al., 2021)	A21	0.52	0.04	0.32	0.36	1.44	0.75
(Septaria et al., 2020)	A22	3.38	0.42	0.32	0.75	0.92	3.14
Total						29.37	30.10
M*							1.02
VM*							0.03

Source	Code	Y_i	V_{Yi}	T^2	$V_{Yi} + T^2$	W_i*	W_i*Y_i
SEM*							0.18
LLM*							0.66
ULM*							1.38
Z							5.55
p-Value							0.00

Based on the results of the effect size analysis of 22 similar articles in Table 2, The results of the Z values of the 22 similar articles show a Z value of 5.55. The results of the hypothesis test show that the value of $p < a$ indicates that the hypothesis H_o is rejected. Rejecting H_o indicates that the use of science teaching materials integrated with natural disaster and disaster mitigation materials has a significant influence on student learning outcomes.

The results of this analysis indicate that teaching materials that integrate natural disasters and disaster mitigation materials have a positive and significant influence on student learning outcomes. Teaching materials integrated with material on natural disasters and disaster mitigation can improve students' critical thinking skills (S. Wahyuni et al., 2021). The teaching materials contain facts, concepts, principles, and procedures (Fauza et al., 2021). Integrating natural disaster and disaster mitigation materials in science teaching materials can make students interested and happy during the learning process. This also makes students active in participating in the learning process (Alfi et al., 2019).

Analysis of The Effect of Similar Research Based on The Type of Learning Materials

Tabel 3. Effect of Similar Articles Based on the Type of Learning Materials

Learning Materials	Code	ES	SEM	LLM	ULM	*P Value*	Decision
Book	A1	0.66	0.14	0.36	1.29	0.00	Rejected H_o
	A2						
	A3						
	A4						
	A5						
	A6						
	A7						
	A21						
Students Worksheet	A8	1.17	0.34	0.49	1.67	0.00	Rejected H_o
	A9						
	A10						
	A11						
	A12						
	A13						
	A14						
	A15						
	A16						
	A17						
	A18						
Module	A19	1.78	1.07	-0.31	3.88	0.04	Rejected H_o
	A20						
	A22						

Based on Table 3, there are three types of teaching materials analyzed. The largest effect size or influence of teaching materials is 1.78 in the use of modules or e-modules, and the lowest is 0.66 in the use of books. The results of the p-value analysis can be seen in the three types of teaching materials with a p-value < 0.05 and this indicates that the use of the three types of teaching materials that are integrated with natural disaster material has a significant influence on student learning outcomes.

The book as learning material integrated with material on natural disasters and natural disaster mitigation has an effect size of 0.66, which means a moderate effect. Students' worksheets as learning materials integrated with material on natural disasters and natural disaster mitigation have an effect size of 1.17, which means high impact. And the integrated module teaching materials on natural disasters and natural disaster mitigation have an effect size of 1.78, which means high impact.

The hypothesis is that the use of integrated science teaching materials on natural disasters and natural disaster mitigation affects student learning outcomes. Accepted book teaching materials have a p-value of 0.00; students' worksheet teaching materials have a p-value of 0.00; and module teaching materials have a p-value of 0.04. The three types of teaching materials have a p-value of less than α. Because the p-value < 0.05, Ho is rejected. Thus, science learning materials are integrated with materials on natural disasters and disaster mitigation, which have an effect on learning outcomes.

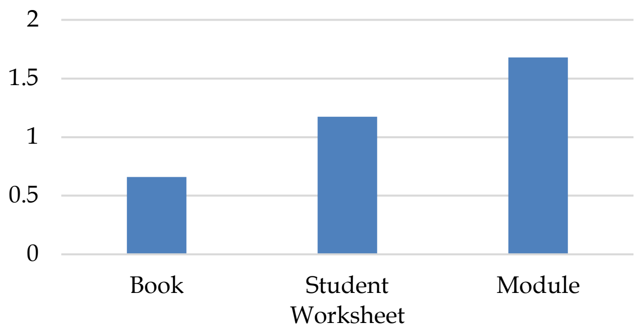

Figure 1. Effect Size Based on the Type of Learning Materials

Based on Figure 1, teaching materials integrated with natural disasters and natural disaster mitigation that have a high effect size value are students' worksheets and modules; the effect size value of book teaching materials is classified as medium. The use of teaching materials in the form of students' worksheets can improve students' understanding and cognitive (Nurhidayah et al., 2016). This is consistent with previous research showing that using students' worksheets as learning materials can significantly improve student learning outcomes (Özek, 2020). The results of this study serve as a reference for the importance of developing and using learning materials in the form of integrated student worksheets because, apart from being effectively used, they are also able to improve students' thinking skills (Hayati et al., 2016). Furthermore, the use of science modules that integrate natural disaster material and disaster mitigation can provide excellent opportunities for students to grasp the material presented (Sumarmi et al., 2021).

Analysis of The Effect of Similar Research Based on The Element of Natural Disaster and Mitigation

Table 4. Effect of Similar Articles Based on the Element of Natural Disaster and Mitigation

The Element of Natural Disasater and Mitigation	Code	ES	SEM	LLM	ULM	*P Value*	Decision
Earth	A2	1.33	0.44	0.46	1.86	0.00	Rejected H_o
	A3						
	A4						
	A5						
	A6						
	A8						
	A10						
	A17						
Water	A7	0.55	0.21	0.14	1.41	0.00	Rejected H_o
	A11						
	A13						
	A15						
Fire/Heat	A9	0.66	0.08	0.49	1.16	0.00	Rejected H_o
	A12						
	A16						
	A20						
	A21						
Disaster Mitigation	A1	1.40	0.51	0.39	2.41	0.00	Rejected H_o
	A14						
	A18						
	A19						
	A22						

Based on Table 4, the natural disasters that are included in the earth element are earthquakes. The water element includes tsunamis, floods, and coastal abrasion. Meanwhile, the elements of fire and heat include fire, fog, and drought. The effect size of the earthquake disaster is 1.33 in the very high category. The combined effect size of the tsunami, flood, and coastal abrasion is 0.55 in the medium category. The combined disaster effect size of fire, drought, and haze is 0.75 in the moderate category. The effect size of integrating disaster mitigation materials is 1.4 in the high category.

The results of the analysis of the p value of an earthquake disaster are 0.00, the p value of a tsunami, flood, and coastal abrasion is 0.00, the p value of fire, drought, and haze is 0.00, and the p value of disaster mitigation is 0.00. It can be seen from the results of this analysis that the p value is < 0.05, which indicates that there is a significant influence of natural disaster and mitigation material integrated into science teaching materials on student learning outcomes.

Based on Figure 2, the learning material integrated with natural disasters and natural disaster mitigation that has the highest effect size value is earthquake disaster material, and the materials with the lowest effect size value are tsunami, flood, and coastal abrasion disaster material. This is in accordance with previous research that the integration of disaster material that is of interest to students is earthquakes (Sumarmi et al., 2021). Integrating natural disasters into learning materials also trains students' higher-order thinking skills, so this innovation is important enough to be studied more broadly for its application in 21st century education (Hidayatullah et al., 2021).

Natural disasters have a big impact on education. If an area is affected by a disaster, schools will be closed, the teaching and learning process will stop temporarily for a long time, and students' mental readiness will be unstable. As a result, natural disasters are the proper integration of physics lessons presented in learning materials (Mcintosh & Student, 2019).

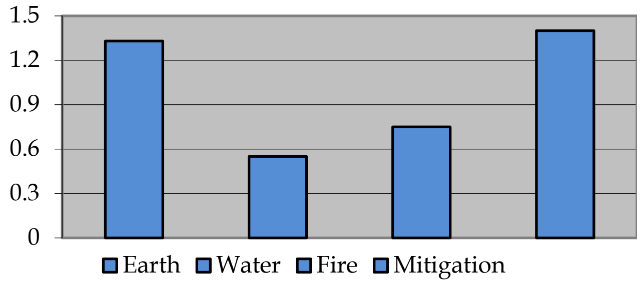

Figure 2. Effect Size Based on The Element of Natural Disaster and Mitigation

Appropriate teaching methodology is needed when integrating natural disasters into a teaching material (Sugano & Mamolo, 2021). Teachers can teach awareness about natural disasters to students in a fun way through teaching materials about disaster mitigation. This is proven by (Gunada et al., 2020) that teaching with the integration of disaster mitigation implemented in urban, coastal, and use-area schools on the island of Lombok shows that 95% of students are very enthusiastic about the learning activity.

Analysis of The Effect of Similar Research Based on School Level

Table 5. Effect of Similar Articles Based on School Level

School Level	Code	ES	SEM	LLM	ULM	*P Value*	Decision
Junior High School	A4	1.73	0.85	0.06	2.67	0.02	Rejected H_o
	A19						
	A21						
	A23						
Senior High School	A1	0.91	0.192	0.54	1.37	0.00	Rejected H_o
	A2						
	A3						
	A5						
	A6						
	A7						
	A8						
	A9						
	A10						
	A11						
	A12						
	A13						
	A14						
	A15						
	A16						
	A17						
	A18						
	A20						

Based on Table 5, the results of the analysis of the effect of integrated learning materials on natural disasters and disaster mitigation based on education level, namely at the junior high school level, obtained an effect size of 1.73 in the high category with a p value of 0.02 < 0.05, which means H_o is rejected so that it can be said that teaching materials that integrate natural disasters and disaster mitigation have an effect on the junior high school level. At the senior high school education level, the effect size obtained was 0.91 in the high category, with a p value of 0.00 < 0.05, which means that H_o was rejected, so that it can be said that teaching materials integrated with natural disasters and disaster mitigation have an effect on the high school level.

The effect of the use of integrated teaching materials on natural disasters and disaster mitigation material on students is only found at the junior and senior high school levels because, at the age of elementary school, the children seem to be still under pressure and are not ready for science lessons (Sulthon, 2017). Integrated learning materials must be understood by students by involving high-order thinking skills and critical thinking. Therefore, integrated learning materials on natural disasters and natural disaster mitigation are not widely used at the elementary school level.

Based on Figure 3, it shows that the average effect size at both levels is included in the large category. However, the junior high school education level has a higher effect size than the senior high school level. However, this indicates that these two levels are effective for implementing integrated learning materials with natural disasters and disaster mitigation.

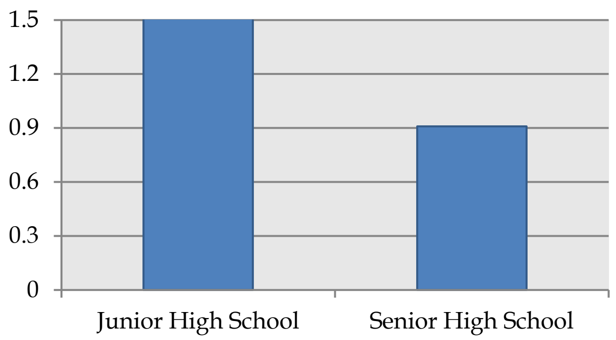

Figure 3. Effect Size Based on Education Level

The purpose of learning is to make students able to adapt and evolve according to the times and conditions in which they live (Riveros, 2020). Because Indonesia is prone to disasters, incorporating disaster material into the learning materials used by students is the best way to adapt and prepare them to better deal with it.

Providing knowledge about disaster mitigation and preparedness facing disasters through education is one way that can be done to reduce the number loss of life when a disaster occurs namely by giving information related to mitigation and disaster preparedness (Opilah et al., 2023). Implementation of disaster mitigation education in the world of education, this is very true needed, where it needs to be implemented in several mitigation simulation activities disasters and disaster education, so that learning can be done from an early age reduce the risk of panic and building disaster preparedness character (Wulandari et al., 2023).

Conclusion

The main conclusions in this study is Tthe use of integrated science learning materials on natural disasters and disaster mitigation has a high influence on student learning outcomes. The application of teaching materials integrated with natural disasters and disaster mitigation on learning outcomes based on the type of learning materials obtained by the effect size values of books in the medium category, students' worksheets in the high category, and modules in the high category. Based on material and natural disaster mitigation, the effect size values for earthquakes are in the very high category; the effect size values for tsunamis, floods, and coastal abrasion are in the moderate category; the effect size values for fire, drought, and haze are in the moderate category; and the effect size values for disaster mitigation are in the high category. Based on the level of education and natural disaster mitigation, the effect size value is obtained at the junior high school level with a very high category, and the effect size value at the senior high school level is in the high category. So, integrated teaching materials for natural disasters and natural disaster mitigation affect learning outcomes based on the type of learning materials used, the material studied, and the level of education currently occupied. This research can be used as a reference for developing science learning materials integrating natural disasters and disaster mitigation on different materials, school levels, and various natural disasters and disaster mitigation.

Acknowledgments

The authors would like to express the deepest gratitude for the award given to the authors, so this article is analyzed and can be used as a reference. The authors feels very honored and happy to know that this work has been accepted and recognized by a respectable journal such as JPPIPA.

Author Contributions

Asrizal: proofreading and reviewing; Nur Hikmah: analyzing the research data, writing the methodology and editing; Dhea Febriya: writing the discussion and conclusion; Filda Mawaddah: writing-original draft preparation and collecting the research data.

Funding

Research and writing of this article were funded by the authors.

Conflict of Interest

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

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