RESEARCH ARTICLE

Implementing ARVi media to enhance students high order cognitive skills

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Abstract: High-order cognitive skills (HOCS) are required to solve problems and make decisions. ARVi or augmented reality virus is a learning medium used to enhance HOCS. Aims of this research is to find out the effect of implementing ARVi media on enhancing high-level cognitive skills of students. The research is a quasi-experiment with a pretest-posttest control group design. The research was conducted in MAN 1 Kota Bogor class 10 using the Merdeka curriculum. The research instrument is a multiple-choice test that has been validated to measure high-level cognitive skills. The result of the t-test shows t-value (3.14) > t-table (1.98), indicating that there is a significant difference between the posttest scores of the control group and the experimental group. This means that the use of ARVi media has an effect on high-level cognitive skills. The improvement in high-level cognitive skills was continuous in C5 (evaluation) at 78%, C6 (creation) at 72%, and C4 (analysis) at 70%. These results are not independent of the support provided by the various content offered by ARVi media, such as augmented reality, literacy, and high-level questionnaires. Current education can benefit from technologies like ARVi media that help increase the high-level cognitive skills of students.

Keywords: ARVi; augmented reality; high order cognitive skills; learning media

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Introduction

High Order Cognitive Skills (HOCS) refer to abilities that go beyond basic understanding and involve the capacity to make decisions under conditions of uncertainty and time constraints. This is important for students to solve problems and make effective decisions. High order cognitive skills imply the ability to learn to identify, integrate, evaluate, and connect concepts in order to make the right decisions and solve problems (Bagarukayo et al., 2012; Ramdiah et al., 2019).

One of the persons who introduced the cognitive taxonomy was Bloom. This taxonomy was based on meaningful and consistent learning, where students can understand their learning experiences. Bloom's taxonomy is represented by knowledge (C1), comprehension (C2), application (C3), analysis (C4), synthesis (C5), and evaluation (C6) (Ghanizadeh et al., 2020). Bloom's taxonomy is often referred to as higher order thinking skills (HOTS), but in his book it is referred to as "The cognitive process dimension". Furthermore, cognitive and thinking are related concepts, but different. Cognitive refers to mental processes related to understanding, processing information, perception, memory, and problem-solving (Breed & Moore, 2022; Gauvain & Richert, 2023; Mishra, 2022; Moini et al., 2024; Shi & Qu, 2021). On the other hand, thinking refers to mental activities such as problem-solving, critical thinking, and creativity (Iskandar et al., 2021).

Anderson & Krathwohl revised Bloom's Taxonomy to include remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6) (Anderson & Krathwohl, 2001). Cognitive abilities are categorized into low order cognitive skills (LOCS) and high order cognitive skills (HOCS). LOCS refer to levels C1 to C3, while the remaining three levels, C4 to C6, are classified as HOCS, which involve more complex cognitive processes.

HOCS consist of analyzing (C4), evaluating (C5), and creating (C6) (Anderson & Krathwohl, 2001).

Analyzing refers to understanding how components relate to each other in a comprehensive process, being able to interpret data, graphs, images, and analyze case studies based on multiple information sources (Crowe et al., 2008). Analyzing involves breaking down complex information into smaller parts, identifying patterns, and making connections from various information (Baron, 2024). Evaluating encompasses cognitive processes such as checking for inconsistencies within a product or its effectiveness, and critiquing a process based on positive and negative values (Anderson & Krathwohl, 2001). Evaluating involves applying various methodologies and evaluation tools to collect data, analyze information, and make decisions about future programs or policies based on the information (Knight et al., 2019). Creating involves using various sources of information to generate new ideas, build hypotheses, and design experiments (Crowe et al., 2008). Creating is the highest level of Bloom's Taxonomy that can be achieved after a deep interpretation, analysis, and synthesis process (Corgnet et al., 2016).

Based on an interview with a biology teacher, it is known that one of the skills that students need to improve on is HOCS. Biology learning has not reached a high cognitive skills because most assessments only target low-level cognitive skills (Fauzi & Sa'diyah, 2019). The international level of the PISA (Program for international student assessment), questions are used that require students to have high cognitive abilities. The results of PISA 2022 show a decline in scores compared to PISA 2018 (OECD, 2022). PISA is an international assessment in reading, mathematics, and science. This indicates the need to improve HOCS by providing some exercises to enhance it. HOCS-based questions can be used to train problem-solving skills, critical thinking, and decision-making skills.

One method to help students develop higher cognitive skills during each session is by posing high-level questions (Lemons & Lemons, 2013). High-level questions can stimulate memory processing to obtain information, thereby playing a role in producing superior performance compared to the use of low-level questions (Jensen et al., 2014). HOCS can be assessed using multiple-choice options, essays, performance tasks, and explanations regarding the reasoning behind their responses (Serevina et al., 2019). Instruments based on multiple-choice formats are also employed for evaluating these advanced cognitive capabilities (Abosalem, 2015; Dahlan, 2021; Driana et al., 2021; Setiawan et al., 2021).

The ARVi (augmented reality virus) learning application is a mobile app that includes quizzes with high-level questions designed to enhance cognitive skills in students. Augmented reality technology has been shown to facilitate understanding of concepts, create an interactive learning environment, and increase motivation (Aldeeb et al., 2024; Amores-Valencia et al., 2023; Marrahi-Gomez & Belda-Medina, 2024). It is used to create engaging and enjoyable science education (Celik et al., 2020), allowing students to learn from different perspectives (Hutchison, 2018) and potentially improving literacy (Ahied et al., 2020). Augmented reality is a technology that projects 3D objects into the real world (Basha et al., 2021; Lara-Calle et al., 2022; Lv et al., 2022; Sarkar et al., 2022). It is hoped that the use of the ARVi app can improve students' high-order cognitive skills (HOCS).

Method

A quasi-experimental study with a pretest-posttest control group design. Sampling technique using multistage random sampling. A school was selected using purposive sampling based on suitable facilities for implementing the ARVi (augmented reality virus) learning app. Suitable schools have Wi-Fi, easy internet access, and students are allowed to bring cell phones every day. A school that meets these criteria and is willing to be a research site is MAN 1 in Bogor, Indonesia. The population was determined using purposive sampling, with the condition of learning about virus concepts, so the population consisted of all students in grade 10 in 2023/2024. Sampling used simple random sampling, with 60 students selected, divided into experimental and control groups, each receiving pretest and posttest. The experimental group used the ARVi app during biology lessons, while the control group used traditional media such as books and PowerPoint. The ARVi app is a mobile app with augmented reality technology to display virus objects. The use of augmented reality is shown to allow students to explore 3D virus forms from various angles, enhancing learning and improving long-term memory retention. The ARVi app is equipped with literacy content that can be used to increase students' understanding of viruses, and quizzes as a problem-solving training. The ARVi app can be used with various learning models, such as the cooperative learning model STAD (Student Team Achievement Division) based on a merdeka curriculum. This learning model is usually used by biology teachers, so it is hoped that it will facilitate the implementation of the ARVi app.

An instrument is used to measure Higher-Order Cognitive Skills (HOCS) of students before and after learning, which is constructed based on the Revised Taxonomy of Learning Domains by Anderson and Krathwohl (2001). This taxonomy consists of three levels: analyzing (C4), evaluating (C5), and creating (C6) (Table 1).

The results of the pretest and posttest were analyzed using the prerequisite test and independent t-test. The prerequisite test consists of the K-S normality test and the F homogeneity test with a significance level of $\alpha = 0.05$. The independent t-test was conducted to observe the influence of ARVi media on students' high order cognitive skills (HOCS) between the experimental and control groups. A paired t-test was used to examine the differences between the pretest and posttest results.

Table 1. The grid of HOCS instrument

HOCS	Assessment Indicators	Item number
Analyzing (C4)	• Analyzing the function of body part affected by two types of viruses • Analyzing events of COVID-19 infection in daily life • Analyzing differences between virus types and infected cell types • Categorizing virus types based on their characteristics • Analyzing the process of virus replication • Analyzing reasons for using viruses against elderly population	4*, 7, 8, 10, 11, 13, 16, 22
Evaluating (C5)	• Suggesting the finding of research by Dmitry Ivanovsky • Proposing the role of RNA/DNA viruses based on case examples • Evaluating the uses of vaccine-based approaches • Evaluating factors contributing of virus spread • Evaluating activities performed during independent isolation processes	1, 9, 12, 14, 15, 19, 20*, 23
Creating (C6)	• Offering hypotheses and research finding by Beijerinck • Providing opinions based on everyday examples in life • Presenting the results of interpreting swab RT-PCR tests and rapid test according to narratives • Suggesting actions that can be taken against viral diseases • Proposing measures for controlling the spread of the COVID-19 virus among healthcare workers	2, 3, 5, 6, 17*, 18, 21, 24, 25

Results and Discussion

ARVi was implemented for classes X-8 and X-9 as experimental groups. Classes X-5 and X-10 served as the control group using conventional visual learning materials like PowerPoint. Pretests and posttests were conducted to determine the differences in learning outcomes between each group.

Figure 1 shows the descriptive data of the results of using ARVi media in the experimental group and visual media in the control group. It can be seen that the average post-test score is higher than the pre-test score in both groups. The results of the normality test indicate that the control group has a significance of 0.13 and the experimental group has a significance of 0.20, with an α = 0.05. Since both groups have normally distributed data, the results of the homogeneity test show that the pretest and posttest data have F values of 1.03 and 1.04, which are less than the F table values, indicating that the data is homogeneous. Since the data is normally distributed and homogeneous, a t-independent test can be performed.

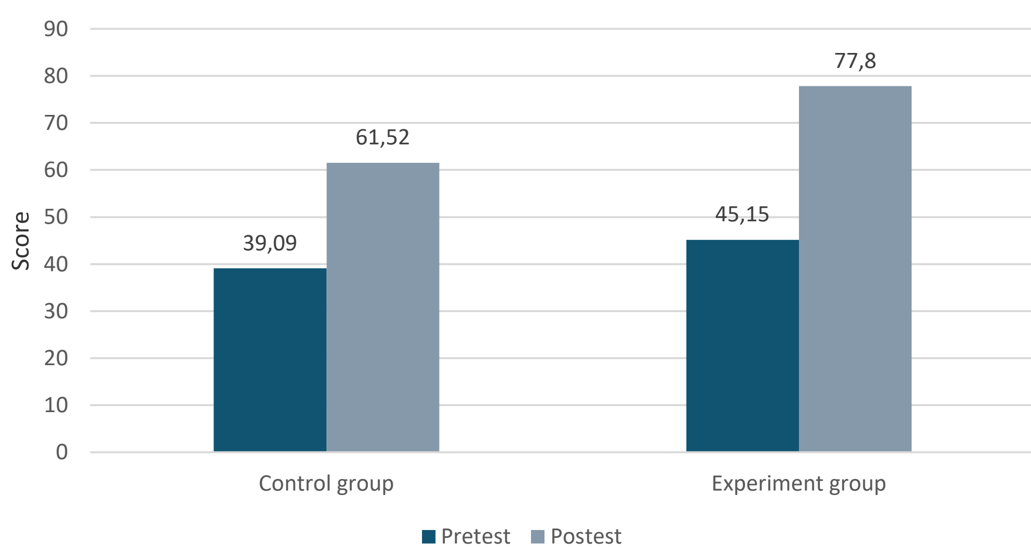

Figure 1. Result of using ARVi media on HOCS

Furthermore, Table 2 demonstrates the results of an independent t-test showing that the calculated t-value (3.14) is greater than the t-table (1.98). Therefore, it can be concluded that there is a difference in post-test scores between the control group and experimental group. This implies that the use of the ARVi application has an effect on HOCS.

Table 2. Result of t independent test

Assumption	t-value	df	t-table	α
Equal variances assumed	3.14	118	1.98	0.05

ARVi Media is a multimedia learning medium that includes augmented reality (AR). ARVi Media can be accessed with smartphones and tablets that support AR. Compared to similar applications, ARVi Media has an advantage because it does not require markers to display AR, allowing AR to be displayed anywhere. The AR virus objects displayed are also equipped with various explanations, such as DNA or RNA, heads, capsids, and tails. In addition, there is basic information about the type of virus displayed, so in one layer, students can obtain multiple pieces of information.

Augmented reality (AR) technology can visualize the shape of viruses in 3D, such as complex T viruses, helical viruses, spherical viruses, polyhedral viruses, and thread-like viruses. 3D AR images allow students to add value to the content and combine text to maximize their attention. Images play a crucial role in focusing attention by processing a portion of the available information through the eyes, memory, and cognition. 3D AR images can enhance memory because the information presented relates to past experiences and is collected and presented again through visual message. Iconic storage will store visual information with imagery coding in the form of a photo archive.

The use of AR can also help improve spatial intelligence (Majeed & ALRikabi, 2022). Learning using 3D shapes allows students to explore the structure of viruses from various angles and scale, making learning more effective. Spatial intelligence allows students to imagine the shape of viruses and describe them in their own words. The process of seeing, imagining, and describing involves cognitive processes of the student. Cognitive processes based on Bloom's taxonomy start from remembering (C1), understanding (C2), and applying (C3). This allows the use of augmented reality to reach the application level (C3) of Bloom's taxonomy. The positive response from students due to the use of AR is because it offers a wealth of content, engaging and interactive (Erwinsah et al., 2019), and allows students to observe the structure of viruses directly, providing an opportunity to learn (Celik et al., 2020; Wu et al., 2013)

The content on ARVi media is not just augmented reality, but also literature and quizzes. Literary content is used to broaden students' understanding, thereby increasing their cognitive skills. Literary content presents several research articles that can be analyzed. When analyzing, students can distinguish relevant and important information, organize messages according to their functions, and connect information to reach conclusions. The ability to analyze means understanding how components are related and interpreting data from various information (Crowe et al., 2008).

In addition to analyzing articles, students can also evaluate research results based on quality, effectiveness, efficiency, and consistency. For example, in the topic of virus benefits, students receive information about vaccine technology, convalescent therapy, gene therapy, and so on. They can evaluate the use of these technologies based on the positive and negative effects they generate. Students who have information from various perspectives can create new solutions to problems. This shows that literary content can train cognitive skills in analyzing (C4), evaluating (C5), and creating (C6). Regular reading of literature can enhance cognitive skills and protect memory from decline (Kairu, 2021; Sylvia et al., 2021).

Other content that can train HOCS includes quizzes conducted at the end of each group meeting. ARVi media quizzes have high-level questions that are not easy to answer. Group activities provide an opportunity for students to discuss and explore their knowledge to find the correct answer. This activity is repeated until a final test is conducted independently. Repeated quizzes encourage students to recall previously obtained information. High-level quizzes can stimulate memory processing by analyzing questions and finding answers from existing knowledge beforehand. This allows for more extensive memory processing compared to low-level questions. The experience of students in solving high-level questions regularly can build the skill of accurately solving problem (Lemons & Lemons, 2013).

HOCS consists of analysis (C4), evaluation (C5), and creating (C6). The use of ARVi media shows that there are differences in the increase in students' cognitive abilities in each domain which can be seen in Table 3.

Table 3. Result of analysis high order cognitive skills

No.	Data	Mean ± SD	
		Pretest	Postest
1.	C4 - Analyzing	43,33 ± 20,37	72,50 ± 17,37
2.	C5 – Evaluating	45,24 ± 22,68	80,24 ± 7,42
3.	C6 - Creating	47,14 ± 10,53	81,43 ± 7,84

Table 3 shows the results of the analysis of high-level cognitive ability in each domain. Based on the table, it is known that the post-test score is higher than the pre-test score in each domain of high-level cognitive ability. The percentage of improvement in each domain can be seen in Figure 2.

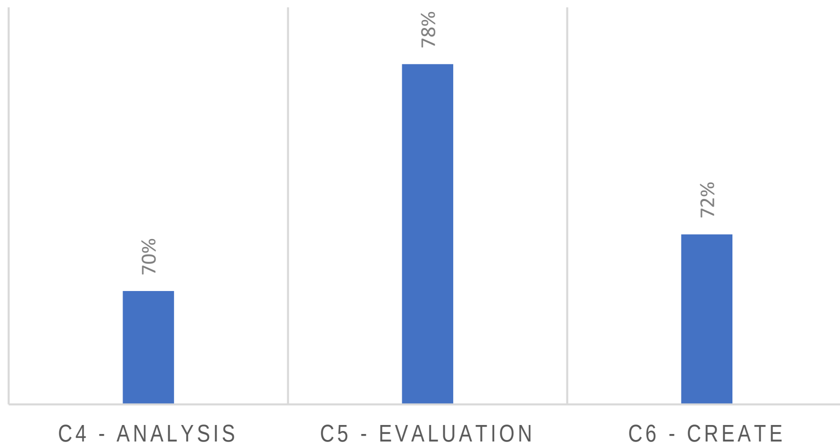

Figure 2. Graph of mean improvement of HOCS dimention

The Figure 2 shows a significant increase in high order cognitive skill after using ARVi. The most significant percentage increase is seen in C5 (evaluation), C6 (creation), and C4 (analysis). The highest increase in evaluation is due to students examining various research, such as the history of viruses. Students engage in background checks, methods, hypotheses, and virus research results. This information is criticized by comparing the strengths and weaknesses of the research conducted. The evaluation means that students can assess data that supports hypotheses (Crowe et al., 2008).

The second highest improvement is creating meaning by generating new insights from the provided information (Corgnet et al., 2016).This is because the ARVi media has quizzes that present problems, allowing students to discuss and obtain answers from their own perspectives. For example, students can learn about the spread of hepatitis B virus through various means such as injections, drugs, blood transfusions, and so on. This information enables students to find the best prevention and treatment methods they can do. The ability to create can be achieved by presenting a problem, making a plan, and generating new solutions (Anderson & Krathwohl, 2001).

The latest improvement in the analysis means that students understand the relationship between components and processes as a whole. This is because students are able to analyze data in the form of graphs, pictures, case studies from literacy articles, and quizzes. One of the questions that requires students to analyze is when they are given a comparison of types of viruses that only infect certain parts. When analyzing the question, students are able to distinguish information based on the level of relationship between types of viruses. They then organize it by recognizing correlations between information such as the relationship between viruses that attack certain parts of the body. This information is then connected to answer the question posed. The process of analysis through cognitive processes distinguishes, organizes, and connects (Anderson & Krathwohl, 2001).

Conclusion

The use of ARVi media can affect the high-level cognitive skills of students. ARVi media is a multimedia application that contains augmented reality without markers, literacy, and quizzes. These three contents are done simultaneously to train the cognitive skills of students. The improvement of high-level cognitive skills occurs sequentially at C5 (evaluation), C6 (creation), and C4 (analysis). The next research recommendation is to conduct research on a learning model that can be integrated with ARVi and can further maximize the improvement of students' cognitive skills.

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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

R.P. Indriani: conducting the reserch, collecting data, writing the original article. **R. H. Ristanto:** developed the methodology, and supervising the reserch. **T.H. Kurniati:** developed supervising the reserch, and manuscript draft writing.

References

Abosalem, Y. (2015). Assessment techniques and students' higher-order thinking skills. *ICSIT 2018 - 9th International Conference on Society and Information Technologies, Proceedings*, *4*(1), 61–66. https://doi.org/10.11648/j.ijsedu.20160401.11

Ahied, M., Muharrami, L. K., Fikriyah, A., & Rosidi, I. (2020). Improving students scientific literacy through distance learning with augmented reality-based multimedia amid the COVID-19 pandemic. *Jurnal Pendidikan IPA Indonesia*, *9*(4), 499–511. https://doi.org/10.15294/jpii.v9i4.26123

Aldeeb, F. H., Sallabi, O. M., Elaish, M. M., & Hwang, G. (2024). Enhancing students' learning achievements, self-efficacy, and motivation using mobile augmented reality. *Journal of Computer Assisted Learning*, *40*(4), 1823–1837. https://doi.org/10.1111/jcal.12989

Amores-Valencia, A., Burgos, D., & Branch-Bedoya, J. W. (2023). The influence of Augmented Reality (AR) on the motivation of high school students. *Electronics*, *12*(22), 4715. https://doi.org/10.3390/electronics12224715

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching and assesing*. Addison Wesley Longman. https://books.google.co.id/books/about/A_Taxonomy_for_Learning_Teaching_and_Ass.html?hl=id&id=EMQlAQAAIAAJ&redir_esc=y

Bagarukayo, E., Weide, T., Mbarika, V., & Kim, M. (2012). The impact of learning driven constructs on the perceived higher order cognitive skills improvement : Multimedia vs . text. *International Journal of Education and Development Using Information and Communication Technology*, *8*(2), 120–130. https://eric.ed.gov/?id=EJ1084175

Baron, J. (2024). Thinking and deciding. In *Thinking and deciding* (Issue 5, pp. 1–15). https://doi.org/10.1017/9781009263672

Basha, C. Z., Reddy, D. P. kiran, Chand, S. R. P., & Krishna, A. (2021). Augmented reality experience for real-world Objects, monuments, and cities. *2021 Third International Conference on Inventive Research in Computing Applications (ICIRCA)*, 670–675. https://doi.org/10.1109/ICIRCA51532.2021.9544792

Breed, M. D., & Moore, J. (2022). Cognition. In *Animal Behavior* (pp. 181–217). Elsevier. https://doi.org/10.1016/B978-0-12-819558-1.00006-3

Celik, C., Guven, G., & Cakir, N. K. (2020). Integration of mobile augmented reality (MAR) applications into biology laboratory : Anatomic structure of the heart. *Research in Learning Technology*, *28*(1063519), 1–11. https://doi.org/http://dx.doi.org/10.25304/rlt.v28.2355

Corgnet, B., Espín, A. M., & Hernán-González, R. (2016). Creativity and cognitive skills among Millennials: Thinking too much and creating too little. *Frontiers in Psychology*, *7*(OCT), 1–9. https://doi.org/10.3389/fpsyg.2016.01626

Crowe, A., Dirks, C., & Wenderoth, M. P. (2008). Biology in Bloom: Implementing Bloom's taxonomy to enhance student learning in biology. *CBE-Life Science Education*, *7*, 368–381. https://doi.org/10.1187/cbe.08

Dahlan, D. (2021). Development of higher-order thinking skills assessment for high school economic.

Journal of Economic Education, *10*(2), 134–141. https://doi.org/10.15294/JEEC.V10I2.52206
Driana, E., Susilowati, A., Ernawati, E., & Ghani, A. R. A. (2021). Assessing students' higher-order thinking skills: knowledge and practices of chemistry teachers in vocational senior secondary schools. *Jurnal Pendidikan Teknologi Dan Kejuruan*, *27*(1), 37–47. https://doi.org/10.21831/jptk.v27i1.32882
Erwinsah, R., Aria, M., & Yusup, Y. (2019). Application of augmented reality technology in biological learning. *Journal of Physics: Conference Series*, *1402*(6), 1–4. https://doi.org/10.1088/1742-6596/1402/6/066090
Fauzi, A., & Sa'diyah, W. (2019). Students' metacognitive skills from the viewpoint of answering biological questions: Is it already good? *Jurnal Pendidikan IPA Indonesia*, *8*(3), 317–327. https://doi.org/10.15294/jpii.v8i3.19457
Gauvain, M., & Richert, R. (2023). Cognitive development. In *Encyclopedia of Mental Health* (pp. 430–437). Elsevier. https://doi.org/10.1016/B978-0-323-91497-0.00048-5
Ghanizadeh, A., Al-Hoorie, A. H., & Jahedizadeh, S. (2020). *Second language learning and teaching higher order thinking skills in the language classroom: A concise guide*. Springer Nature. https://doi.org/10.1007/978-3-030-56711-8
Hutchison, A. (2018). Using virtual reality to explore science and literacy concepts. *International Literacy Association*, 1–11. https://doi.org/10.1002/trtr.1720
Iskandar, N., Mustaji, M., Jannah, M., & Wicaksono, S. R. (2021). The problem based learning in enhancing students' critical thinking for reading skills in english teaching at vocational school. *IJORER : International Journal of Recent Educational Research*, *2*(2), 237–249. https://doi.org/10.46245/ijorer.v2i2.93
Jensen, J. L., Mcdaniel, M. A., Woodard, S. M., & Kummer, T. A. (2014). Teaching to the test … or testing to teach: Exams requiring higher order thinking skills encourage greater conceptual understanding. *Educ Psychol Rev*, *2010*, 1–23. https://doi.org/10.1007/s10648-013-9248-9
Kairu, C. (2021). Augmented reality and its influence on cognitive thinking in learning. *American Journal of Education Research*, *9*(8), 504–512. https://doi.org/10.12691/education-9-8-6
Knight, A. T., Cook, C. N., Redford, K. H., Biggs, D., Romero, C., Ortega-Argueta, A., Norman, C. D., Parsons, B., Reynolds, M., Eoyang, G., & Keene, M. (2019). Improving conservation practice with principles and tools from systems thinking and evaluation. *Sustainability Science*, *14*(6), 1531–1548. https://doi.org/10.1007/s11625-019-00676-x
Lara-Calle, A., Cruz, J., & Mejía, N. (2022). Augmented reality and 3D balance learning. In *The Fairchild Books Dictionary of Fashion* (pp. 550–555). Bloomsbury Publishing Plc. https://doi.org/10.1007/978-3-031-19679-9_69
Lemons, P. P., & Lemons, J. D. (2013). Questions for assessing higher-order cognitive skills: It's not just Bloom's. *CBE-Life Science Education*, *12*(2), 47–58. https://doi.org/10.1187/cbe.12-03-0024
Lv, Z., Wang, J.-Y., Kumar, N., & Lloret, J. (Eds.). (2022). *Augmented reality, virtual reality, semantic 3D reconstruction*. MDPI. https://doi.org/10.3390/books978-3-0365-6062-5
Majeed, B. H., & ALRikabi, H. T. S. (2022). Effect of augmented reality technology on spatial intelligence among high school students. *International Journal of Emerging Technologies in Learning (IJET)*, *17*(24), 131–143. https://doi.org/10.3991/ijet.v17i24.35977
Marrahi-Gomez, V., & Belda-Medina, J. (2024). Assessing the effect of Augmented Reality on English language learning and student motivation in secondary education. *Frontiers in Education*, *9*. https://doi.org/10.3389/feduc.2024.1359692
Mishra, R. K. (2022). *Cognitive science*. Routledge India. https://doi.org/10.4324/9781003316053
Moini, J., LoGalbo, A., & Ahangari, R. (2024). Cognitive functions. In *Foundations of the Mind, Brain, and Behavioral Relationships* (pp. 211–228). Elsevier. https://doi.org/10.1016/B978-0-323-95975-9.00002-0
OECD. (2022). PISA 2022 results factsheets Indonesia. *OECD*, *1*, 1–9. https://www.oecd.org/en/publications/2023/11/pisa-2022-results-volume-i-and-ii-country-notes_2fca04b9/indonesia_0e09c072.html
Ramdiah, S., Abidinsyah, A., Royani, M., & Husamah, H. (2019). Understanding, planning, and implementation of HOTS by senior high school biology teachers in Banjarmasin-Indonesia. *International Journal of Instruction*, *12*(1), 425–440. https://doi.org/10.29333/iji.2019.12128a
Sarkar, S., & Adhish, S., Adarsh, V., Divakar, K. (2022). Exploration and aspects on augmented reality. *2022 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS)*, 1–6. https://doi.org/10.1109/ICPECTS56089.2022.10047434
Serevina, V., Sari, Y. P., & Maynastiti, D. (2019). Developing high order thinking skills (HOTS) assessment instrument for fluid static at senior high school. *Journal of Physics: Conference Series*, *1185*, 012034. https://doi.org/10.1088/1742-6596/1185/1/012034
Setiawan, J., Sudrajat, A., Aman, & Kumalasari, D. (2021). Development of higher order thinking skill assessment instruments in learning Indonesian history. *International Journal of Evaluation and Research in Education*, *10*(2), 545–552. https://doi.org/10.11591/ijere.v10i2.20796
Shi, Y., & Qu, S. (2021). Cognitive ability and self-control's influence on high school students'

comprehensive academic performance. *Frontiers in Psychology*, *12*(December), 1–10. https://doi.org/10.3389/fpsyg.2021.783673

Sylvia, F., Ramdhan, B., & Windyariani, S. (2021). Efektivitas augmented reality terhadap higher order thinking skills siswa pada pembelajaran biologi. *Biodik: Jurnal Ilmiah Pendidikan Biologi*, *7*(2), 131–142. https://doi.org/https://doi.org/10.22437/bio.v7i2.13034

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers and Education*, *62*, 41–49. https://doi.org/10.1016/j.compedu.2012.10.024