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Augmented Reality and Coding in Education: A Food Pyramid Media to Foster Self-Directed Learning and Computational Thinking

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ABSTRAK

Permasalahan rendahnya kemandirian belajar dan kemampuan berpikir komputasional siswa masih menjadi tantangan dalam pembelajaran di sekolah dasar. Penelitian ini bertujuan untuk mengembangkan media piramida makanan berbasis augmented reality *(AR) yang dikombinasikan dengan* coding *guna meningkatkan kemandirian belajar dan kemampuan berpikir komputasional siswa kelas V Sekolah Dasar. Penelitian ini menggunakan model pengembangan ADDIE. Validitas media diuji oleh para ahli, sedangkan kepraktisan dan efektivitas media dinilai melalui implementasi di kelas. Data dikumpulkan melalui kuesioner kemandirian belajar, soal esai untuk mengukur kemampuan berpikir komputasional, serta wawancara dengan wali kelas untuk memperkuat data kualitatif. Hasil penelitian menunjukkan bahwa media piramida makanan berbasis AR memiliki tingkat validitas yang tinggi, dengan skor rata-rata penilaian dari para ahli berada dalam kategori sangat valid. Kepraktisan media ini juga dinilai tinggi berdasarkan respon positif dari siswa dan guru selama implementasi di kelas. Uji efektivitas menunjukkan bahwa media ini signifikan dalam meningkatkan kemandirian belajar dan kemampuan berpikir komputasional siswa. Berdasarkan uji statistik, nilai signifikansi (sig. 2-tailed) untuk kedua variabel menunjukkan angka < 0,001. Hasil ini menunjukkan bahwa $F_{hitung} > F_{tabel}$, sehingga H_0 ditolak dan H_1 diterima, yang berarti terdapat pengaruh signifikan dari penggunaan media terhadap kemandirian belajar dan kemampuan berpikir komputasional siswa. Simpulan dari penelitian ini adalah bahwa media piramida makanan berbasis* augmented reality *dan* coding *dapat menjadi alat pembelajaran yang efektif dalam meningkatkan kemandirian belajar dan kemampuan berpikir komputasional siswa.*

ABSTRACT

The issue of low self-directed learning and Computational Thinking skills among elementary school students remains a challenge in the learning process. This study aims to develop an augmented reality (AR)-based food pyramid media integrated with coding to enhance self-directed learning and Computational Thinking skills of fifth-grade elementary school students. The research employed the ADDIE development model. The media's validity was assessed by experts, while its practicality and effectiveness were evaluated through classroom implementation. Data were collected using self-directed learning questionnaires, essay questions to measure Computational Thinking skills, and interviews with homeroom teachers to strengthen qualitative data. The findings revealed that the AR-based food pyramid media has a high validity level, with expert evaluations categorized as highly valid. The media also demonstrated high practicality, receiving positive responses from both students and teachers during classroom implementation. The effectiveness test showed that the media significantly improved students' self-directed learning and Computational Thinking skills. The statistical test results indicated a significance value (sig. 2-tailed) of < 0.001 for both variables. This result shows that $F_{calculated} > F_{table}$, rejecting H_0 and accepting H_1, indicating a significant impact of the media on enhancing students' self-directed learning and Computational Thinking skills. In conclusion, the augmented reality and coding-based food pyramid media can serve as an effective learning tool to improve students' self-directed learning and Computational Thinking skills.

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1. INTRODUCTION

Learning Natural and Social Sciences (IPAS) can provide various important benefits for student development in various aspects of life (Sakila et al., 2023; Widiari et al., 2023). Such as a deeper understanding of the world around, critical thinking skills, and strengthening analytical skills (Paratiwi & Ramadhan, 2023; Shah et al., 2020; Silberman et al., 2021). With a strong foundation of knowledge in the field of science, students will find it easier to relate theory to practice, and develop their ability to explore and solve problems independently. This directly contributes to increasing students' learning independence (Rizky et al., 2024; Sugih et al., 2023). Learning independence is the ability that a student has to try to be independent in exploring learning information other than the learning resources provided by the teacher (Nuritha & Tsurayya, 2021; Siagian et al., 2021). Demands for high independence, and if not handled properly, this can have a negative impact on student development in the future. Students who have an independent attitude will be braver in deciding things related to themselves, free from the influence of others, able to take the initiative and develop creativity and stimulate to achieve better. Learning independence can also form a high sense of responsibility and be active in learning (Hamsina et al., 2023; Suwintara et al., 2022). Learning independence is important to develop because it can improve students' skills in managing time, identifying relevant learning resources, and developing effective learning strategies (Hamsina et al., 2023; Uki & Ilham, 2020). In the context of modern education, independent learning is not only about accessing textbooks and materials provided by teachers, but also involves the use of abundant technology and digital resources.

In addition, the application of Computational Thinking is a crucial aspect in strengthening students' learning independence. Computational thinking is an important aspect for students because it is able to hone logical, mathematical, mechanical knowledge, which is combined with modern knowledge about technology, digitalization, and computerization, even forming a character of self-confidence, open-mindedness, tolerance and sensitivity to the environment (Ansori, 2020; Tang et al., 2020). Computational Thinking in the context of science in elementary schools involves the application of computational thinking principles to understand and solve scientific problems systematically (Angeli & Giannakos, 2020; Ansori, 2020; Rafiq et al., 2023). Computational Thinking is a critical thinking process that involves how to formulate problems and solutions, so that they can be presented in an effective form (Kallia et al., 2021). Thus, Computational Thinking influences a person's critical thinking ability, one of which is improving problem-solving abilities (Dewi et al., 2021; Merino-Armero et al., 2022). Computational Thinking students are directed to have critical, creative, communicative thinking skills as well as skills to collaborate in solving problems (Tikva & Tambouris, 2021; Tsarava et al., 2022). The application of Computational Thinking is not only limited to computer-related activities, but is also related to other study subjects (Dewi et al., 2021; Merino-Armero et al., 2022; Tikva & Tambouris, 2021). For example, in a science project, students can use computational thinking to design experiments, collect and analyse data, and present their findings logically and systematically.

However, many students' Computational Thinking skills are still relatively low due to a lack of understanding related to logical and analytical problem solving, limited access to supporting technology and minimal opportunities to develop skills early on. So that Computational Thinking skills are a special concern in today's education world. The low Computational Thinking of students in schools will have an impact on students' learning independence (Angeli & Giannakos, 2020; Tang et al., 2020). Low student learning independence is caused by a lack of self-confidence in conveying the problems faced to achieve learning goals (Diana et al., 2020; Suwintara et al., 2022). The observation result shows that 90% of the interaction is dominated by the teacher, 90% of the students receive information from the teacher, and only 10% of the students have the initiative, ask questions, and give opinions. These activities do not show any learning independence. In addition, low learning independence is also caused by learning habits and technology that are less supportive.

Efforts to improve students' learning independence can utilize learning media in delivering materials, where learning media is an appropriate tool used to improve students' learning independence in class. Based on interviews with grade V teachers in Cluster 7 (SD Negeri 3 Suwug, SD Negeri 1 Suwug, SD Negeri 4 Suwug, and SD Negeri Sinabun), it was found that students still lack participation in learning and have weak Computational Thinking skills. Students also have difficulty understanding the material due to the lack of teacher innovation in developing PBL and PJBL-based learning models, as well as the minimal use of learning media that support learning independence. Teachers stated that the learning media used, such as PowerPoint, are still monotonous and less interesting, so students get bored quickly and lose interest in learning. In fact, on average, schools in Cluster 7 already have digital facilities, such as Chromebooks, LCDs, and adequate internet, but their use is more often limited to ANBK and is rarely applied in daily teaching and learning activities. To overcome this obstacle, more interesting learning media are needed to increase students' interest in learning, independence, and Computational Thinking skills.

In addition to conducting interviews with grade V teachers, an initial test was conducted to determine students' learning independence and Computational Thinking abilities. The test was conducted by giving ten essay questions or descriptions containing several aspects related to Computational Thinking and a questionnaire to measure students' learning independence. The test results of grade V students in cluster 7 related to learning independence showed less than optimal results as seen from the inappropriate choices reaching a percentage of 58.54%, which means that students' learning independence is still very lacking. The test results related to the Computational Thinking abilities of grade V students on the food web material are still relatively low with a percentage of 54.88% of students who have not reached the minimum score. In addition, there are several factors that cause low learning independence and Computational Thinking based on interviews with grade V teachers, including lack of concrete practical experience, overly theoretical learning focus and lack of direct practice, and the use of less interesting learning media. In addition, the lack of intensive support from teachers, and materials that are not connected to the context of everyday life also contribute to this problem.

Solutions to improve students' understanding, participation, and independence in food web material require appropriate solutions such as the development of augmented reality food pyramid media. This media is expected to overcome problems that cause low learning independence and students' Computational Thinking abilities. The development of science learning media in food web material can add to students' learning experiences so that they are more in-depth and real, and can increase learning independence and strengthen students' Computational Thinking. One of the media that can be developed is Augmented Reality media. Augmented Reality media is a type of media that includes animated videos, audio, text, and graphics, allowing students to interact with the elements in the media (Dinayusadewi & Agustika, 2020; Sa'diah et al., 2022; Sahin & Yilmaz, 2020). In order for the learning media developed to be more interesting and the learning process more interactive, a coding-based learning approach can be developed. Thus, students are not only actively involved, but also make the learning experience more dynamic and relevant to the needs of the times (Alalwan et al., 2020; Maharani et al., 2023). The importance of Augmented Reality learning media to be applied in learning in elementary schools, this aims to ensure that the objectives of science learning can be conveyed well through innovations in learning media in the world of education. Innovations in learning media in the world of education are very numerous (Chen, 2020; Nugraha et al., 2021). Innovation can be interpreted as the creativity of teachers who change the style and method of teaching. The use of innovative media in learning that requires novelty and changes the style and method used in learning so that it can attract students' interest in learning so that they enjoy receiving the material delivered by the teacher (Bursali & Yilmaz, 2019; Iskandar & Mayarni, 2022; Sahin & Yilmaz, 2020).

Previous research findings stated that Augmented Reality-based media on Animal Classification Material is suitable for use in Grade V Elementary Schools (Wibowo et al., 2022). This PIN.AR learning media makes learning more interactive, so that students find it easier to understand the material, can increase interest in learning, and can improve student understanding (Darul Hamim, 2024; Nugraha et al., 2021). Electronic comic media of the circulatory system integrated with augmented reality can increase students' interest in learning (Ningrum et al., 2022). Based on previous research findings, it is necessary to develop media that can support the learning process to improve students' learning independence and Computational Thinking in the learning process in the classroom. The difference between the development research conducted and this research is that the media developed is a website that contains Augmented Reality content that can be scanned, and is combined with the concept of unplugged coding, while the previous research developed an Augmented Reality-based application. The media developed is augmented reality media, augmented reality in this media is in the form of animated videos that contain problems related to food web material in the ecosystem and explanatory videos of animal food web material, especially land ecosystems. This study aims to develop Augmented Reality (AR)-based food pyramid media combined with coding to improve learning independence and computational thinking skills of grade V Elementary School students.

2. METHOD

This research is a research on the development of augmented reality Food Pyramid media based on coding on the material of food web science for grade V Elementary School. Based on this, the approach model used in this development research is the ADDIE model. In the ADDIE model, it is carried out through 5 stages, including: Analysis, Design, Development, Implementation, and Evaluation (Wisada et al., 2019). This development research aims to produce a specific product and test its effectiveness by applying the ADDIE model. This model was chosen because it is relevant to the characteristics of development research. The research process consists of five stages. The first stage is analysis, which includes four main aspects, namely analysis of the needs of fifth grade students at SD Negeri 3 Suwug through interviews with fifth

grade homeroom teachers on April 6, 2024, analysis of student characteristics, analysis of the curriculum used by the school, and analysis of learning media to be developed. The second stage is design, which begins with designing science learning materials about food webs, then developing a media design for "Coding-based Augmented Reality Food Pyramid". This design includes the selection of images, text, audio, video, and the addition of games and quizzes to train students' understanding. The media is designed in a flipbook format that resembles a digital book and can be accessed via the website. Furthermore, consult with the supervising lecturer to obtain input for improving the media.

The third stage is development, the learning media is developed based on the refined design. Furthermore, an assessment is carried out by material experts, media experts, and student response tests through product evaluation sheets. This evaluation aims to assess the validity and practicality of the learning media on the IPAS material on the topic of food webs. The fourth stage is implementation, which involves revising the product based on input from experts and trials on small groups in stages. This trial aims to assess the impact, quality, and results of the developed learning media, as well as being a guideline for evaluating the practicality and effectiveness of the product. The last stage is evaluation, which assesses the quality of the product and the teaching process before and after implementation. This evaluation includes summative assessments to ensure that the product meets the criteria for validity, practicality, and effectiveness. By following the stages of the ADDIE model, the developed learning media is expected to be able to improve the quality of learning, learning independence, and students' computational thinking skills.

The subject of this development research trial is the Augmented Reality food pyramid media based on coding in the science and science material, the object of this research is the validity, practicality and effectiveness of the Augmented Reality food pyramid media based on coding. This study uses a one-group pre-test-post-test design. In this study, the results of the treatment can be known more accurately, because it can be compared with the conditions before being given treatment and after being given treatment. At this stage, the activity begins with the implementation of a pre-test followed by a post-test. Data collection and measurement of effectiveness are carried out using a questionnaire sheet containing a number of statements that have been designed previously. The grid of the instruments used can be seen in Table 1, Table 2, Table 3, Table 4, and Table 5.

Table 1. The Media Expert Instrument Grid

Component	Indicator	Item Number	Number of grains
Text	Conformity of text type and size.	1	1
	Clarity of text on each topic of discussion.	2	1
	Match the color of the text to the media Augmented Reality Food Pyramid Coding Based	3	1
Picture	2D clarity in Augmented Reality media.	4	1
	The attractiveness of the image.	5	1
	Image accuracy supports explanation of the material.	6	1
	Media image placement suitability Augmented Reality Food Pyramid coding based	7	1
Animation	Animation quality on Pyramid media Coding Based Augmented Reality Food.	8	1
	Appropriateness of the animation used in Food Pyramid media Augmented Reality Coding Based	9	1
Video	Video quality on animated videos.	10	1
	Clarity of sound in animated videos.	11	1
	Suitability of the video to the learning material.	12	1
	The attractiveness of the video used.	13	1
	Matching music and sound effectsused.	14	1
Audio	Matching music and sound effects used.	15	1
Amount		**15**	

Table 2. The Material Expert Instrument Grid

Aspect	Indicator	Item Number	Number of Items
Design Learning	Suitability of the material presented	1	1
	in learning media with indicators.	2	1
	Suitability of the material concept with	3	1

Aspect	Indicator	Item Number	Number of Items
	media used	4	1
	Depth and completeness of the material.	5	1
		6	1
	Ease of understanding the material.	7	1
		8	1
	Systematic, coherent, logical and clear flow.	9	1
		10	1
Amount		**10**	

Table 3. The Student Response Instrument Grid

Aspect	Indicator	Number Item	Amount Item
Media Presentation Food Pyramid Augmented Reality Coding Based	Material published in Pyramid media Augmented Reality Based Food Coding explained easily	1	1
	Presentation of questions given in the media Augmented Reality Food Pyramid Coding Based according to aspects understanding of learning independence and computational thinking ability elementary school.	2	1
	Augmented Food Pyramid Media RealityCoding based that complies with surrounding environment.	3	1
Media View Food Pyramid Augmented Reality Coding Based	Food Pyramid Media View Augmented RealityCoding Based is interesting.	4	1
	Augmented Food Pyramid View RealityCoding based readable clearly.	5	1
	Image display on Pyramid media Augmented Reality based food Coding is clearly visible	6	1
	Sound display on media Augmented Reality Food Pyramid Coding based in harmony with backsound in the explanatory video material.	7	1
	Food Pyramid media display Augmented RealityCoding based.	8	1
Media operation Food Pyramid Augmented Reality Coding Based	Augmented Food Pyramid Media Reality Coding based can be used easily in supporting the process learning in the classroom.	9	1
	Pyramid Media Augmented Reality based food Coding can be used repeatedly repeat so that it helps effectiveness learning.	10	1
Amount		**10**	

Table 4. The Grid of Learning Independence Instruments

Indicator Independence Study	Sub Indicator Learning Independence	Item Number	
		Positive	Negative
Creative Thinking	Fluent thinking skills	1	
	Original thinking skills	2	
	Attitude of feeling challenges	3	4
	Attitude of curiosity	5	6
Self-confident	Optimistic about doing something	7	8
	Creative and dynamic	9	
	Respect others	10	
	Be calm	11	12

Indicator Independence Study	Sub Indicator Learning Independence	Item Number	
		Positive	Negative
Responsible Attitude	Doing study assignments with routine without being informed	13	14
	Can explain the reasons for the learning undertaken	15	16
	Don't blame others in learning	17	18
	Able to determine learning activity choices from several alternatives	19	20
Amount		**20**	

Table 5. The Computational Thinking Instrument Grid

Aspect	Indicator	Objective Learning	No. Question
Decomposition	Students are able to break down problems into parts that simpler	Students can analyze the relationships between living things in an ecosystem in the form of food webs.	1,2,3
Pattern recognition	Students are able to identify patterns, similarities and relationships between previous and current issues		4,5,6
Abstraction	Students are able to evaluate information that is considered important		7.8
Algorithm	Students are able to make steps to solve problem		9,10
Amount			**10**

An instrument is said to be qualified if it is evaluated using the right procedure, in other words, the instrument must meet the validity criteria. Content validity analysis is carried out using the content validity ratio approach known as the Content Validity Ratio (CVR). The CVR approach is used to measure the level of validity of learning media, in this study, the validity of the instrument content was assessed by four experts (judges) (Lawshe, 1975).

3. RESULT AND DISCUSSION

Result

This development research produces a coding-based augmented reality food pyramid media with a focus on food web material. The development process of this media is carried out in five stages, namely analysis, design, development, implementation, and evaluation. Analysis is the first stage carried out, at this stage a study was conducted on grade 5 Elementary Schools connected in cluster 7, namely SD Negeri 3 Suwug. The analysis includes student needs, student character, curriculum, and the potential use of augmented reality media to be developed. Based on the results of the analysis, it was found that the learning independence of grade 5 students is still relatively low, only 23.17% students who have their own initiative in learning and are active in the learning process. In addition, from the computational thinking aspect, the average student is classified as low, with 54.88% of students not reaching the minimum score.

The second stage is design, where at this stage the researcher begins to design coding-based augmented reality media. This media is designed in digital form with various interesting content in it. In this media, there is augmented reality content that allows students to see visual representations of animals in three dimensions, making it easier for them to imagine the original form of animals involved in food webs. In addition, there is an interactive video consisting of two main parts: problem videos and discussion videos. In the problem video, students are invited to solve problems related to food webs and are asked to create food webs based on the given situation. After completing the task, a discussion video will be shown to provide further understanding, as well as to evaluate whether the food webs that students have created are in accordance with the correct concept. The creation of this media utilizes several applications, such as Canva to create visual content, CapCut for video editing, and Assembler Edu as a platform for developing augmented reality features. Some parts of the design results of this coding-based augmented reality media can be seen in Figure 1.

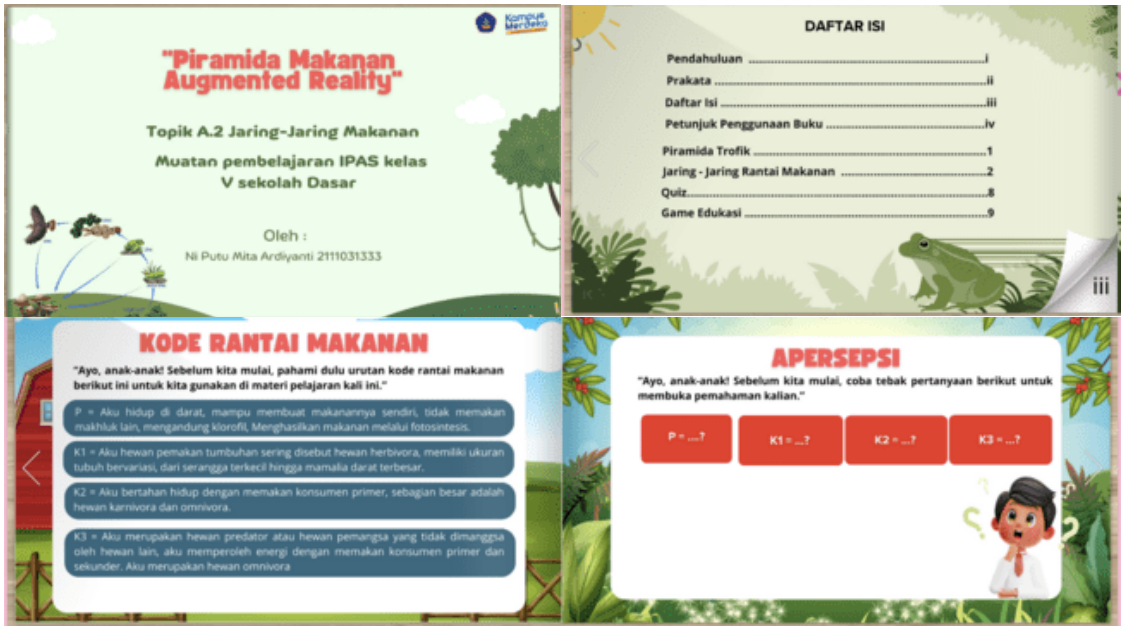

Figure 1. The Augmented Reality Food Pyramid Media Design Based on Coding

The third stage is development, where at this stage in addition to designing the media thoroughly until it is ready to use, the next step is to conduct a product validation test by involving media experts and material experts. The validation process is carried out by filling out the product validation and practicality assessment sheet. The results of the media validation test can be seen in Table 6 and Table 7.

Table 6. The Media Expert Validation Results

Item	Expert				S1	S2	S3	S4	∑s	V	Note
	I	II	III	IV							
Items 1-12	46	44	46	45	34	32	34	33	133	0.9236111	Tall

Table 7. The Results of Material Expert Validation

Item	Expert				S1	S2	S3	S4	∑s	V	Note
	I	II	III	IV							
Items 1-10	38	38	40	35	28	28	30	25	111	0.925	Tall

Based on the tests that have been carried out, the results of the instrument are in the very high content validity category. Then for the content validity of the effectiveness instrument, it gets a score of 1 with a very appropriate qualification using the CVR/CVI formula. After being said to be feasible, it is continued with validation of the media's feasibility to experts who are experts in their fields. The results of the media content validation test with experts, the results of the media expert validation reached a score of 0.92 with very high validity criteria, and the material expert validation obtained a score of 0.93 with very high validity criteria. In addition, the practicality test conducted with grade V students at SD Negeri 3 Suwug showed a score of 90%, which is included in the very good category. The fourth stage is implementation, at this stage the developed media is tested on grade V students of SD Negeri 3 Suwug. In addition to the application of the media, the effectiveness of the media is also tested through an initial test (pre-test) and a final test (post-test).

Based on the results of the t-test analysis, it was found that the sig. (2-tailed) results listed in the Tow-Sided table showed a number <0.001. This indicates that the F_{count} value> F_{table}. Thus, it can be concluded that H_0 is rejected and H_1 is accepted. This means that there is a significant difference in the Learning Independence of fifth-grade elementary school students before and after participating in science learning using augmented reality food pyramid media based on coding containing food web material. In addition, the results of the analysis in the Two-Sided table also show a sig. (2-tailed) value of <0.001, which again shows that F_{count}> F_{table}. So, H_0 is rejected and H_1 is accepted. This shows a significant difference in the Computational Thinking abilities of fifth-grade elementary school students before and after using augmented reality food pyramid media based on coding on the science content. Thus, from the results of

the analysis, it can be concluded that the use of augmented reality food pyramid media based on coding is effective in increasing learning independence and Computational Thinking of fifth-grade elementary school students.

Discussion

This study aims to produce a Coding-Based Augmented Reality Food Pyramid Media. Augmented Reality media certainly has its own characteristics compared to other previously existing Augmented Reality media. This Coding-Based Augmented Reality Food Pyramid Media is designed by integrating modern technology with the concept of unplugged coding. This media is considered suitable for fifth grade students because it contains materials that are relevant to classroom learning. The use of interactive learning media based on Augmented Reality is effective in improving student understanding. AR is a modern technology that connects two-dimensional or three-dimensional virtual objects to the real environment directly, three dimensions then provide a picture of the virtual object that is available directly, but AR only adds objects or animations and complements reality. The application of AR is able to realize the virtual world into the real world, displaying 2-dimensional image objects as 3-dimensional objects (Kholifah & Buchori, 2023; Norris et al., 2023). This causes the learning activities to not be monotonous and the students become motivated to find out more.

Augmented Reality Food Pyramid Media Based on Coding is effective in improving learning independence and Computational Thinking of fifth grade students in Elementary School. This can be seen from the appearance of media based on Augmented Reality based on Coding. Good Augmented Reality has a display system. The display system aims to display virtual objects that are created, in this context geometric objects. By using this technology, a device is needed to add virtual objects and display the results to the user, besides that a camera is also needed to get images of the surrounding environment. The better the camera, the better the Augmented Reality display produced has clearer visual quality (Faiza et al., 2022; Iskandar & Mayarni, 2022). This shows Augmented Reality can be applied to learning because AR is a learning medium that combines the virtual and real worlds, allowing students to imagine (Anuar et al., 2021; Sahin & Yilmaz, 2020). Thus, AR becomes an interactive learning media and can increase students' interest in learning. The use of Augmented Reality technology in learning can improve students' skills, cognitive, and affective students and can minimize abstract and complex understanding in students.

This finding is reinforced by previous research findings stating that the Augmented Reality-based media that was developed was effective in improving students' understanding (Iskandar & Mayarni, 2022; Novia Cendy, Hendriana Benny, 2023; Sahin & Yilmaz, 2020; Wibowo et al., 2022). In addition, augmented reality is considered to make learning effective, interesting and able to improve students' understanding of material concepts (Chen, 2020; Lampropoulos et al., 2022). Students' interest in this media shows that augmented reality is able to improve students' Learning Independence and Computational Thinking during the learning process in class. The implications of the Coding-Based Augmented Reality Food Pyramid media in science learning are able to significantly improve the learning independence and Computational Thinking of fifth grade students.

4. CONCLUSION

The results of this study indicate that coding-based augmented reality media is effectively used in classroom learning, especially to improve learning independence and Computational Thinking of fifth grade students. This media integrates digital technology, in the form of a website equipped with augmented reality, interactive videos that can be accessed directly on the website. It is recommended for teachers and further research to provide more variation in learning, for example using various innovative learning media so that learning is not monotonous and teacher-centered. So that it can increase students' enthusiasm for learning.

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