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The Development of Interactive Multimedia Based on TPACK to Enhance Students' Science Process Skills on Living Cell Matter

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Abstract: This work aims to create interactive multimedia based on TPACK to enhance students' science process skills (SPS) on living cell matter. It offers an alternate method of learning that relies on creating and applying information technology to achieve learning goals (SPS). The ADDIE paradigm was utilized in the research and development process to create Interactive multimedia. These steps are Analysis, Design, Development, Implementation, and Evaluation. The Interactive Multimedia development product was determined to be possible to be incorporated into a learning product based on the research findings and several validation and implementation tests carried out during the development process. The Interactive Multimedia is practicable, as evidenced by the percentage of data collected from the validator and the outcomes of the implementation test to the pupils. The students' SPS N-Gain analysis results obtained a score of 0.78 in the high category. In other words, a product that has undergone testing and validation may be one that can be used to aid in learning about living cells and can enhance students' science process skills.

Keywords: Interactive Multimedia; Science Process Skills; TPACK

Introduction

The 21st century emphasizes creating quality human resources (van Laar et al., 2020). In the world of education, the revolution in the pattern of education this century is characteristic of the era of openness (Hug, 2017), with indications of the development of science and technology and collaboration between the two (Cornelius & Wilson, 2021). The learning of 21st-century students is different from the previous century. Today's generation relies heavily on technology (Lemley et al., 2014) Because their lives are surrounded by technology, and they learn a lot with the technology around them. Therefore, nowadays, teachers cannot rely on old methods in teaching and only become subject matter experts, but teachers also need to formulate knowledge of teaching pedagogy content and be skilled in integrating technology in learning, known as Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006). TPACK is an approach that is a wedge among content knowledge, pedagogy knowledge and technology knowledge.

21st-century education demands that students have 21st-century skills (Ravenscroft et al., 2012). So, to ensure students have these skills, learning must practice 21st-century skills. According to the World Economy, students must have 16 skills in 3 categories in the 21st century, namely basic literacy, competence and character qualities (WEF, 2015). Science process skills are part of the basic literacy skills of the 21st century. Science process skills are important to be trained so that students can find learning concepts based on scientific steps they do themselves so that they become more remembered and satisfied with their learning (Winandika, 2020). Students need strong learning concepts to build self-quality to compete in the 21st century (Budiyono & Hartini, 2016).

According to early research, a lack of learning resources that allow students to see cells in their natural environment makes studying cells difficult. According to the findings of interviews with science teachers, studying science by experimentation is uncommon

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today due to a lack of laboratory resources. The students' science process skills were found to be impacted by this condition. According to test results, students' understanding of the scientific method is lacking.

Science process skills can be trained with inquiry-based learning (Durmaz & Mutlu, 2017; Ekici & Erdem, 2020; Panjaitan & Siagian, 2020; Patonah et al., 2020). The inquiry learning model is important to be implemented in science learning. Inquiry learning involves students' active role in discovering the concept of knowledge through a series of scientific investigations so that students have experience in discovering their knowledge (Mieg et al., 2017). However, teachers do not widely use inquiry learning for several reasons, such as limited tools, materials, time and research space, thus hampering the training of students' science process skills. While on the other hand, technology integration can solve these problems by developing technology-based learning media designed to facilitate inquiry learning that can train science process skills, such as interactive multimedia.

Interactive multimedia is a program that combines two or more information components such as text, images, sound, and video (Putra et al., 2020; Sari & Ridwan, 2020; Siregar et al., 2020). Several studies have shown that the use of interactive multimedia has benefits in science learning, including improving character (Indah Septiani et al., 2020), creativity (Heliawati et al., 2020), critical thinking skills (Seftian et al., 2017) dan *problem solving* (Giyanto et al., 2020), science literacy (Gunawan et al., 2022; Widodo et al., 2020), digital literacy (Natsir et al., 2022) and help explain abstract concepts and form discovery-based learning environments (Nurtanto et al., 2020). Based on these problems and needs, this study aims to develop TPACK-based interactive multimedia on cell matter as a learning media to improve students' science process skills.

Method

The research method used in this study is the Research and Development (R&D) method with the ADDIE model developed by Branch (Branch, 2009). The ADDIE model comprises five stages: analysis, design, development, implementation and evaluation (Branch, 2009; Gagne et al., 2005; Reyes & Oreste, 2017).

The flow of the interactive multimedia development using the ADDIE model are as follows: (1) Analyze; the analysis stage aims to analyze the problems that occur to be solved with the most appropriate solution and collect various related information on the product to be developed. (2) Design; this stage aims to design the form, appearance and navigation of interactive multimedia and also includes making flowcharts and multimedia storyboards. (3) Development; this stage aims to develop interactive multimedia based on a pre-made design. Multimedia that has been developed is further validated by experts (material and media experts followed by revision) and practitioners. (4) Implementation; the implementation phase comprises limited and field trials. In the limited trial phase, an interactive multimedia implementation trial was carried out on 10 students. Limited trials collect suggestions and input from students' perspectives when implementing interactive multimedia (followed by revision). The next stage is a field trial with the implementation of interactive multimedia in the learning cell for 27 grade VII students. (5) Evaluation; the evaluation stage is the final stage by revising and evaluating the developed product based on feedback from each stage of research conducted. This stage aims to improve the quality and measure the achievement of the development goals. Reporting is also carried out as the final research stage in this stage.

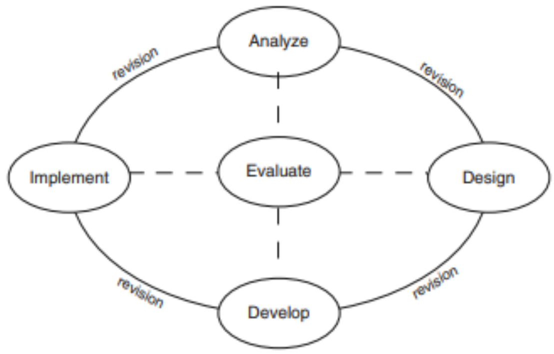

Figure 1. Adaptation of the ADDIE instructional model by Branch

Data collection tools

The science process skill test, the media validation judgment sheet, the content validation judgment sheet, and the student response sheet following interactive multimedia make up the data collection tool. Media validation assessment tools include a display, video, animation, and practical design. Language, curriculum, and material content are used to validate content judgment. This tool is intended to evaluate the acceptability of the material for interactive media and collect validator rating data and views on developed interactive media. Both qualitative and quantitative data were gathered through the media validation questionnaire. As a result, this tool can serve as a reference and a roadmap for updating interactive media. The suitability of the material's substance, correctness, and completeness comprise material validation. Media validation judgment instruments include display, video, animation and useful design. Instrument judgement validation material includes curriculum, material and language. This instrument is used to obtain validator rating data and opinions on developed interactive media and assess the suitability of the material with interactive media. The data obtained from the media validation questionnaire are qualitative and quantitative. So this instrument can act as a guide and reference in revising interactive media. Material validation consists of the suitability of the material's content, accuracy and completeness.

Testing is carried out to measure the scientific process's skills. Twenty-seven science process skills questions developed from 9 science process skills indicators were used to measure students' science process skills. Indicators of such science process skills are questioning, hypothesizing, observing, classifying, planning experiments, using tools, communicating, interpreting data and applying concepts. The science process skills used have been validated rationally and empirically by experts and students and tested using the Bivariate Pearson correlation method.

Data analysis technique

Descriptive and inferential analysis was used to analyze the data. Material and media experts analyzed data from product validation results using descriptive analysis, and inferential analysis was utilized to test the hypotheses. A significance value of 0.05 was used in the SPSS version 26 tool to test the hypothesis. The assessment criteria, which ranged from 1) is very good to 2) is good, 3) is enough, 4) is lacking, to 5) is extremely deficient, were used to interpret the results of the product evaluation. A hypothesis test was carried out with a Paired T-test analysis to determine the product's effectiveness.

Result and Discussion

Developing interactive multimedia followed the Analyze, Design, Development, Implementation and Evaluation stages, which are explained as follows.

Analyze Stage

Research mapping was analyzed using Publish or Perish software and VOS Viewer. The mapping was done on 100 articles discussing interactive multimedia on the Google Scholar page published in the last 5 years (Figure 2). The analysis was carried out to find research gaps in the field of research to be developed.

The results of mapping with Vos viewer show that the realm of interactive multimedia research in the last five years has discussed a lot about the role of interactive multimedia as a learning medium in the field of science which is shown by the very high density of the word science and medium compared to other words. The research map shows that two groups of research subjects are often studied in interactive multimedia studies, namely elementary and junior high school students. The mapping also shows the realm of development, android-based applications, implementation and skill domains appearing on the map, but in low density. These results show that the research domain has not been studied much, so it can examine as gap research with other studies.

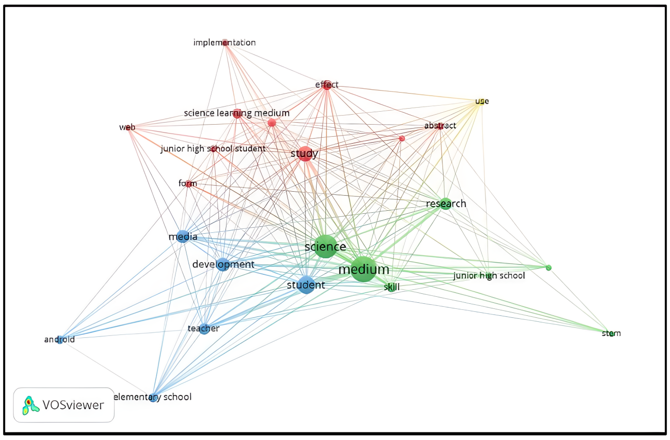

Figure 2. Research mapping

The results of the overall learning style analysis are shown in figure 3. The results show that the kinesthetic type of learner dominates the student's learning style compared to other learning styles (Visual, Auditory, and Read/Write). Student learning styles show the tendency of students to receive information to be received optimally.

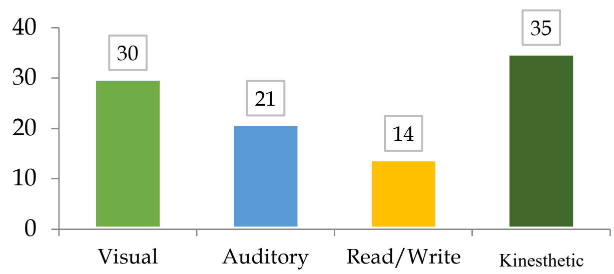

Figure 3. Student learning style result percentage (%)

Interactive multimedia needs were analyzed by distributing questionnaires to 120 grade VIII students. Based on the needs analysis results, 95.4% of students like learning media combined with images, video, audio, animation and graphics compared to text-only books. Meanwhile, 72.7% of student respondents stated that they understand more information in the form of videos, images and modelling than just text, and 97.70% of students strongly agree and are ready to use Interactive Multimedia as a science learning medium on cell-level life organization system material. The results of the study are in line with research that students like varied learning media such as audio-visual media (Nuhatati, 2020), games (Murtiningsih, 2022), infographics (Apriyanti, 2020), and video (Hidayati, 2018).

Design Stage

The stage for designing interactive multimedia included two stages; the first step was to create flowcharts, and the second was to create storyboards. Making flowcharts is carried out to illustrate the flow of the learning process using interactive multimedia, making it easier to prepare storyboards, plan learning to be carried out and develop interactive multimedia in general.

Development Stage

The third stage is the development stage. At this stage, the interactive multimedia design that has been created is then realized. The results of interactive multimedia development can be seen in figure 4, 5 & 6.

Figure 4. Front Cover of Interactive Multimedia

Figure 5. Virtual Laboratory Menu

Figure 6. Interactive Games on Multimedia Menu

The product validity test is carried out with a judgement sheet given to material and media experts to assess the product's suitability. The results of the assessment by experts are shown in Tables 1, 2, and 3.

Table 1. Content Expert Validation Result

Content Expert	Total Score	Overall Score	Percentage (%)	Category
Expert 1	69	137	98	Valid
Expert 2	68			

The validation results showed a percentage score of 98%, with expert conclusions stating that the material presented in multimedia was valid without revision.

Table 2. Media Expert Validation Result

Media Expert	Total Score	Overall Score	Percentage (%)	Category
Expert 1	80	159	99.4%	Valid
Expert 2	79			

The validation results showed a percentage score of 99.4%, with expert conclusions stating that the material presented in multimedia was valid with revision.

Table 3. Practitioners Validation Result

Total Respondents	Overall CVR Score	Overall CVI Score	Category
20	0.990	0.995	Valid

The results of processing validation data by practitioners using CVI and CVR show that the CVR value is 0.990 and CVI is 0.995, which is in the Valid category (Ayre & Scally, 2014).

Implementation Stage

At the implementation stage of learning with interactive multimedia, 3 meetings were held. At the end of learning, evaluation is carried out with a science process skills test. The paired t-test hypothesis test was performed using SPSS 26 software.

Hypothesis test decision making is if the value of sig. < 0.05, then h_0 is rejected, and h_1 is accepted; otherwise if the value of sig. >0.05 then h_1 is rejected and h_0 is accepted. The paired t-test results can be seen in Table 4.

Table 4. Paired Samples Test

		t	df	Sig. (2-tailed)
Pair 1	Pretest-Posttest	-24.074	26	0.000

The test results show a sig value = 0.000 or a sig.< value of 0.05. This value means that H0 is rejected and H1 is accepted; in other words, there is a difference in the average science process skills scores of students before using interactive multimedia based on TPACK and after using it.

Analysis of the average improvement of students' science process skill scores before using interactive multimedia based on TPACK and after further use was performed with N-Gain Test on each science process skill indicator. Here are the results of the analysis of the average N-Gain (Table 5) and N-Gain values on each indicator of students' science process skills (Table 6):

Table 4. Overall N-Gain SPS Score

Total Respondents	Overall N-Gain	Category
27 Students	0.78	High

Table 5. N-Gain score of SPS indicators

Total Respondents	SPS Indicators	Overall N-Gain	Category
27 Students	Hypothesizing	0.83	High
	Communicating	0.73	High
	Applying Concepts	0.80	High
	Questioning	0.76	High
	Observing	0.79	High
	Using Laboratory Tolls	0.63	Medium
	Classifying	0.74	High
	Interpreting	0.82	High
	Planning Experiments	0.76	High

The results of the overall N-Gain analysis showed an average N-Gain score of students' science process skill score is 0.78, which was included in the High category. While the N-Gain value in 9 indicators of science process skills trained shows 8 indicators: hypothesizing, communicating, applying concepts, asking questions, observing, classifying, interpreting and planning experiments have N-Gain in the High category, while 1 indicator, namely using lab tools, is in the N-Gain in the medium category.

The final analysis of this interactive multimedia implementation results is the analysis of student responses after using interactive multimedia based on TPACK in classroom learning. The results of student responses can be seen in table 6:

Table 6. Students' respons result

Item	Total Score	Percentage (%)	Criteria
Content	640	95	Very Good
Media Display	1297	96	Very Good
Objectives	1278	95	Very Good
Average score		95.3	Very Good

From table 6, it can be seen that students give a positive response to 3 aspects that are valued by interactive multimedia, namely the material aspect, the display aspect and the learning aspect. The material aspect obtained a score percentage of 95% in the excellent category. Aspects of the material include clarity, completeness and suitability of the material contained in interactive multimedia. The display aspect scored 96%, which is very good. The display aspect includes all displays that contain multimedia, namely colour display, fonts, background selection, music, video and animation displayed in interactive multimedia. The third aspect is the aspect of learning objectives which obtained a percentage score of 95% which is in the very good category. Aspects of learning objectives include students' self-assessment of mastery of 9 indicators of students' science process skills trained after using interactive multimedia. The average overall result of the assessment or student response to the use of interactive multimedia cell-level life organization system based on TPACK was at a percentage score of 95% in the excellent category.

As basic literacy skills of the 21st century, science process skills are important skills that students need to have. Mastery of science process skills influences 21st-century skills (Turiman et al., 2012) like creativity (Yildiz & Guler Yildiz, 2021) and critical thinking skills (Darmaji et al., 2020).

Intervention in learning is important in training students' science process skills (Ambross et al., 2014; Shahali et al., 2017), such as selecting learning models and learning media. Several studies state that the inquiry-based learning model can have a positive effect on science process skills (Ekici & Erdem, 2020; Setiawaty et al., 2018; Solé-Llussà et al., 2022), including the guided inquiry model (Koksal & Berberoglu, 2014). Other research also states that the use of mixed and technology-based learning media can help improve science processing skills in science learning, such as e-modules in learning the concepts of temperature and heat Serevina et al. (2018), simulation videos in studying the anatomy of living things (Solé-Llussà et al., 2020) and virtual laboratories in simulation-based scientific observation (Aysegul Kınık Topalsan, 2020).

Students mastery of science process skills also has a good impact on other aspects such as learning outcomes (Damopolii et al., 2019), scientific attitude and creativity (Aktamis & Ergin, 2015) and students' argumentation abilities (Darmaji et al., 2022). According to research Yildiz & Guler Yildiz (2021), there is a correlation between gender and the quality of the family environment on creativity, which is influenced by students' science process skills.

Implementing an interactive multimedia life organization system based on TPACK improves students' science process skills. Integrating inquiry-based learning models in technology-based learning media is a step towards creating the ideal learning of the 21st century.

Conclusion

This study concluded that: 1) The development steps produce interactive multimedia, 2) Validation by material and media experts showed that the interactive multimedia is very good and feasible to use in the learning process of Information Technology Education, and 3) The application showed that the interactive multimedia on TPACK is effective to enhance science process skills.

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Author Contributions
Conceptualization, S.S., and B.R.; methodology, S.S., and B.R; software, S.S.; validation, B.R., and S.K.; formal analysis, S.S.; investigation, S.S.; resources, S.S.; data curation, S.S., S.K., and B.R; writing—original draft preparation, S.S.; writing—review and editing, S.K., and B.R.; visualization, S.S.; supervision, B.R.; project administration, S.S.; funding acquisition, S.S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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