

The Use of Differentiated Digital Learning Models to Enhance Science Problem-Solving in Elementary Schools

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ABSTRACT

Differentiated learning is a way to identify talents and teach according to students' different learning styles. Digital-based differentiated learning is an innovation in elementary school teaching and learning processes. This research aims to determine the use of digital-based differentiated learning models in improving science problem-solving in elementary schools because students tend to experience difficulties understanding the material taught in science subjects, and students are still lacking in developing the ability to solve science questions. This research method used quantitative research methods with the Pre-Experimental Design One Group Pretest-Posttest research model. The research sample consisted of 29 grade IV students who had a learning style of 76% visual, 14% auditory, and 10% kinesthetic. Data collection techniques used tests and questionnaires. Data analysis techniques used the Z test and the Mann-Whitney U test. The research results for the Mann-Whitney test obtained a significance value of 0.001, meaning $0.001 < 0.05$, so H_0 was rejected, and H_a was accepted. Thus, the use of digital-based differentiated learning models can improve science problem-solving in elementary schools. The research findings indicate that digital-based differentiated learning models significantly enhance science problem-solving abilities.

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1. INTRODUCTION

Ki Hajar Dewantara, a prominent figure in Indonesian educational philosophy, posited that education should serve as a guide for all the inherent strengths that students possess, enabling them to attain genuine safety and pleasure as both individuals and members of society (Hardiansyah, 2022). Ki Hajar Dewantara also stated that education must acknowledge the unique qualities of each student. In the process of guiding and educating students, students should be allowed to exercise their autonomy; however, an educator must provide guidance and direction to ensure that students maintain a sense of direction, which can jeopardize their own well-being and the unique abilities, talents, and expertise of each student (Hardiansyah & Zainuddin, 2022). Differentiated learning is a method that adapts the

learning process to accommodate the unique learning requirements of each pupil. The adjustments in question are associated with the readiness of students to attain the highest possible learning outcomes, as well as their interests and learning profiles (Hasanah et al., 2022).

Content differentiation, process differentiation, and product differentiation are the three types of differentiated learning strategies (Simanjuntak et al., 2023; Yuen et al., 2018). By taking into account the student's learning characteristics, areas of interest, and level of preparedness, content differentiation is implemented. Process differentiation is achieved by assigning students to groups according to their interests, abilities, and aptitudes, as well as by establishing diverse tasks and implementing tiered activities. Product differentiation is achieved by providing students with the autonomy to determine the manner in which they exhibit their learning outcomes. Knowledge that is intended to be acquired (Chandra Handa, 2020). To effectively implement differentiated learning, educators must administer diagnostic assessments to determine the learning readiness of students based on their level of comprehension. This allows educators to customize their approach to each pupil in the classroom (Gaitas & Alves Martins, 2017). Student interests are taken into account in differentiated learning, which entails the identification and execution of pertinent learning experiences (Jackson & Evans, 2017). Furthermore, it encourages the development of innovative concepts that begin with the individual students. Conducting surveys or posing thought-provoking queries to students is one method of determining the degree of diversity in the class. The final element that necessitates examination is the learning profile, which includes visual, aural, and kinesthetic learning, as well as learning style, intellect, and contextual preferences. Educators should either employ a combination of various learning styles or select a variety of styles based on the specific task at hand (Pozas et al., 2020; Rashidov, 2020).

A driving school has been employing an independent curriculum since last year, according to researchers at an elementary school in the Sumenep district. The school has already created textbooks that are consistent with the learning objectives of the independent curriculum. At present, the independent curriculum is being implemented exclusively in class I and class IV. The learning planning aspect of class IV entails a sequence of lecture objectives and teaching modules, which are substantiated by class papers. Learning is conducted in groups and employs tangible learning materials during the execution phase. The student activity aspect serves as an illustration of the students' restricted attention span, as demonstrated by their lack of concentration during project execution. The classroom environment is adversely affected by this lack of focus, rendering it less conducive to learning. Additionally, the presentation of project results indicates that certain group members are not entirely invested in presenting the project's results. The examination of the learning styles of fourth-grade students demonstrates that ten students, four of whom are male and six of whom are female, manifest a visual learning style. Furthermore, 5 male students are among the 10 students who exhibit an auditory learning style. The category comprises 5 females and 9 males who possess a kinesthetic learning style. Classroom IV students demonstrate a wide variety of learning approaches. The diversity of learning styles is influenced by both internal and environmental factors. Typically, each student possesses three distinct learning styles, with one style being more predominant than the others. Six male students and three female students are the remaining students who have not yet met the requirements for achieving their learning objectives. The learning experience is devoid of significance, and the students' learning quality is suboptimal, as indicated by the learning outcomes.

According to interviews conducted by researchers with the fourth teacher's class regarding the teaching and learning of certain activities in the learning material science on the form of substances and their changes, the fourth class implements learning media that is tailored to the learning material, typically utilizing concrete media in the form of images. Concrete media include stones, water, papers, plastic bags, dyes, cords, and sticks, among others, in the context of science education. Concrete media is a straightforward medium to acquire and offers students a practical experience. Nevertheless, researchers have identified weaknesses in its use during fourth-grade instruction. Teachers must possess effective student management skills to ensure that students can comprehend the instructions provided, as the use of concrete media necessitates explicit and detailed instructions. The utilization of

technology-based media needs to be enhanced, with video content typically sourced from YouTube. The infrastructure and facilities of the school are highly supportive of instructors in the implementation of any learning model, including digital-based learning. LCD projectors, computers, speakers, and an internet network are all available in the classroom, providing educators with all the necessary resources to implement engaging learning experiences and enhance student learning outcomes. Nevertheless, in spite of the fact that instructors have the ability to design more engaging learning processes, such as digital-based differentiated learning, they only utilize the available facilities to search for material on the internet, such as YouTube and Google.

Differentiated learning can be implemented by capitalizing on the ongoing advancements in technology (Variacion et al., 2021). Technological advancements induce renewal in the application of technological outcomes in the field of education, particularly in the context of classroom instruction and learning. A teacher must possess the ability to employ technology as a digital-based learning medium to enhance the learning experience for students (Bikić et al., 2016; Sitorus et al., 2022). Innovative technology-based learning media have the potential to enhance students' academic performance and pique their interest in learning (Reis & Renzulli, 2018). Consequently, it is imperative that educators optimize the utilization of the digital resources at their disposal. The quality of learning can be enhanced by utilizing school digital facilities as learning resources, learning media, and access to information (Marshall, 2016; Mulyawati et al., 2022).

In a study titled "Effects of Learning Style-Based Differentiated Activities on Gifted Individuals," Demir (2021) conducted previous research. Utilizing experimental and quantitative research methodologies in order to evaluate the influence of instructional design on the creativity of quasi-experimental pupils, a control group was included in the pre-test and post-test experiment. The findings suggested that differentiated and enriched learning methods were effective in fostering creativity. Talented children's creative thinking abilities are positively influenced by Kolb's learning style and Bloom's taxonomy. Variables utilized in this investigation include the independent variable, which pertains to diverse learning methodologies, and the dependent variable, which pertains to student learning outcomes. At a significance level of $\alpha = 0.05$, the t-test hypothesis test produced a t-count value of 2.381, which exceeds the critical t-table value of 2.014. This implies that the null hypothesis (H_0) is denied and the alternative hypothesis (H_a) is accepted, as defined by the test requirements. In this study, the learning outcomes of two subjects are analyzed: physics, specifically the sub-material of work and energy, and fiqh, specifically the sub-material of the primary PAI subject. The participants in this study were high school students in class X, while the participants in the other study were junior high school students in class VIII. Sugiyono recommends that the optimal number of participants in research should not exceed 30, as this can reduce the likelihood of errors that could potentially undermine the overall validity of the results. Furthermore, educators are able to manage their classrooms more effectively with a reduced research team. The saturation sampling method was implemented in this investigation, which entailed the utilization of all 49 students in the population as samples. Nevertheless, a sample of 27 students was employed for this specific investigation. Additionally, Brüngel et al. (2020) conducted a study titled "Project-Based Learning in a Machine Learning Course with Differentiated Industrial Projects for Various Computer Science Master Programs Using Experimental Methods" that illustrates the positive influence of differentiated project-based learning on student perceptions, thereby promoting their identification with previously unpopular coursework. The differentiation technique aims to improve the academic performance of all pupils, regardless of whether they are below the anticipated educational standard or excel in their studies. This illustrates that students in a variety of classrooms that necessitate differentiated instruction or techniques must utilize multiple intelligences to enhance their engagement in the learning process.

Through differentiated learning, children are afforded the chance to develop their independence, creativity, and initiative in accordance with their unique talents, interests, and physical and psychological development. Diversified learning enables the individualized requirements of all pupils

in the field of science to be accommodated according to their learning preferences or interests. Differentiated learning allows educators to identify and develop educational experiences that are consistent with the principles of science, specifically by emphasizing the differentiation of materials, processes, and products. The curriculum and learning materials are adapted by teachers through content diversification to accommodate the unique learning styles and profiles of students. The process of differentiation assists students in understanding and participating in scientific concepts and information by emphasizing readiness and learning styles. Students are able to effectively demonstrate their acquired knowledge as a result of the teacher's product differentiation. Students are afforded the opportunity to exhibit their understanding in a manner that aligns with their individual preferences, including the production of posters, artworks, music, poetry, or films. A comfortable learning environment that has a positive impact on students during the science learning process can be established in order to attain an ideal learning outcome. The analysis indicates that the incorporation of innovative and inventive learning methods is essential for the purpose of increasing the enjoyment and excitement of the learning process. One effective strategy is to implement a differentiated learning model that encourages a sense of acceptance and unity among students. This is anticipated to result in a positive learning outcome by increasing students' motivation to actively participate in their education. Consequently, researchers are captivated by the examination of the application of digital-based differentiated learning models in scientific lectures at the primary school level.

2. METHODS

The research employed a quantitative experimental approach utilizing the Pre-Experimental Design One Group Pretest-Posttest research methodology. The goal of a Pre-Experimental Design One group test-posttest is to gather data that provides an approximation of the data gained from a real experiment, in situations when it is not feasible to control or alter all the important variables. This research methodology was selected due to the focus on studying students, making it impractical to establish identical conditions for both the experimental and control groups. Consequently, there exist variables with differing conditions, such as intelligence level, learning style, interest in learning, readiness to learn, socio-economic status, and others. When carrying out the One-Group Pretest-Posttest Design experiment, the researcher administered an initial test (pre-test) to assess the students' learning outcomes. Subsequently, the researcher implemented a digital-based differentiated learning model with the students. Following this, the researcher administered a post-test to assess the students' learning results following the intervention.

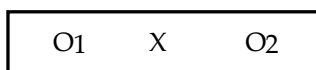


Figure 1. Pre-Experimental One-Group Pre-test Post-test Design

The sample size for this study was 29 students, with 14 being male and 15 being female. In this study, a saturated sample was employed, which means that if there are fewer than 100 subjects, the entire population is included as the research sample. However, if there are more than 100 participants, a sample of 10-15% or 15-25% can be taken. The study included a sample of 29 students, which was chosen since the population size was less than 30. By utilizing a saturated sample, the researchers aimed to establish accurate generalizations with minimal errors. This research methodology utilizes tests as a means of obtaining data, by posing a series of questions or issues that conscientious participants must answer in order to determine or quantify something (Arikunto, 2014). The test instrument was developed by initially examining competency standards and fundamental scientific knowledge related to gaseous materials and their transformations. Subsequently, the instrument was administered to class IV students in the form of multiple-choice questions, with the objective of assessing variations in students' proficiency in solving science-related problems.

Table 1. Test grid

Basic Competencies	Indicator	Question Number
Change In Gas State	C1	1,2
	C2	3
	C3	4,5,6,7,8,9,11,13,15,16
	C4	10,12,14
	C5	17,20,21,22,25
	C6	18,19,23,24
Amount		25

Before the instrument is given to the research sample, the test instrument is tested first to determine validity and reliability. If the instrument meets the specified requirements, it can be suitable for use. The test measurements are by the cognitive domain indicators C1-C6 based on the revised Bloom's taxonomy, where each question scores 1 if the answer is correct. Three categories of scores are arranged to determine the criteria for student completion: low, medium, and high.

Table 2. Completion Criteria Value Interval

No.	Value Interval	Information
1	80-100	high
2	65-79	medium
3	<65	low

The second data collection technique uses a questionnaire by making a set of questions or written statements to respondents to determine students' activeness and learning styles. The questionnaire in this research is closed as a statement, measured using a Likert scale. The questionnaire is prepared as a checklist by providing five alternative answers consisting of 15 statement items; each instrument item has a gradation from very positive to very negative: always, often, sometimes, rarely, and never.

Table 3. Student Learning Style Questionnaire Grid

Indicator	Statement Number	Total Statement
Visual Activities	1	2
	2	
	3	
Oral Activities	4	4
	5	
	6	
Listening Activities	7	2
	8	
Writing Activities	9	3
	10	
	11	
Activity Metrics	12	2
	13	
Emotional Activities	14	2
	15	
Amount		25

Questionnaire grids and statements are scored according to the respondent's answers to the questionnaire scoring criteria.

Table 4. Questionnaire Scoring Criteria

Alternative Answers	Positive	negative
always	5	1
Often	4	2
sometimes	3	3
Rarely	2	4
Never	1	5

The data analysis technique in this research consists of a validity test, which is a measure to measure whether the instrument used measures what it wants to measure. The higher the validity of an instrument, the better the instrument to use. The validity test carried out in this research was an empirical validity test using the Pearson product-moment correlation technique assisted by IBM SPSS 26 by correlating the scores obtained by students on a question item with the scores obtained. The validity test in this research used item analysis, correlating each item's score with the total score, which is the sum of each item's score. An item must meet the requirements to be studied further.

The Shapiro-Wilk normality test is employed in this study to ascertain the distribution of random data obtained from a limited sample. The Shapiro-Wilk method is a reliable and valid approach for testing the normality of small samples. The Shapiro-Wilk normality test is employed for samples with a size smaller than 50 ($N < 50$). Data is considered to follow a normal distribution in testing if the significance level is greater than 0.05. In addition, this research employs the Levene test as a homogeneity test. The homogeneity tests were conducted using the SPSS version 26 application by the researchers. The Levene test decision is determined based on the significance value. If the significance value is more than 0.05, it indicates that the variation in the data is homogeneous. Conversely, when the significance value is less than 0.05, it indicates that the data variation is not homogeneous. The Z test is employed in research for hypothesis testing when the data has a normal distribution. The Z test is used to make decisions based on a significance level of 5%. If the value of α is less than 0.05, the alternative hypothesis (H_a) is accepted. If the value of α is more than or equal to 0.05, the alternative hypothesis (H_a) is rejected. If the data acquired does not follow a normal distribution, statistical tests are conducted utilizing the Mann-Whitney test. Due to the sample size being greater than 20 ($n < 20$), the large sample Mann-Whitney U rank test was employed in this investigation. The calculation technique for the Mann-Whitney U rank test is largely consistent between big and small sample sizes, with the sole exception being the usage of the Z test for statistical analysis in large samples.

3. FINDINGS AND DISCUSSION

The validity test was carried out on 29 class IV students, with a total of 25 questions tested. As for the results of the validity test carried out using corrected item-total correlation, 20 valid questions were obtained because $r_{\text{count}} > r_{\text{table}}$. Next, the researcher used 20 valid questions as a research instrument.

Table 5. Validity Test Results

No	r count	r table	Information	No	r count	r table	Information
1	.620	0.374	Valid	14	.581	0.374	Valid
2	.530	0.374	Valid	15	.591	0.374	Valid
3	.590	0.374	Valid	16	.223	0.374	Invalid
4	.620	0.374	Valid	17	.398	0.374	Valid
5	.430	0.374	Valid	18	.425	0.374	Valid
6	.412	0.374	Valid	19	.441	0.374	Valid
7	.560	0.374	Valid	20	.330	0.374	Invalid
8	.418	0.374	Valid	21	.257	0.374	Invalid
9	.480	0.374	Valid	22	.440	0.374	Valid
10	.420	0.374	Valid	23	.472	0.374	Valid
11	.441	0.374	Valid	24	.223	0.374	Invalid
12	.442	0.374	Valid	25	.254	0.374	Invalid
13	.560	0.374	Valid				

The results of the validity test of the test instrument using corrected item-total correlation show that of the 25 question items, five have $r_{\text{count}} < r_{\text{table}}$, namely question number 16 with a r_{count} value of 0.223, question number 20 with a r_{count} value of 0.330, question number 21 with a r_{count} value of 0.257, question number 24 with a r_{count} value of 0.223, and question number 25 with a r_{count} value of 0.254. The total number of questions that can be used as research instruments is 20. The data on the pre-test and post-test results of class IV students;

Table 6. Recapitulation of Pre-test Post-test Results

Students	Questions	Pre-test	Mean	Category	Post-test	Mean	Category
29	20	1940	66.90	Medium	2370	81.72	High

The validity test results are derived from the pre-test data. The medium category had an average score of 66.90, while the high category had an average score of 81.72. The digital-based differentiated learning model has resulted in improved learning outcomes for class IV students in terms of their science problem-solving abilities, as illustrated in Table 6. It is well-documented that the post-test results indicated that 15 students (74%) had learning outcomes in the very high category, 10 students (16%) had learning outcomes in the high category, and 4 students (10%) had learning outcomes in the medium category. The validity test of the questionnaire sheet instrument was conducted by trialing 15 statement items using corrected item-total correlation. The results indicated that 14 questionnaire statement items were valid, as $r_{\text{count}} > r_{\text{table}}$. Subsequently, the researcher employed 14 legitimate questionnaire statements for the research. The corrected item-total correlation of the instruments indicates that five of the 25 question items have $r_{\text{count}} < r_{\text{table}}$. These items are question number 16 with a r_{count} value of 0.223, question number 20 with a r_{count} value of 0.330, question number 21 with a r_{count} value of 0.257, question number 24 with a r_{count} value of 0.223, and question number 25 with a r_{count} value of 0.254. A total of 20 queries may be employed as research instruments. The results of the pre-test and post-test for fourth-grade students;

Table 7. Questionnaire Validity Test Results

No	r count	r table	Information	No	r count	r table	Information
1	.430	0.374	Valid	9	.402	0.374	Valid
2	.447	0.374	Valid	10	.402	0.374	Valid
3	.325	0.374	Invalid	11	.440	0.374	Valid
4	.520	0.374	Valid	12	.420	0.374	Valid
5	.460	0.374	Valid	13	.400	0.374	Valid
6	.395	0.374	Valid	14	.422	0.374	Valid
7	.440	0.374	Valid	15	.502	0.374	Valid
8	.470	0.374	Valid				

The results of the questionnaire validity test showed that of the 15 statement items, there was one questionnaire item that had $r_{\text{count}} < r_{\text{table}}$, namely questionnaire number 3 with an account value of 0.325, and was declared invalid or invalid. The total number of questionnaire statements that can be used as a research instrument is 14 statement items, and they meet the criteria. The data from the questionnaire results for class IV students are as follows:

Table 8. Recapitulation of Questionnaire Results

Students	Statement	Amount	Mean	Category
29	14	1680	57.93	Medium

Based on the results of the questionnaire, an average score of 57.93 was obtained in the medium category; there were 19 students with a percentage of 68% who had problem-solving in the high category, and 10 students with a percentage of 32% had problem-solving in the medium category. After the question items and questionnaire have been tested for validity, the next step is to test the reliability of the questions and questionnaires with the aim of measuring the consistency of the measuring

instrument so that it is trusted to be used as the data collection tool. The results of the reliability test of questions and questionnaires that have been carried out using the SPSS version 26 for Windows application are as follows:

Table 9. Reliability Test Results

Variable	Cronbach's Alpha	N of Items	Information
Questionnaire	.782	14	reliable
Test	.722	20	reliable

The results of Cronbach's alpha reliability calculations show that the Cronbach's alpha value of the questionnaire instrument is $0.782 > 0.60$, so it is concluded that the instrument is reliable. Meanwhile, the test results for the reliability of the test questions were $0.722 > 0.60$, so it was concluded that the test instrument was reliable. Both instruments were declared reliable and suitable for using in research. The standard deviation in this research provides an overview of the distribution of instruments in the form of tests and questionnaires among the research sample group.

Based on the results of descriptive analysis, the questionnaire obtained an average score of 57.93, a Medium standard deviation of 4.86, a maximum value of 58, and a minimum score of 44. The results of the test analysis obtained an average score of 66.90 pre-tests and 81.72 post-tests; a standard deviation of 19,155 pre-tests and 10,445 post-tests; a maximum score of 90 pre-tests and 100 post-tests; minimum score of 30 pre-tests and 75 post-test. From the descriptive analysis data, it can be concluded that student learning outcomes experience significant differences. The minimum scores obtained in the pre-test and post-test are 100 and 90. The normality test is used to determine whether the samples used during the research are normally distributed or not. The normality test used in this research uses Shapiro-Wilk using SPSS version 26.0 for Windows as follows;

Table 11. Kolmogorov-Smirnov and Shapiro-Wilk Test Results

	Tests of Normality					
	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
Pre-Test	.251	29	.008	.883	29	.034
Post-Test	.195	29	.051	.981	29	.041

The research data obtained is not normally distributed, as the Sign value is < 0.05 , which means that nothing meets the normal distribution criteria, as indicated by the results of the normality test in the Tests of Normality table using the Kolmogorov-Smirnov and Shapiro-Wilk normality test types. Consequently, SPSS version 26.0 for Windows was employed to conduct the Wilcoxon non-parametric normality test. The Wilcoxon test is a non-parametric test that is used to estimate the significance of data on an ordinal or interval scale that is not normally distributed. If the paired t-test or paired t-test fails to satisfy the assumption of normality, the Wilcoxon Signed Rank Test is an alternative test. The Wilcoxon Test Results data are presented below:

Table 12. Wilcoxon Test Results

Test Statistics ^a	
	Pre-test post test
Z	-4.216 ^b
Asymp. Sig. (2-tailed)	.000

The Wilcoxon output ranks test results indicate that the negative rank result is 1, indicating that one student experienced a decline in learning outcomes for the pre-test and post-test following treatment. The positive rank result is 23, indicating that 23 pupils experienced an improvement in their learning outcomes between the pre-test and the post-test. The post-test results and the tie results were 5, indicating that five pupils achieved comparable pre-test and post-test results following the treatment. In order to facilitate the continuation of hypothesis testing, both the pre-test and post-test are normally distributed. The Mann-Whitney test is employed in this research as an alternative to the independent

t-test for hypothesis testing, which is applicable to research data that is not normally distributed. The following serves as the foundation for decision-making: The differentiated learning model can enhance the ability to solve scientific problems if the value is less than 0.05. The differentiated learning model is unable to enhance the problem-solving abilities of scientists if the value is ≥ 0.05 .

Table 13. Hypothesis testing

Test Statistics			
Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
140.000	370.000	-3.052	.001

Based on the Mann-Whitney Test table above, the Sig (2-tailed) value is $0.001 < 0.05$, so it can be said that there is a significant increase. Based on the data taken, hypothesis H_0 is rejected, and H_a is accepted, so it is concluded that the use of the differentiated learning model can improve science problem-solving abilities.

Discussion

Based on the research findings obtained from conducting validity tests, reliability tests, normalcy tests, and hypothesis testing, it has been determined that the individuals possess strong problem-solving skills in the field of science. In the student's fourth class, the final grades revealed that 15 students, who scored 74%, achieved learning outcomes in the very high category. Additionally, 10 students, who scored 16%, achieved learning outcomes in the high category. Lastly, 4 students, who scored 10%, achieved learning outcomes in the medium category. The utilization of a digital-based differentiated learning model fosters increased enthusiasm for learning among students. This approach tailors instruction to accommodate individual learning styles, ensuring that all students receive the necessary support depending on their unique needs. Properly implementing digital-based differentiated learning strategies will enhance the effectiveness and efficiency of learning. The research findings demonstrate that the average score of the questionnaire results falls into the medium group, namely at 57.93. The research findings align with a study conducted by Demir (2021), which determined that employing instructional design based on Kolb's Bloom's taxonomy learning style for differentiated and enriched learning has a beneficial impact on the development and expression of creative thinking abilities in gifted students. According to the findings of this research, it is advised that teachers aiming to foster and enhance students' creative thinking abilities should initially assess students' aptitude, interests, and preferred learning styles. Subsequently, teachers should create a conducive learning environment where students can freely showcase their creativity, confidently advocate for their ideas, and generate innovative solutions to the challenges they encounter. Finally, teachers should employ approaches, methods, or techniques that have been scientifically validated in the literature to effectively promote creative thinking.

Utilizing technology in education stimulates students' motivation and interest, leading to the acquisition of learning skills and fostering innovation through educational activities. This aligns with the attributes of contemporary students in the 21st century who exhibit a preference for engaging with digital media in a sophisticated manner, have a greater inclination towards social media presence, feel at ease in an internet-connected setting, and have a preference for practical experiences (Kozhevnikov et al., 2022). Technological resources enhance teachers' ability to provide tailored learning aids that align with students' characteristics. Additionally, they support schools in improving instructional facilities and ensuring the completeness of school papers. There are 10 students who have a visual learning style, consisting of 4 male students and 6 female students. Additionally, there are 10 students who have an auditory learning style, with 5 of them being male students. There are 5 female pupils and 9 male students who possess a kinesthetic learning style. Mann-Whitney's research findings indicate a statistically significant value of 0.001, demonstrating a substantial improvement in learning outcomes when employing digital-based differentiated learning strategies tailored to students' individual learning needs, as determined by their profiles, interests, and learning styles. Greater autonomy in the

learning process leads to improved learning outcomes for pupils. Students are essential for attaining learning objectives, specifically to achieving the best possible learning outcomes. According to Brüngel et al. (2020), the differentiation strategy is designed to enhance the academic performance of all students, regardless of whether they are below or above the expected educational level. In order to facilitate greater student participation in classroom learning, students in different classes who require differentiation strategy or instruction should utilize various forms of intelligence.

In order to attain learning goals, it is crucial for students to engage in active and diverse activities while studying. This approach helps establish a pleasant learning atmosphere and ensures that students gain valuable learning experiences. The teacher has organized student activities in a strategic manner as part of the learning planning. Common activities undertaken during the process of learning typically involve observing, inquiring, doing experiments, communicating, and making connections with information (Boelens et al., 2018). The purpose of student activities is to enhance the learning experience and optimize the learning process. In order to accomplish this, it is necessary to: 1) utilize suitable educational tools and resources in the classroom that align with the students' characteristics and class conditions, 2) employ a variety of engaging learning media to enhance student interest and enjoyment, and 3) consistently address any weaknesses that may arise during the learning process (Saykili, 2019). The student response questionnaire administered to 29 individuals yielded a score of 57.93 in the medium category. This suggests that the material presented was perceived as engaging by students, easy to comprehend, compatible with different electronic devices, and supportive of differentiated learning, particularly in relation to students' individual learning preferences. Based on the results of the student response questionnaire, it can be concluded that the implementation of digital-based differentiated learning models is highly beneficial in enhancing science problem-solving skills.

Teachers in differentiated learning must possess a comprehensive understanding of their students, consistently enhance their knowledge of their students' strengths and weaknesses, and actively watch and assess their students' readiness, interests, and learning preferences. Teachers should also consider students' preferences when it comes to expressing their learning preferences in terms of content, methods, products, and learning settings. Hence, the attainment of proficient, impactful, and streamlined education will be achieved when educators consistently acquire knowledge about the possibilities of student heterogeneity. Various educational experiences might indirectly foster students' creativity by providing ample opportunities for them to showcase their acquired knowledge. Given the ongoing development of creativity, employing differentiated learning in education is strongly advised to facilitate the attainment of learning objectives.

4. CONCLUSION

Based on the results of research conducted by researchers, the use of digital-based differentiated learning models in improving science problem-solving abilities is in the high category. Differentiation in content, processes, and products has been proven to increase student learning activity, develop creativity, and improve learning outcomes. Unfortunately, researchers did not look for other supporting factors in this study. For further research, supporting variables can be added to research on differentiated learning. The use of digital-based differentiated learning models can be combined with media and learning methods so that students can be motivated to participate in the learning process. The results of the research can be used as teaching material to help teachers explain lesson material, facilitate students' learning according to the characteristics of learning styles, and help students understand learning material.

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that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed.

REFERENCES

- Bikić, N., Maričić, S. M., & Pikula, M. (2016). The effects of differentiation of content in problem-solving in learning geometry in secondary school. *Eurasia Journal of Mathematics, Science and Technology Education*, 12(11), 2783–2795. <https://doi.org/10.12973/eurasia.2016.02304a>
- Boelens, R., Voet, M., & De Wever, B. (2018). The design of blended learning in response to student diversity in higher education: Instructors' views and use of differentiated instruction in blended learning. *Computers & Education*, 120, 197–212. <https://doi.org/10.1016/j.compedu.2018.02.009>
- Brüngel, R., Rückert, J., & Friedrich, C. M. (2020). Project-based learning in a machine learning course with differentiated industrial projects for various computer science master programs. *2020 IEEE 32nd Conference on Software Engineering Education and Training (CSEET)*, 1–5. IEEE. <https://doi.org/10.1109/CSEET49119.2020.9206229>
- Chandra Handa, M. (2020). Examining students' and teachers' perceptions of differentiated practices, student engagement, and teacher qualities. *Journal of Advanced Academics*, 31(4), 530–568. <https://doi.org/10.1177/1932202X20931457>
- Demir, S. (2021). Effects of learning style based differentiated activities on gifted students' creativity. *Journal for the Education of Gifted Young Scientists*, 9(1), 47–56. <https://doi.org/10.17478/jegys.754104>
- Gaitas, S., & Alves Martins, M. (2017). Teacher perceived difficulty in implementing differentiated instructional strategies in primary school. *International Journal of Inclusive Education*, 21(5), 544–556. <https://doi.org/10.1080/13603116.2016.1223180>
- Ginja, T. G., & Chen, X. (2020). Teacher Educators' Perspectives and Experiences towards Differentiated Instruction. *International Journal of Instruction*, 13(4), 781–798. <https://doi.org/10.29333/iji.2020.13448a>
- Hardiansyah, F. (2022). the Implementation of Tolerance Character Education Through Social Science Learning in Elementary School. *AULADUNA: Jurnal Pendidikan Dasar Islam*, 9(2), 168–180. <https://doi.org/10.24252/auladuna.v9i2a5.2022>
- Hardiansyah, F., & AR, M. M. (2022). Enhancing Students' Learning Motivation through Changing Seats in Primary School. *Mimbar Sekolah Dasar*, 9(1), 253–268. <https://doi.org/10.53400/mimbar-sd.v9i1.43002>
- Hardiansyah, F., & Mas'odi, M. (2022). The Implementation Of Democratic Character Education Through Learning Of Social Science Materials Of Ethical And Cultural Diversity In Elementary School. *Journal of Innovation in Educational and Cultural Research*, 3(2), 234–241. <https://doi.org/10.46843/jiecr.v3i2.101>
- Hardiansyah, F., & Wahdian, A. (2023). Improving Science Learning Outcomes Through the Development of the Magic Card Box Learning Media. *AL-ISHLAH: Jurnal Pendidikan*, 15(1), 823–833. <https://doi.org/https://doi.org/10.35445/alishlah.v15i1.2711>
- Hardiansyah, F., & Zainuddin, Z. (2022). The Influence of Principal's Motivation, Communication, and Parental Participation on Elementary School Teachers' Performance. *Al Ibtida: Jurnal Pendidikan Guru MI*, 9(2), 319–334. <https://doi.org/10.24235/al.ibtida.snj.v9i2.9936>
- Hardiansyah, F., Zainuddin, Z., Sukitman, T., & Astutik, C. (2023). Development Of Learning Media Smart Book To Improve Understanding Of Elementary School Students In Science Learning. *Lentera Pendidikan: Jurnal Ilmu Tarbiyah Dan Keguruan*, 26(1), 72–87. <https://doi.org/https://doi.org/10.24252/lp.2023v26n1i7>
- Hasanah, E., Suyatno, S., Maryani, I., Badar, M. I. Al, Fitria, Y., & Patmasari, L. (2022). Conceptual Model of Differentiated-Instruction (DI) Based on Teachers' Experiences in Indonesia. *Education Sciences*, 12(10), 650. <https://doi.org/10.3390/educsci12100650>
- Hersi, A. A., & Bal, I. A. (2021). Planning for Differentiation: Understanding Maryland Teachers' Desired and Actual Use of Differentiated Instruction. *Educational Planning*, 28(1), 55–71.

- <https://files.eric.ed.gov/fulltext/EJ1284804.pdf>
- Jackson, N., & Evans, L. (2017). Self-reflections on differentiation: Understanding how we teach in higher education. *Networks: An Online Journal for Teacher Research*, 19(1), 5. <https://dx.doi.org/10.4148/2470-6353.1012>
- Lindner, K.-T., Nusser, L., Gehrler, K., & Schwab, S. (2021). Differentiation and grouping practices as a response to heterogeneity—teachers' implementation of inclusive teaching approaches in regular, inclusive and special classrooms. *Frontiers in Psychology*, 12, 676482. <https://doi.org/10.3389/fpsyg.2021.676482>
- Lindner, K.-T., & Schwab, S. (2020). Differentiation and individualisation in inclusive education: a systematic review and narrative synthesis. *International Journal of Inclusive Education*, 1–21. <https://doi.org/10.1080/13603116.2020.1813450>
- Marshall, K. (2016). Rethinking differentiation—Using teachers' time most effectively. *Phi Delta Kappan*, 98(1), 8–13. <https://doi.org/10.1177/0031721716666046>
- Mulyawati, Y., Zulela, M. S., & Edwita, E. (2022). Differentiation Learning to Improve Students Potential in Elementary School. *Pedagonal: Jurnal Ilmiah Pendidikan*, 6(1), 68–78. <https://doi.org/10.55215/pedagonal.v6i1.4485>
- Olimov, S. (2020). The differentiation of education is an important factor of pedagogical technology. *European Journal of Research and Reflection in Educational Sciences*, 8(11). <http://www.idpublications.org/wp-content/uploads/2020/11/Full-Paper-the-differentiation-of-education-is-an-important-factor-of-pedagogical.pdf>
- Pozas, M., Letzel, V., & Schneider, C. (2020). Teachers and differentiated instruction: exploring differentiation practices to address student diversity. *Journal of Research in Special Educational Needs*, 20(3), 217–230. <https://doi.org/10.1111/1471-3802.12481>
- Rashidov, A. (2020). Use of differentiation technology in teaching Mathematics. *European Journal of Research and Reflection in Educational Sciences Vol*, 8(7). <http://www.idpublications.org/wp-content/uploads/2020/07/Full-paper-use-of-differentiation-technology-in-teaching-mathematics.pdf>
- Reis, S. M., & Renzulli, J. S. (2018). The five dimensions of differentiation. *International Journal for Talent Development and Creativity*, 6, 87–94. <http://files.eric.ed.gov/fulltext/EJ1296874.pdf>
- Saykili, A. (2019). Higher education in the digital age: The impact of digital connective technologies. *Journal of Educational Technology and Online Learning*, 2(1), 1–15. <https://doi.org/10.31681/jetol.516971>
- Sharp, K., Jarvis, J. M., & McMillan, J. M. (2020). Leadership for differentiated instruction: Teachers' engagement with on-site professional learning at an Australian secondary school. *International Journal of Inclusive Education*, 24(8), 901–920. <https://doi.org/10.1080/13603116.2018.1492639>
- Simanjuntak, S. D., Tinambunan, R., Imelda, I., Sembiring, R. K., & Sitepu, I. (2023). Effectiveness of differentiation learning strategies in mathematics learning at junior high school. *Edunesia: Jurnal Ilmiah Pendidikan*, 4(1), 247–258. <https://doi.org/10.51276/edu.v4i1.310>
- Sitorus, P., Simanullang, E. N., Manalu, A., Laia, I. S. A., Tumanggor, R. M., & Nainggolan, J. (2022). The Effect of Differentiation Learning Strategies on Student Learning Results. *Jurnal Penelitian Pendidikan IPA*, 8(6), 2654–2661. <https://doi.org/10.29303/jppipa.v8i6.2114>
- Stavrou, T. E., & Koutselini, M. (2016). Differentiation of Teaching and Learning: The Teachers' Perspective. *Universal Journal of Educational Research*, 4(11), 2581–2588. <http://files.eric.ed.gov/fulltext/EJ1118715.pdf>
- Taylor, S. C. (2017). Contested knowledge: A critical review of the concept of differentiation in teaching and learning. *Warwick Journal of Education-Transforming Teaching*, 1, 55–68.
- Variacion, D. A., Salic-Hairulla, M., & Bagaloyos, J. (2021). Development of differentiated activities in teaching science: Educators' evaluation and self-reflection on differentiation and flexible learning. *Journal of Physics: Conference Series*, 1835(1), 12091. IOP Publishing. <https://iopscience.iop.org/article/10.1088/1742-6596/1835/1/012091/pdf>

Yuen, M., Chan, S., Chan, C., Fung, D. C. L., Cheung, W. M., Kwan, T., & Leung, F. K. S. (2018). Differentiation in key learning areas for gifted students in regular classes: A project for primary school teachers in Hong Kong. *Gifted Education International*, 34(1), 36–46. <https://doi.org/10.1177/0261429416649047>