



Integration of Challenge Based on STEM Learning Assisted by 2D Game Interactive Scratch to Numeracy Literacy

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Abstract

This research is development research of 2D games based on Scratch integrated challenge based on STEM context learning in the context of weather station. The aims of developing learning media which is feasible in terms of material and media, and has a positive response from students. The media will facilitate learners in interesting 2D visualization, various interactive activities, and presentation of contextual materials and problems around the elements of STEM context themed weather station. The challenge based on STEM context learning model used will train learners in constructing their knowledge independently so that it can encourage the improvement of learners' numeracy literacy skills. The research method in the form of Research and Development with the ADDIE model has been carried out by considering the material feasibility test, media feasibility test, and learner response assessment. The results of descriptive statistical analysis were conducted after the data were collected using a questionnaire. The results show that the media learning media is said to be feasible in terms of material with a percentage of 91.02% and feasible in terms of media with a percentage of 90.23%. The media fulfils average completeness, proportion completeness, and excellent N-Gain value at 0.77. The media has a positive response of 89.54% from students. Thus, the media is said to be feasible in terms of material and media, effective, and has a positive learner response to improve the numeracy literacy skills of students to boost PISA results so that the ideals of "Indonesia Emas 2045" can be achieved.

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1. Introduction

The era of society 5.0 provides a real challenge for Indonesia in realizing one of the nation's great visions known as "Indonesia Emas 2045" which aims to direct Indonesia to become a developed country in 2045, exactly 100 years after independence (Puspa et al., 2023). In order to encourage the realization of this vision, it is necessary to improve the quality of education in Indonesia. The educational achievement of a country is reflected in the quality of its human resources (Siregar et al., 2024). One of the fulfillments of abilities that can be a measure of the smartness of the nation's generation is numerical literacy skill. Numerical literacy indicates mathematical reasoning skills such as formulating, using, and interpreting mathematical concepts to solve various problems in real-world contexts (OECD, 2022).

Internationally, Indonesia's numeracy literacy score is still far from the world average. Based on the last three PISA publications, it can be seen that the numeracy literacy score in Indonesia shows 386 out of 490 average PISA 2015 scores, 379 out of 489 average PISA 2018 scores, and 366 out of 472 average PISA 2022 scores, in other words, every year Indonesia's score is always in the low category. This also shows a decrease in scores that occurred in the last 10 years. Therefore, an innovative strategy is needed to improve numerical literacy skills in Indonesia.

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One of the efforts to overcome the low numerical literacy skills is to develop an educational game-based learning media in the form of 2D interactive game. 2D interactive game is designed in the form of virtual world innovation with 2-dimensional visuals as environmental objects in learning activities. Learning with interactive activities by learners allows them to not only be passive recipients of information, but also engage in the learning process through discussion, collaboration, experimentation, and other active participation (Simamora, 2023). This will make them put their full focus on the learning process. In addition, based on research conducted by Sakinah et al. (2024), learning that is integrated into interactive digital games can make the learning atmosphere fun which has an impact on increasing their interest in learning, including in numerical literacy-oriented learning. The use of interactive games with 2D visuals in learning can support an interesting learning process and have a positive influence on students' numerical literacy skills (Adrilian, 2023).

The use of innovative learning media in the classroom needs to be supported by the application of the right learning model (Luthfiralda, 2022). As an effort to improve numerical literacy skills, the learning model that can be implemented is challenge based on STEM context learning. In its application, this learning model integrates the STEM (Science, Technology, Engineering, and Mathematics) approach into each stage of CBL (Challenge Based Learning). The STEM context approach presented can include one of the elements, one of the concepts that can be applied is the weather station theme which focuses on the science element in STEM. The combination of CBL and STEM will present various math problems related to science in the daily lives of students (Taconis and Bekker, 2023). The combination of these two things into a learning model can encourage students' interest in participating in the learning process and train students' skills in mathematical reasoning with the STEM concepts presented (Putri et al., 2019). This is included in the indicator of encouraging numerical literacy skills.

Based on the above background, this study aims to develop an innovative mathematics learning media in the form of 2D games based on Scratch integrated challenge based on STEM context learning with the theme of a weather station that is feasible, effective in improving numerical literacy skills, and has a good student response. This effort was made as one of the efforts currently needed to improve students' numeracy literacy skills.

2. Methods

2.1. The Location and Duration of Research

The research was conducted at SMP Negeri 3 Ungaran, which was located at Jl. Patimura No.1-A, Suwaktu, Bandarjo, West Ungaran District, Semarang Regency. The study started from November 11 to 20, 2024.

2.2. Research Design

This research used the Research and Development (RnD) method to develop media and test the effectiveness of the media. The research employed the ADDIE development model by Robert Maribe Branch (2009), including the stages of analyzing, designing, developing, implementing, and evaluating. The media developed in this research was a Scratch-based game on the weather station integrated with challenges based on the STEM learning model.

2.3. Research Stages

The stages of research with the ADDIE model are shown in Figure 1.

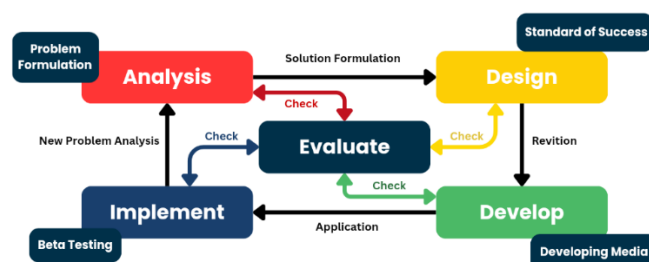


Figure 1. ADDIE Research Stages.

The initial stage of research with the ADDIE model was the analysis stage, which aimed to identify problems through literature studies and analysis of PISA results related to numeracy literacy skills that were still low. Next, the design stage involved formulating the standards for the media's success. This was followed by the development stage, during which the game was created and the media's validity was tested. After the validity test, media development proceeded to the implementation stage, where the media was tested in a learning environment to measure its effectiveness. If necessary, evaluation and revision were conducted at each stage before moving to the next.

2.4. Research Object or Variable

The subjects in this study were VIII-grade students in the 2024/2025 school year at SMP Negeri 3 Ungaran. Sampling was conducted using a cluster random sampling technique by randomly selecting one experimental class as the research subject. The research sample consisted of the experimental class, where learning was conducted using the media.

The variables in this study included the level of validity, effectiveness, and students' responses to the media. The validity variable was assessed based on media feasibility and material feasibility. The effectiveness variable was evaluated through the average completeness, proportion of completeness, and the improvement in numerical literacy results of the research sample, as measured by N-Gain.

2.5. Data Collection Sources and Techniques

Data collection for each variable was carried out using questionnaires and tests during the development stage. Material feasibility data were obtained through a material feasibility questionnaire filled out by four material experts and four practitioners. Media feasibility data were collected through a media feasibility questionnaire completed by four media experts and four practitioners. Learner response data were gathered through a learner response questionnaire administered to the research sample. Tests were conducted in two phases: a pretest before the learning process and a posttest after using the 2D game, to gather numerical literacy test data.

2.6. Data Analysis Technique

The data in this study were analyzed using validity tests, effectiveness tests, and students' response tests to evaluate the implementation of the learning media integrated with a challenge-based learning model in the STEM learning context. Validity data and learner responses from each individual (expert, practitioner, or research subject) were calculated using the following formula $P = \frac{a}{N} \times 100\%$. With P = Percentage points, a = Number of points in the questionnaire, N = Maximum possible points to be obtained. The percentage values were then averaged to calculate the mean test value (X) for each variable. The average value is then concluded based on the assessment criteria by Arikunto and Jabar (2009) in Table 2.

Table 1. Recapitulation of media feasibility test results.

Average (X)	Criteria
$0\% < X \leq 20\%$	Very Bad
$20\% < X \leq 40\%$	Bad
$40\% < X \leq 60\%$	Fair
$60\% < X \leq 80\%$	Good
$80\% < X \leq 100\%$	Very Good

The effectiveness test in this study included prerequisite tests and hypothesis tests. Prerequisite tests were performed on the pretest and posttest results of students, involving normality tests and paired-sample t-tests. The normality test was conducted to determine the data distribution using the Nonparametric One-Sample Kolmogorov-Smirnov test. The homogeneity test was performed to check for an increase in scores, using the Paired-Sample T-Test One-Tailed Left Side test. If the data were normally distributed and showed an increase in numeracy literacy skills, hypothesis testing was conducted. The hypothesis testing included average completeness, proportion completeness, and N-Gain tests. The average completeness test compared the average posttest score with the Minimum Completeness Criteria (MCC) at the research location using

the One-Sample T-Test One-Tailed Left Side test. The proportion completeness test compared the percentage of students in the sample group meeting the MCC with a target proportion of 80%, using the Nonparametric Binomial Test. The N-Gain test measured the improvement in numeracy literacy skills by calculating the average N-Gain value for each research sample using the formula $N\text{-Gain} = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Ideal Score} - \text{Pretest Score}}$. The average criteria for the N-Gain test results are summarized based on Table 3.

Table 2. N-Gain Criteria

N-Gain Average (N)	Criteria
$N < 0$	Bad
$0 < N \leq 0.3$	Enough
$0.3 < N \leq 0.7$	Good
$N > 0.7$	Very Good

2.7. Conclusion of Research Result

The development of the 2D game based on Scratch integrated with challenges based on STEM learning was considered successful if the media met at least good criteria in terms of media feasibility, material feasibility, and student responses, and was effective in improving students' numerical literacy skills, as indicated by meeting average completeness, proportion completeness, and achieving at least good criteria on the N-Gain test results.

3. Results & Discussions

The design stage in the development of the media ends with the formation of the initial 2D game design of the learning media. Furthermore, the media went through the develop stage to perfect the media before it was implemented on the research subjects. Validation was conducted by 4 experts (lecturers) from Semarang State University and 4 practitioners. The validity test on the media includes media feasibility test which includes aspects of software and visual communication of media, as well as material feasibility test which includes language and content and presentation on the media. The learning media is declared to meet the validation test if the validation criteria obtained are at least good categories. The following media feasibility test results are attached in Table 3. and the material feasibility test results are attached in Table 4.

Table 3. Recapitulation of media feasibility test results.

Validator	Aspects Assessed		Average
	Software	Visual Communication	Per Validator
Expert (E)			
A1	95.00%	94.23%	94.50%
A2	90.00%	90.38%	90.21%
A3	90.00%	88.46%	89.13%
A4	95.00%	92.31%	93.47%
Practitioners (P)			
P1	90.00%	92.31%	91.00%
P2	90.00%	88.46%	89.13%
P3	80.00%	78.85%	79.30%
P4	92.50%	96.15%	94.57%
Average per Aspect	90.31%	90.14%	
Average Media Validation Results	90.23%		

Table 4. Average Material Validation Results.

Validator	Aspects Assessed		Average
	Software	Visual Communication	Per Validator
Expert (E)			
A1	89.58%	93.75%	90.90%
A2	85.42%	93.75%	88.19%
A3	91.67%	91.67%	91.67%
A4	92.71%	89.58%	91.67%
Practitioners (P)			
P1	89.58%	89.58%	89.58%
P2	91.67%	91.67%	91.67%
P3	89.58%	87.50%	88.80%
P4	92.50%	96.15%	94.57%
Average per Aspect	90.34%	91.71%	
Average Media Validation Results		91.02%	

The learning media that has fulfilled the develop stage, then implemented to the research subjects in the implement stage. The implement stage is carried out to obtain data on the numeracy literacy skills of research samples both before and after the implementation of the learning media in the challenge-based learning model, as well as data on students' responses after the implementation of the media. The learning media is declared to meet the effectiveness test if the results of the implementation of the learning media are able to improve the numeracy literacy skills of students so as to achieve average completeness, proportion completeness, and the average N-Gain factor which is categorized as at least good. The following are the results of the pretest, posttest, LOAC completeness, and N-Gain for each student attached in Table 5.

Furthermore, learner response data is collected using a learner response questionnaire which includes 20 (twenty) statements. The learning media is declared to meet the learner response test if the results of the implementation of the learning media are able to get an average of learner responses categorized as at least good. so as to achieve average completeness, proportion completeness, and the average N-Gain factor which is categorized as at least good the results of learner responses are attached in Figure 2.

The design stage in the media development produces the final result in the form of 2D game along with other supporting learning tools. All components then go through the validation stage by experts and practitioners to test the validity of the 2D game learning media, resulting in the learning media that is ready to be implemented in research subjects.

Based on Table 3, the average media feasibility test results of 2D game is more than 80% in each aspect, so the learning media meets the criteria of excellent in the aspects of software and visual communication. When viewed on average per validator, 7 validators out of 8 validators provide feasibility test results on excellent media criteria. Thus, it can be concluded that the media meets very good criteria on media feasibility with an average percentage of 90.23%. In Table 4, the average result of the material feasibility test of the learning media is more than 80% in each aspect, so that the learning media meets very good criteria in the aspects of content and presentation devices, as well as language. If reviewed on average per validator, then all validators provide material feasibility test results on very good criteria. So, it can be concluded that the media meets the criteria for excellent material feasibility with an average percentage of 91.02%. Therefore, the learning media has fulfilled the develop stage with excellent criteria in both validation tests.

Table 5. Recapitulation of Material Feasibility Test Results.

Learners (L)	Pretest Results	Reached LOAC (Pretest)	Posttest Results	Reached LOAC (Posttest)	N-Gain Value
L1	26.7	Not Reached	83.3	Reached	0.8
L2	24.5	Not Reached	75	Not Reached	0.7
L3	53.3	Not Reached	86	Reached	0.7
L4	40	Not Reached	89.3	Reached	0.8
L5	26.7	Not Reached	73.3	Not Reached	0.6
L6	66.7	Not Reached	92.5	Reached	0.8
L7	50.3	Not Reached	86.7	Reached	0.7
L8	58.3	Not Reached	92.3	Reached	0.8
L9	35	Not Reached	84.7	Reached	0.8
L10	50.3	Not Reached	100	Reached	1.0
L11	58.3	Not Reached	84.3	Reached	0.6
L12	55.3	Not Reached	93	Reached	0.8
L13	66.7	Not Reached	92	Reached	0.8
L14	35	Not Reached	87.3	Reached	0.8
L15	53.3	Not Reached	95	Reached	0.9
L16	26.7	Not Reached	94.7	Reached	0.9
L17	35	Not Reached	86.7	Reached	0.8
L18	40	Not Reached	73.3	Not Reached	0.6
L19	46.3	Not Reached	95	Reached	0.9
L20	45	Not Reached	92	Reached	0.9
L21	53.3	Not Reached	84.3	Reached	0.7
L22	45	Not Reached	80	Reached	0.6
L23	50.3	Not Reached	88	Reached	0.8
L24	26.7	Not Reached	80	Reached	0.7
L25	26.7	Not Reached	81.7	Reached	0.8
L26	48.3	Not Reached	93.3	Reached	0.9
L27	43	Not Reached	95	Reached	0.9
Average	43.95		87.36		0.78

The learning media that has fulfilled the develop stage, then implemented to the research subjects in the implement stage. The implement stage is carried out to obtain data on the numeracy literacy skills of the research sample both before and after the implementation of the learning media in the challenge-based learning model, as well as data on students' responses after the implementation of the media. Based on Table 5, the numeracy literacy data on the pretest and posttest results of the research sample will go through a prerequisite test which includes normality test and mean comparison using paired sample t-test. The normality test was conducted using a nonparametric test using one-sample Kolmogorov-Smirnov, with the hypothesis (Nuryadi, et. al, 2017) Based on Table 3, the average media feasibility test results of the 2D game were more than 80% in each aspect, so that the learning media met the excellent criteria in the software and visual communication aspects. When viewed on average per validator, 7 validators out of 8 validators provide feasibility test results on excellent media criteria.

H_0 : $Sig. > 5\%$, data is normally distributed

H_1 : $Sig. \leq 5\%$, data is not normally distributed

The results of the normality analysis are attached in Table 6.

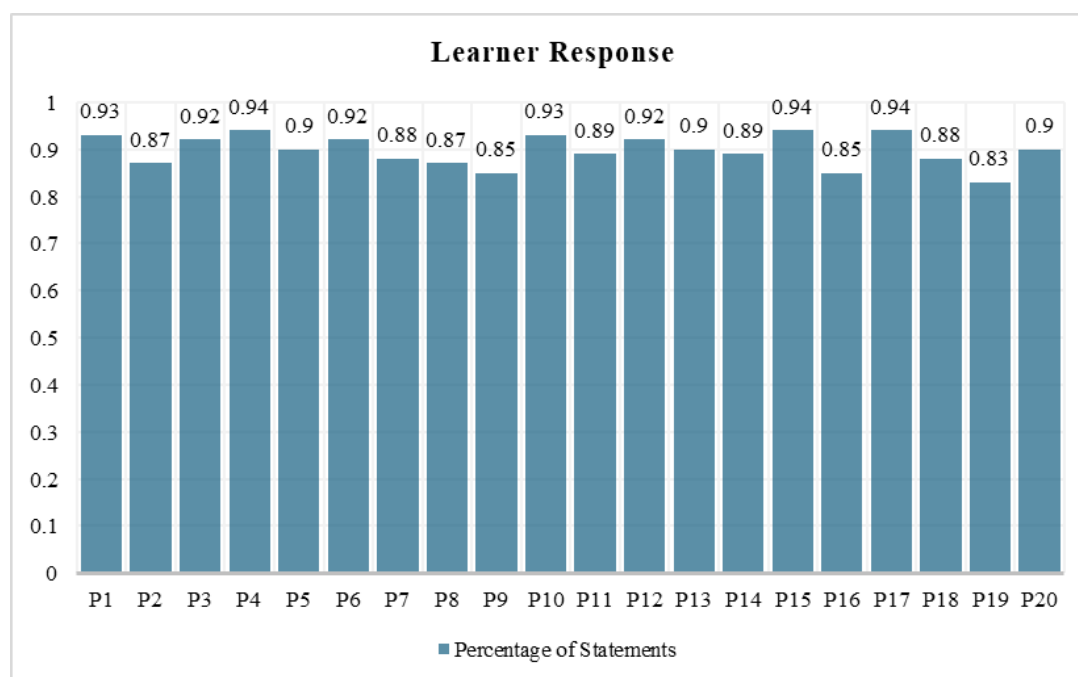


Figure 2. Learner Response Results

Table 6. Normality Test Results

One-Sample Kolmogorov-Smirnov Test			
		HasilPreTest	HasilPostTest
N		27	27
Normal Parameters ^{a,b}	Mean	43.9519	87.3593
	Std. Deviation	12.59458	7.03679
Most Extreme Differences	Absolute	.137	.153
	Positive	.137	.102
	Negative	-.100	-.153
Test Statistic		.137	.153
Asymp. Sig. (2-tailed)		.200 ^c	.107 ^c

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

Table 7. Paired Sample T-Test Results

Paired Samples Test								
		Paired Differences					t	df
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			
					Lower	Upper		
Pair 1	HasilPostTest-HasilPreTest	43.40741	10.81669	2.08167	39.12847	47.68635	20.852	26

The normality test results for the pretest and posttest outcome variables showed $Sig. = .2 > 5\%$ and $Sig. = .107 > 5\%$, respectively. Therefore, the pretest and posttest data are both normally distributed.

Furthermore, the data of the pretest and posttest results will go through a paired sample t-test mean comparison test using paired sample t-test one tailed left side, with hypothesis

$H_0: \mu_{pretest} \leq \mu_{posttest}$, the average posttest score is not more than the pretest average

$H_1: \mu_{pretest} > \mu_{posttest}$, the average posttest score is more than the average pretest.

Thus, the values of degrees of freedom (df) and t_{count} are attached in Table 7.

If the value of $\alpha = 5\%$, then the value of t_{table} based on table G in Sudjana (2005) is $t_{table} = -t_{(.05;28)} = -1.71$. Since $t_{count} = 20.85 > -1.71$, the hypothesis H_0 is rejected or in other words, there is an increase in the average score of the numeracy literacy test in the research sample. Thus, the pretest and posttest data of the research sample have been declared both normally distributed and there is an increase in the average numeracy literacy test score of the research sample. Furthermore, to measure the effectiveness of the learning media, this media was tested on the average completeness test, proportion completeness test, and N-Gain test. The effectiveness test was conducted to measure the amount of improvement in the numeracy literacy skills of the research subjects. The average completeness test is a comparative test of posttest data against the Learning Objective Achievement Criteria (LOAC) of the research sample posttest results using a one sample t-test one tailed left side. If it is known that the learning objective achievement criteria applicable at the test location is 75, then the research hypothesis of the average completeness test is as follows

$H_0: \mu_{posttest} \leq 75$, the average posttest score is not more than the applicable LOAC

$H_1: \mu_{posttest} > 75$, the average posttest score is more than the applicable LOAC

Therefore, the value of degrees of freedom (df) and t_{count} is attached in Table 8.

Table 8. Average Completeness Test Results

One-Sample Test					
	Test Value = 75				
	t	df	Mean Difference	95% Confidence Interval of the Difference	
				Lower	Upper
HasilPostTest	9.126	26	12.35926	9.5756	15.1429

If the value of $\alpha = 5\%$, then the value of $t_{table} = -t_{(.05;28)} = -1.71$. Because $t_{hitung} = 9.126 > -1.71$, the hypothesis H_0 is rejected or in other words, the average numeracy literacy ability of the research sample after the implementation of the media in challenge-based learning on STEM context learning is able to meet the minimum completeness criteria.

The proportion completeness test is a comparative test of the percentage of data groups that meet and do not meet the LOAC which refers to the posttest results of the research sample using the nonparametric binomial test with the hypothesis,

$H_0: Sig \leq 5\%$, the ratio of students who meet the LOAC is more than 80%

$H_1: Sig > 5\%$, the ratio of students who meet the LOAC is not more than 80%

If, the minimum completeness criteria applicable to the test location is 75 and the test proportion value is 80%, then the results of the proportion completeness test are attached in Table 9

Table 9. Proportion Completeness Test Results

Binomial Test					
	Category	N	Observed Prop.	Test Prop.	Exact Sig. (1-tailed)
HasilPostTest	Group 1	<= 75	3	.1	.000 ^a
	Group 2	> 75	24	.9	
	Total	27	1.0		

a. Alternative hypothesis states that the proportion of cases in the first group < .8.

The results of the proportion completeness test for the percentage of data groups that meet and do not meet the LOAC show $Sig. = .000 < 5\%$. Therefore, hypothesis H_0 is rejected or in other words the

proportion of students who meet the LOAC after implementing the media in challenge based on STEM context learning is more than 80%.

The N-Gain test is a test measuring the magnitude of the increase in the posttest results of research samples on their pretest scores using the formula $N - Gain = \frac{Posttest\ Score - Pretest\ Score}{Ideal\ Score - Pretest\ Score}$ whose scores will be averaged and then concluded based on the criteria in Table 2. With, the N-Gain test results are attached in Table 10.

Table 10. N-Gain Result

Descriptive Statistics				
	N	Minimum	Maximum	Mean
NGain	27	.55	1.00	.7766
Valid N (listwise)	27			

Based on the results of the N-Gain test, it is shown that the average N-Gain value of the research sample is in the Very Good category with an average N-Gain of $.7766 = 77.66\%$. Therefore, it can be concluded that the media is able to very well improve the numeracy literacy skills of any sample of research subjects. By fulfilling the average completeness, proportional completeness, and having an N-Gain value in the very good category, it can be stated that the media is able to improve literacy skills so that it meets the effectiveness test.

Not only looking at the effectiveness of the media in learning, the learning media must also get a positive response from students in order to provide comfort for students in using it. Based on Table 7, the average percentage of student response results was 89.54%. Thus, these results show that the development of the 2D game which integrated challenge based on STEM learning contexts received very good student responses.

The development of the 2D media game which is integrated with challenges based on STEM context learning is able to properly train students' numeracy literacy skills. Apart from that, interactive learning activities in the form of a virtual environment can facilitate students in analyzing abstract concepts and processing them independently to form new knowledge (Mulyani, 2022). This shows that the 2D game learning media which is integrated with challenge based on STEM context learning has the potential to facilitate students to develop their numeracy literacy skills by presenting problems that require mathematical modeling in them. Thus, the integration of the 2D game which is integrated with challenges based on STEM context learning has the potential to increase the value of numeracy literacy skills in PISA results.

4. Conclusion

The development of the learning media can effectively improve numerical literacy skills. Based on the results of the media feasibility test which showed an average final score is 90.23% and the results of the material feasibility test with an average final score is 91.02%, so the media has very good feasibility criteria in terms of media and material. The application of the media to the test subjects also showed an increase in numerical literacy skills that was very good with the fulfilment of average completeness, proportion completeness, and an excellent N-Gain value at 0.77. The results of students' responses after using the media also showed good results with an average final score of 89.54%. These results show that Integration of Challenge based on STEM Learning to 2D Game Interactive Scratch-Assisted is considered as a feasible and effective media to increase the value of numeracy literacy skills. Also, it has the potential to improve PISA results if applied on a wider scale.

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