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Fostering students' mathematical critical thinking skills on number patterns through digital book STEM PjBL

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Abstract

21st-century learning requires students to have the competency problem-solving and critical thinking, creative thinking, collaboration and communication. However, the mathematical critical thinking skills of Indonesian junior high school students remain relatively low. Therefore, the study aims to develop a digital book STEM PjBL to foster the students' mathematical critical thinking skills. To achieve this aim development and research of the Borg and Gall (Gall et al., 2007) model continued with the experimental research conducted using one group pre- and post-test design. Instrument tests of mathematical critical thinking skills and student perception questionnaires were employed to collect data. The findings indicate that the digital book STEM PjBL is valid and significant in fostering students' critical thinking skills and has a positive impact on other 21st-century learning skills. Furthermore, the data shows that students are satisfied and interested in learning through active teaching and learning methods that incorporate ICT tools and STEM-PjBL aspects.

Keywords: critical thinking, digital book, STEM-PjBL, 21st-century learning

INTRODUCTION

21st-century learning requires that students should be literate in the development and advancement of information and communication technology (ICT). With the rapid advancement of ICT, numerous researchers have recently discussed interactive digital books (Pearson, 2018). Technological advancement has unquestionably brought innovative technologies that could play a major role in restructuring teaching and learning practices (Simon & Garcia-Belmar, 2016). These advancements have given students access to far more information than was readily accessible. They have also influenced how students interact with materials. Digital books have more engaging tools that facilitate student learning both inside and outside of the classroom (Rockinson-Szapkiw et al., 2013). The use of interactive digital books is easier for students to understand compared to ordinary textbooks (Bih-Yaw et al., 2013), because it provides opportunities to practice students' critical thinking skills, especially in making question indicators that can foster students' thinking skills. Furthermore, the incorporation of multimedia in classroom instruction promotes the development of critical thinking skills and concept mastery (Rosida et al., 2017).

Digital books can foster critical thinking skills by utilizing electronic media, which contain information in the form of text, images, audio, video and graphics using tools that can be applied to interaction, creation and communication activities (Hofstetter, 2001). Several studies have shown the effectiveness of using digital books to improve students' critical thinking skills (Arini, 2017; Fardani et al., 2019; Nurcahyono & Kustijono, 2019;

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Contribution to the literature

- The digital book STEM PjBL is valid and significant in fostering students' critical thinking skills, that positively impact 21st-century learning skills, such as creative thinking, communication, and collaboration.
- The digital book STEM-PJBL provides the students with activities and exercises that involve the engineering design process related to Number Patterns that promote and stimulate critical thinking skills in mathematics.
- Students are satisfied and interested in learning once technology and STEM-PjBL aspects are incorporated into digital books utilizing active teaching and learning methods.

Qibtiya & Kustijono, 2018; Rasiman & Pramasdyahsari, 2014; Rosida et al., 2017; Suarsana & dan Mahayukti, 2013; Zulhelmi et al., 2017)

Furthermore, the students should have the competency and knowledge relevant to 21st-century learning such as critical thinking skills. Critical thinking is a cognitive process that encompasses the capability to analyze, assess, draw a conclusion, and solve a problem (Chen, 2017; Jatmiko et al., 2018; Rodzalan & Saat, 2015). Mathematical critical thinking skills are an important component of the 4C skills (problem-solving and critical thinking, creative thinking, collaboration, and communication) because it encourages students to interact with both natural and social environments in a practical and effective manner (Mahanal et al., 2019). However, Indonesian junior high school students of mathematical critical thinking skills remain relatively low. The current learning models and teaching materials are inadequate to fulfill the educational requirements of the 21st-century. Therefore, to accommodate the students' needs the learning process needs to provide the learning model and the teaching materials that support 21st-century learning.

One of the learning approaches that support the achievement of students' abilities in 21st-century learning is STEM (*science, technology, engineering, and mathematics*) approach, which links several fields of science so that students gain a holistic understanding of learning (Triyatma et al., 2017). Learning with STEM approach is contextual learning that allows students to understand phenomena in everyday life so that they can stimulate students' curiosity and understand cause and effect. STEM learning also has the potential to involve students directly and improve critical thinking (A'yun et al., 2020; Mutakinanti et al., 2018). Through the STEM approach students are honed to think critically by learning to solve and examine problems using technological tools and creative collaborative learning strategies (Nursyahidah et al., 2021; Pramasdyahsari et al., 2021). In addition, the STEM approach also has several advantages that are in line with 21st-century learning including presenting students' interdisciplinary perspectives, developing 21st-century skills, developing problem-solving abilities, critical thinking, and supporting digital literacy (Bybee, 2010; Gulhan & Sahin, 2016; Kennedy & Odell, 2014; Morrison, 2006; Olivarez, 2012; Ricks, 2006; Roberts, 2012; Sahin etal., 2014). Therefore, the implementation of STEM approach to learning mathematics can be carried out in Indonesia to prepare quality human resources who are ready to face challenges and competition in the 21st-century (Anindayati & Wahyudi, 2020). Collaborating to project-based learning (PjBL) that integrated with technology resulted in better students learning outcomes (Inayah et al., 2021), PjBL-STEM has advantages and disadvantages that complement each other. PjBL students learn concepts by creating products, whereas STEM learning students produce the best product through a process of design and redesign (Lutfi et al., 2018) called as an engineering design process (EDP).

Therefore, to accommodate the students' needs the learning process needs to provide the learning model and the teaching materials that support 21st-century learning. This study aims to develop a digital book STEM PjBL to foster the students' mathematical critical thinking skills.

METHODS

Research Design

This study is used for research and development (R&D) continued by the quantitative research method. The first stage is developing the digital book STEM-PjBL employing Borg and Gall's model (Gall et al., 2007; Sugiyono, 2010) for the first nine stages. Then the second stage was conducted through experimental research design, where the final prototype of the digital book STEM-PjBL was implemented. A quantitative method with a pre-experimental design and one group pretest post-test design (Creswell, 2014; Sugiyono, 2010, 2014). The study included both the independent and dependent variables. A digital book based on STEM-PjBL is the independent variable, while mathematical critical thinking skill is the dependent variable (Sugiyono, 2010). The study included one group only consisting of males and females. There is no rehearsal material related to the number pattern before the treatment. This study gave the pre- and post-test. The pre-test is the first test given before treatment, while the post-test is the second test given after treatment. The

purpose of giving these two tests is to determine the increase in mathematical critical thinking. The research took place in blended learning, which involves the application WhatsApp for collecting information and students' responses through Google Forms. The research subject involved 21 students were distributed into three students selected for participating in the preliminary testing, six different students with the previous testing selected for participating in the main field testing, and 12 different students with two previous testing selected for participating in the operational field testing. Meanwhile, for determining the effectiveness of the digital book there were 13 students were selected to participate completing the written test of mathematical critical thinking skill. The implementation involves the use of the laptop to access the digital book both online HTML and or application versions. Moreover, it requires the use handphone to access Adobe Animate for completing the project activity and reporting EDP, which follows the Jolly's (2016) framework that students have done. The selection of Google Forms and WhatsApp applications with the consideration that these applications are familiar to students and can help organize and communicate in the learning process (Lyken-Segosebe et al., 2022; Mallampalli & Goyal, 2021; Morsidi et al., 2021; Rahmadi, 2020).

Research Procedures

The current study is divided into two stages procedures: research and development (Borg and Gall's model) and experimental research. The following is a brief description of the research procedure.

Research & development stage (Borg & Gall's model)

Regarding the first nine stages of Borg and Gall's model (Gall et al., 2007; Sugiyono, 2010), the results from developing the digital book STEM-PjBL using context Semarang city are elaborated, as follows:

Research information: At the stage of collecting research information, the activities carried out are studying related literature, needs analysis from the school information related to the curriculum, students and the possible topic, then preparing a framework for indicators of mathematical critical thinking skills. Researchers collected information from relevant theories related to the design of the digital book, the mathematics learning activities based on STEM-PjBL, a framework for indicator mathematical critical thinking skills.

Planning: At the planning stage, the researcher designed the procedures for developing the digital book STEM-PjBL by determining the topics on the number patterns for junior high school and considering the framework of indicators of mathematical critical thinking skills. Furthermore, the researchers planned the necessary feasibility studies, namely developing media using the flip PDF pro-software and Adobe Animate then implementing prototypes; formulating the objectives of each stage; designing a digital book prototype design involving the main teaching principles, objectives, content, the learning sequence, syllabus format, and method of presenting material, as well as the type of assessment used in the digital book STEM-PjBL using context Semarang City.

Developing a preliminary form of the product: In this stage, the activities carried out were preparing teaching materials for the number pattern topic and designing the project activity-related topic and context of Semarang City, which is "DAM for flood controlling in Semarang". After designing the project activity, then the lesson plan and EDP were developed to be embedded in the digital book. In the end part of the digital book, it provides the possibility of students' answer or hypothetical learning trajectory (HLT) to solve the problem related to the given project activity in "DAM for flood controlling in Semarang". Moreover, the digital book also provides guidance for evaluation. These instructions function to evaluate the student's success on their projects.

Preliminary field testing: After the preliminary product was developed then preliminary field testing was carried out. This stage involved a limited scale of several selected students, there are three students in this pilot study. At this stage, the data is collected through interviews, students' responses and observation. Furthermore, the data is used to find various shortcomings or weaknesses as consideration for revising the prototype of the digital book STEM-PjBL using the context of Semarang City. Based on the interview and observation results, the three students respond positively to the use of a digital book in the classroom learning process that they had never used before. However, they were preoccupied with the large amount of text that was boring them. Moreover, interacting with digital flipbooks is quite challenging because it is recent to them. As a result, it becomes one of the factors to consider when improving the design of a digital book.

The questionnaire measuring aspect design, program, and learning as displayed in **Table 1** was distributed to obtain the students' responses. This questionnaire was used related to several aspects to evaluate the prototype of the digital book STEM-PjBL using context Semarang cities such as design, programming and learning.

The result of students' responses shown in **Figure 1** corresponds to each aspect based on a Likert scale of 1-5 that is designed aspect is 4.722 of 5, the programming aspect 4.556 of 5, and the learning aspect 4.75 of 5.

Revising main product of preliminary product: This stage is a refinement of the initial prototype of the digital book STEM-PjBL using the context of Semarang City that has been tested at the beginning. At this stage,

Table 1. Assessment aspect of questionnaires

No	Aspect	Statement
1	Design	The design of the digital book is clear.
		The design of the digital book is interesting.
		The arrangement of the material makes it easier to learn.
		The font display on the material can be read clearly.
		The supporting images on the material can be seen clearly.
2	Program	The digital book can be operated easily.
		The page I want can be accessed/searched easily.
		The digital book can be accessed easily on a computer/laptop.
3	Learning	The material provided in the digital book is clear.
		The title of each chapter is clear.
		The material in the digital book is easy to understand.
		Instructions for questions/tests in the digital book are clear.

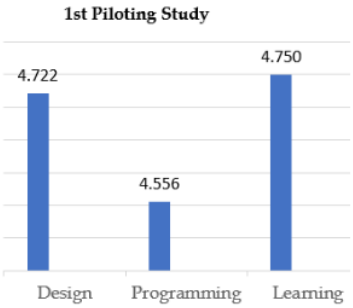


Figure 1. Students' response to each aspect of digital book in the 1st piloting study (Source: Authors' own elaboration)

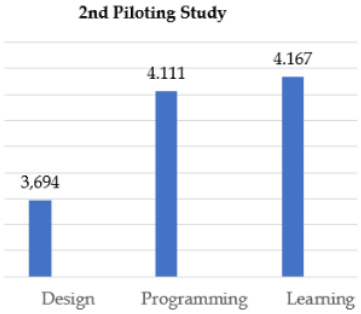


Figure 2. Students' response to each aspect of digital book in the 2nd piloting study (Source: Authors' own elaboration)

improving the quality of the previous product, which is a large amount of text instead of a picture, causes the students to become bored. As a result, the refinement product was modified by including more images that were closely related to the learning context. The students' responses from the distributed questionnaire become a consideration for improving the quality of each aspect. Revisions were carried out until obtaining a better product prototype, which is called the main product. This main product is then ready to be tested again on a wider scale.

Main field testing: At this stage, the main product of the digital book STEM-PjBL using the context of Semarang city was tested on a larger scale with six different students. The reason for choosing six students is based on Gall et al. (2007), where the main field testing it involves 5-15 schools with 30-100 users. However, because it was carried out in a single classroom, the rationale is to employ a ratio of at least six students in one school. The students' responses to the distributed questionnaire are considered when improving the quality of each aspect. The results show that different students in the first piloting study achieve a wide range of distribution scores for various aspects.

As shown in **Figure 2**, the aspect design received the lowest score among the others. The score for aspect design was 3.694 out of 5, aspect programming received

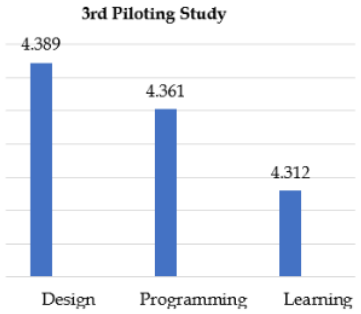


Figure 3. Students' response to each aspect of digital book in the 3rd piloting study (Source: Authors' own elaboration)

4.111 out of 5, and aspect learning received 4.167 out of 5. In comparison to the previous results, it can be seen that with the different students, even though the product's quality has improved based on the students' interview and questionnaire results, the design aspect remains the primary concern.

Figure 3 shows the 3rd pilot study.

Revising operational product: The activities carried out during the operational product revision stage include revising the main product of the digital book STEM-PjBL that has been tested in field trials. The

Table 2. Expert validation results

No	Aspect	Average score each aspect	Maximum score	Conclusion
1	Learning	4.4	5	
2	Critical thinking	4.6	5	
3	Evaluation	4.8	5	
4	Design activities STEM-PjBL	4.6	5	Can be used with minor revision
Total		18.4	20	
Average score		4.6	5	
Validity level		**92%**		
Category		**Very valid**		

product is then created as an operational model design, which is then validated. Through a focus group discussion (FGD), researchers put a prototype digital book STEM-PjBL to be tested. The reviewers involved in this process are mathematics education study program experts such as mathematical critical thinking experts, digital mathematics media development experts, and STEM in mathematics education experts. FGD activities provide researchers with feedback and suggestions for revising the prototype of the digital book STEM-PjBL. The definition of a digital book is still debated among mathematics education experts in FGD forum. Therefore, the suggestions for improvement include the digital book format and the features required, aspects of critical thinking that must be highlighted in STEM projects, and clearly visible aspects of EDP.

Operational field testing: At this stage, the revising product of the digital book STEM-PjBL is called the prototype product. The prototype product was carried out on a wider scale with 12 different students with the previous testing. Gall et al. (2007) explain that the number of chosen students in this stage is greater than the number of students in the previous stage. The consideration of selecting 12 different students because the total number of students in the classroom is 21, while nine students have participated in previous testing. The students' response from the distributed questionnaire becomes a consideration for improving the quality of each aspect.

During this stage, activities included expert validation of mathematical critical thinking skills aspects, STEM-PjBL aspects, and digital book validation in terms of learning and evaluation aspects. Based on the average score of the expert validation result in **Table 2**, the aspect of mathematical critical thinking skills and design activities on the digital book receives an average score of 4.6 out of 5. Meanwhile, the average score for the learning aspect is 4.4 out of 5, while the evaluation aspect is 4.8 out of 5. The overall average score is 4.6 out of 5. According to the Likert scale, the digital book contains a category that is very valid. With a minor revision, the product could be used. This validation result is taken into consideration when revising the product in the final step. Furthermore, the validated product has been revised and is ready for testing.

Considering the results of each stage, all of the aspects measured appear to have improved and obtained a good average score. Despite the fact that each stage involves different students, the results for each testing stage demonstrated an improvement in a specific aspect. This implies that the improvement could be accepted by all students and be generally valid. The significant increase in each value is due to quality assurance advancement based on the students' questionnaire and constructive feedback from the expert validator.

Regarding expert validity, the product gains a validity score of 92%, it similar to Creswell (2014) and Sugiyono (2010, 2014) who conducted a design and development study with the goal of validating an effective instructional model, and this model demonstrates that it facilitates the teaching process for teachers and student learning after expert validation.

Revising the final product: The activity carried out at this stage is to revise the final product, which is completely revised by the data obtained in step eight and launched as the final product of the digital book STEM-PjBL. The researchers revised the product for better quality after expert validators provided feedback and suggestions on the strengths and weaknesses of the digital book STEM-PjBL. The final outcome is a collection of digital book prototypes based on STEM-PjBL that can be further developed to meet the needs of mathematical critical thinking. This digital book is divided into two categories: teachers' books and students' books.

As shown in **Figure 4**, the teacher's book contains references to STEM-PjBL and critical thinking, as well as a lesson plan, project activity, evaluation, a hypothetical learning trajectory, and rubric scores. Meanwhile, the students' book only contains the project plan and report activities completed with the Adobe Animate application.

Experimental design

In this stage, the prototype was implemented into one class. Before conducting the implementation product, the researcher develops the instrument test of mathematical critical thinking. This instrument used Ennis' (1991) framework for determining the indicators

Figure 4. Digital book: Lesson plan (Source: Authors' own elaboration)

of mathematical critical thinking. The instrument was tested in the trial class then the validity and reliability instruments test of mathematical critical thinking was analyzed by using Rasch model using the Winstep application. After obtaining the valid and reliable test of mathematical critical thinking skills then it was distributed as the pretest. In the experiment classroom, the students experience the treatment. There is no rehearsal material related to the number pattern before the treatment. During the treatment, the students use the digital book STEM-PjBL on their chrome book and laptop. After the material have been read, then within a group consisting of five-six students, worked on the STEM-PjBL project activity by following the procedures of EDP. Each group presents the progress of their work. After the treatment, a post-test was conducted on a different day to check how the treatment effect on students' mathematical critical thinking.

The data was analyzed for its normality and homogeneity for both the pretest and posttest using SPSS. Then the alteration of students' mathematical critical thinking was measured using the N-Gain formula.

RESULTS AND DISCUSSION

Digital Book STEM-PjBL

Regarding the revision of the final product, the hypothesis product was implemented to understand how students respond to the learning process by using the digital book STEM-PjBL project activity. To make it easier for both students and teachers to complete the project, the digital book includes a lesson plan for teachers, as shown in **Figure 4**. However, the learning process is not restricted to this plan. Depending on the circumstances in the classroom, both teachers and students could improve and elaborate on it.

Table 3 shows the students' responses when they used the digital book STEM-PjBL during the lesson. It demonstrates that project-based learning with a STEM approach elicits positive responses from students. According to Bih-Yaw et al. (2013), the use of interactive digital books is easier for students to understand than traditional textbooks.

The digital book is designed based on the student's level of understanding; it shows from **Table 3** that 90.5% of students respond that the digital book enables students to self-learning according to their ability. Besides, 85.7% said that the digital book also provides independent teaching material. These results were confirmed by Gupta and Sharma (2016), Rani and Chinnasamy (2014), and Wagwu and Obuezie (2019) that students are satisfied with the use of digital resources. The students are also interested in learning through active teaching and learning methods, by integrating ICT tools and using a textbook (Jolly, 2016). Moreover, the digital book STEM PjBL gains a 90.5% score for its attractiveness to motivate students to learn. The digital book STEM-PjBL is interesting to attract the students to learn. It is in line with Albert et al. (2021), Martins (2012), and Suarsana (2021) that students are satisfied with the use of a textbook. The use of digital tools encourages student engagement in learning activities (Moundy et al., 2021, 2022; Snape, 2017). Moreover, it shows that more than half of respondents respond that the digital book encourages the students to concentrate on thinking, constructing concepts, and facts

Table 3. Students respond by using the digital book STEM-PjBL during the lesson

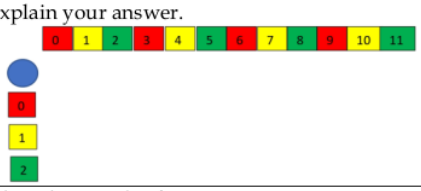
No	Statement	Respond (%)				
		SA	A	F	D	SD
1	I can understand the material in STEM-PjBl-based digital books to improve mathematical critical thinking skills.	19.0	38.1	33.3	9.5	0.0
2	Digital book STEM-PjBL based to improve mathematical critical thinking skills allows me to study according to my abilities.	42.9	47.6	9.5	0.0	0.0
3	Digital book STEM-PjBL based to improve mathematical critical thinking skills could become an independent teaching material for students.	38.1	47.6	9.5	4.8	0.0
4	Digital book STEM-PjBL based to improve mathematical critical thinking skills encourage me to be active in activities and experiments.	33.3	42.9	14.3	9.5	0.0
5	Digital book STEM-PjBL based to improve mathematical critical thinking skills inspires me to concentrate on thinking, constructing concepts, facts, & drawing conclusions.	14.3	42.9	33.3	0.0	9.5
6	I am interested in learning materials using digital book STEM-PjBL based to improve mathematical critical thinking skills.	33.3	47.6	19.0	0.0	0.0
7	The learning process using STEM-PjBL based digital books to improve mathematical critical thinking skills is fun.	23.8	52.4	19.0	4.8	0.0
8	The display of digital book STEM-PjBL based to improve mathematical critical thinking skills attracts me to learn.	42.9	47.6	9.5	0.0	0.0
9	The use of language is easy to understand so I am clear with the material presented.	23.8	52.4	19.0	0.0	4.8
10	Presentation of digital books STEM-PjBL based to improve mathematical critical thinking skills broadens my understanding of how to use math applications effectively.	38.1	57.1	4.8	0.0	0.0

Figure 5. Digital book: STEM-PjBL project activity (Source: Authors' own elaboration)

and drawing conclusions. It confirmed that the previous study reveal that the use of digital simulations enables students to develop visual images during the learning process, which improves their critical reasoning (Fraile-Fernández et al., 2021; Yoon et al., 2021). As a result, the utilization of digital books STEM-PjBL can promote students' mathematical critical thinking, which is consistent with previous research showing that STEM students' reasoning ability can be enhanced by gaining knowledge using digital simulation (Verawati et al., 2022). Furthermore, 76.2% of students show that the digital book could encourage them to be active in the activities and experiments.

As illustrated in **Figure 5**, STEM-PjBL project activities are divided into three sections in the digital book. The first activity requires students to understand the problems and plan out several potential solutions. The second activity requires students to devise the best solutions to the problem. Finally, the third activity allows students to discuss in groups how to minimize the problem once the main problem has been solved.

Table 4. Instrument test of mathematical critical thinking skill STEM-PjBL based

No	Test
1	Cheerleaders in a basketball match do attractions that form a human pyramid. Attractions shown are standing between players, then at its peak only one person stands. If pyramid is 1 level, then 1 person is needed, if it is 2 levels, 3 people are needed, if it is 3 levels, 6 people are needed, & if it is 4 levels, 10 people are needed, & so on. a. What information do you know from the questions above? b. What number pattern is formed from the attraction? Explain your reasons. c. Do you agree that if the pyramid is 5 levels the number of people needed is 27? Explain your reasons.
2	The following are pieces of ribbon in red, yellow, green containing numbers as shown below. a. If the band is extended with an existing pattern, will it form a number pattern? Explain your answer. b. Write down the number pattern formed from the bands of the same color. c. Is the band at number 100 red? Explain your answer. 
3	Rewanda Kirab is a tradition carried out by people of Gunung Pati, Semarang City in month of Shawwal after Eid al-Fitr. This tradition aims to commemorate legacy of Sunan Kalijaga when looking for teak wood to be used for construction of Great Mosque Demak. In enlivening Rewanda Carnival, community makes mountains of various market snacks, fruits, & vegetables. One community group arranges a mountain of vegetables in first place at top of mountain there is 1 vegetable, then in second place there are 2 vegetables, in third place there are 4 vegetables, in fourth place there are 8 vegetables, & so on with same pattern. Help community group to determine number of vegetables needed if community group wants to arrange up to 7th order? a. What information do you know from the story above? b. What problems must be solved? c. What are the steps to solve this problem? d. What is the pattern formed in the preparation of the mountain of vegetables? e. Do you agree that number of vegetables needed for a mountain of up to 7th place is 130 vegetables? Explain your reasons.
4	Every August my father put up colorful flags in front of the house to enliven the atmosphere of independence. The flag consists of green, yellow, and red and repeats continuously with the same pattern. The number of these flags is 25 each. Determine the color of the flag that will rank 17th. a. What are the steps in determining it? Explain your answer. b. The yellow flag always appears in an even-numbered sequence. What do you think, do you agree with this statement? Give your reasons.

Instrument Test of Mathematical Critical Thinking Skill STEM-PjBL Based

The instrument test of mathematical critical thinking skill STEM-PjBL was developed based on the indicator Ennis's (1991) framework. The instruments were checked its validity through expert judgement as elaborated in **Table 4** and then distributed to students to check the practice validity. After the instrument test was distributed then the validity and reliability were determined by using Rasch model analysis through the Winstep software application.

Validity and reliability

The validity and reliability instruments test of mathematical critical thinking STEM-PjBL was analyzed by using the Rasch model using the Winstep application. **Figure 6** shows that the *person reliability*, *Cronbach's alpha* and *reliability* show numbers of 0.76, 0.81 and 0.72 respectively. Based on the reliability requirements, the critical thinking test instrument on number pattern material is said to be consistent or *reliable* since the results are >0.70 (Sumintono & Widhiarso, 2015).

```
|          TOTAL                        MODEL        INFIT        OUTFIT    |
|          SCORE     COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-------------------------------------------------------------------------------|
| MEAN      67.3      13.0         .15     .11      1.04     .0   1.08     .1 |
| S.D.      17.9        .0         .26     .02       .46    1.1    .52    1.1 |
| MAX.     100.0      13.0         .53     .18      2.64    2.7   2.87    3.0 |
| MIN.      22.0      13.0        -.63     .10       .46   -2.1    .48   -1.8 |
|-------------------------------------------------------------------------------|
| REAL RMSE    .13 TRUE SD     .23  SEPARATION  1.77  PERSON RELIABILITY  .76 |
|MODEL RMSE    .11 TRUE SD     .24  SEPARATION  2.06  PERSON RELIABILITY  .81 |
| S.E. OF PERSON MEAN = .05                                                     |
-------------------------------------------------------------------------------
PERSON RAW SCORE-TO-MEASURE CORRELATION = .98
CRONBACH ALPHA (KR-20) PERSON RAW SCORE "TEST" RELIABILITY = .72
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Figure 6. Winstep output reliability test (Source: Authors' own elaboration)

The difficulty level of the critical thinking test instrument on the number pattern material with *Winstep in the measure* column show numbers in the range of -0.32 to 0.29, which, based on the criteria Rasch model analysis (Sumintono & Widhiarso, 2015) the level of difficulty of this test instrument is in the medium category.

ITEM STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	ITEM
10	108	32	.29	.08	1.55	1.7	1.57	1.8	.42	.39	12.5	18.9	3d
12	122	32	.21	.08	1.44	1.5	1.40	1.4	.48	.41	18.8	18.2	4a
9	124	32	.20	.08	1.31	1.2	1.19	.7	.41	.42	15.6	17.6	3c
11	127	32	.18	.07	.37	-3.2	.42	-2.7	.62	.42	18.8	18.3	3e
2	140	32	.11	.07	.99	.0	1.50	1.8	.01	.44	15.6	17.1	1b
4	149	32	.07	.07	.69	-1.5	.81	-.8	.44	.45	12.5	18.5	2a
13	155	32	.04	.07	1.00	.1	.98	.0	.62	.46	25.0	18.2	4b
6	172	32	-.04	.07	.51	-3.0	.61	-2.1	.55	.48	21.9	13.8	2c
3	189	32	-.11	.07	.66	-2.0	.86	-.7	.28	.50	12.5	9.1	1c
8	206	32	-.18	.07	1.02	.2	1.06	.4	.56	.52	3.1	9.4	3b
1	211	32	-.21	.07	1.20	1.1	1.13	.7	.58	.52	6.3	9.3	1a
7	216	32	-.23	.07	1.31	1.6	1.27	1.3	.58	.53	3.1	8.0	3a
5	236	32	-.32	.07	1.28	1.3	1.21	.9	.51	.56	6.3	6.6	2b
MEAN	165.8	32.0	.00	.07	1.02	-.1	1.08	.2			13.2	14.1	
S.D.	40.4	.0	.19	.00	.36	1.7	.33	1.4			6.7	4.6	

Figure 7. Winstep output validity test (Source: Authors' own elaboration)

After analyzing difficulty level, the discriminating power was determined as seen at **Figure 7**.

The results show that there is only one item number 1b that needs to be followed up because it placed at less criteria 0.01. However, this items still could be used. The next analysis is to analyze the validity based on predetermined criteria. The first criterion reviewed based on the validity requirements of this first criterion is that MNSQ outfit value placed within 0.5-1.5 (Sumintono & Widhiarso, 2015).

Based on this requirement, there are three invalid items, namely 3d, 3e, and 1b with respective values of 1.57, 0.42, and 1.50. Except, these three items are all valid. Then the second criterion is reviewed, the items were valid if the value within -2<x<2. In this criterion, there are two invalid items, namely in items 3e and 2c with respective values of -2.7 and -2.1. Except these two items are determined as valid since fulfilling the criterion.

Finally, the third criterion is reviewed. In this third criterion, the items are considered valid instruments if the value of *point measure correlation is* within 0.4<x<0.85. Based on this criterion, there are two items that do not meet the criteria or are invalid, namely items 1b and 1c with respective values of 0.01 and 0.28, apart from these two other items are said to be valid because they meet the criteria. However, based on the three criteria above, an item is said to be valid if it meets at least one criterion (Sumintono & Widhiarso, 2015). Then, all the items on the critical thinking test instrument are declared valid because they meet at least one of the criteria.

Table 7. Pre- & post-test of critical thinking on number patterns

Description	Pre-test	Post-test
The highest score	58	100
The lowest score	22	40
Average score	37	70

Effectiveness of Digital Book STEM-PjBL to Foster Students' Mathematical Critical Thinking Skills

Normality test

The researchers involved 13 students from the total students in the developing stage in this stage to test the effectiveness of the digital book STEM-PjBL. This decision was made due to the willingness to participate. The normality test on the pretest and post-test critical thinking on the number patterns resulted in positive results, with a value of 0.658 for the pretest and 0.84 for the post-test after being tested with a data distribution of 13 student scores from each test, indicating that the results of the pre- and post-test critical thinking material on number patterns are normally distributed (**Table 5**).

Homogeneity test

Following the normality test, the homogeneity test was conducted to determine whether the data obtained is homogeneous. **Table 6** describes the results of homogeneity test. According to the criteria, data is said to be homogeneous if it is greater than 0.05 and the results of the critical thinking pretest and posttest on the number pattern material are homogeneous.

As illustrated in **Table 7** that the lowest score that could be achieved was 13 and the average obtained in the class after the posttest was 39. Thus, the use of digital books shows an increase in students' mathematical critical thinking skills in number patterns material. Based on the results of a critical thinking pretest on number pattern material given to 13 class VIII students at SMP Barunawati Semarang, the highest score was 58, while the lowest score was 22. The average score then shows a number of 37 with a total of 486 from the

Table 5. Tests of normality

Class	Kolmogorov-Smirnov [a]			Shapiro-Wilk		
	Statistics	df	Sig.	Statistics	df	Sig.
Pre-test	.157	13	.200 *	.954	13	.658
Post-test	.119	13	.200 *	.966	13	.840

Note. *This is a lower bound of the true significance & [a]Lilliefors significance correction

Table 6. Tests of homogeneity

Student test results	Levene's statistics	df1	df2	Sig.
Based on means	3,445	1	24	.076
Based on median	2,591	1	24	.121
Based on the median and with adjusted df	2,591	1	20,624	.123
Based on trimmed mean	3,453	1	24	.075

Table 8. The results of the analysis of N-gain scores on the critical thinking number pattern material

	Descriptive statistics				
	n	Minimum	Maximum	Mean	Standard deviation
N-gain score	13	.09	1.00	.5067	.29235
N-gain person	13	9.09	100.00	50.6731	29.23502
Valid N (listwise)	13				

maximum possible score, which is 1300. Based on the results of the student answer sheets, it was determined that the students were unable to explain the steps in solving the problems presented. Furthermore, during the pretest, students appeared to have difficulty working on the questions given because they were unsure of how to solve the problem. This demonstrates that students' critical thinking skills at SMP Barunawati Semarang remain low.

Following that, it was asked if holding learning using a digital book based on STEM-PjBL could improve student posttest results. The posttest results showed a significant increase, with one student achieving a perfect score of 100, while the lowest score was 40. Furthermore, the average obtained after treatment increased significantly, from 37 to 70. The total number of student scores was also increased from 486 to 907. Based on these findings, it is possible to conclude that learning with digital books STEM-PjBL can improve critical thinking skills at Barunawati Middle School Semarang.

N-gain score attempts to determine whether or not a method increases. N-gain test is performed by subtracting pre- and post-test values. The results of the pre- and post-test material on critical thinking number patterns were conducted with a total of 13 students at Barunawati Middle School Semarang, consisting of eight students and five female students. The average result of the N gain test, as shown in **Table 8**, is 0.5. This method is based on the N-gain test with moderate criteria, according to the results. This is due to students' failure to take the post-test seriously. Furthermore, even though the concepts and material had been presented previously and reviewed again during implementation, students' initial abilities remained below average.

In general, the use of digital books based on STEM-PjBL could improve students' mathematical critical thinking. Given the students' initial abilities, which are below average, this will be a long learning experience for them. Through STEM project-based learning, students gained experience with collaboration and communication. Furthermore, they are accustomed to solving problems step by step and have the opportunity to raise their arguments in group discussions. The presence of an EDP in this project allows students to achieve 21st-century learning skills such as problem solving, critical thinking, creative thinking, collaboration, and communication, which is in line to Jolly (2016).

CONCLUSIONS

The results show that the digital book STEM PjBL has been developed using the model Borg and Gall are valid. This digital book was developed by incorporating the mathematical critical thinking skills indicators and STEM-PjBL aspects. The students have the opportunity to stimulate their mathematical critical thinking skills through EDP. Moreover, the digital book STEM-PJBL provides the students with activities and exercises that promote mathematical critical thinking skills. The instruments of mathematical critical thinking skills have checked the validity and reliability of each item by using Rasch model analysis. The implementation of the digital book STEM-PjBL showed that there is a significant gain to foster students' critical thinking skills. Furthermore, the implementation of a digital book STEM-PjBL stimulates the skills required for 21st-century learning, such as creative thinking, collaboration, and communication. Students are impressed with the digital book STEM-PjBL and are interested in acquiring knowledge through active teaching and learning methods that incorporate ICT tools and STEM-PjBL aspects. The findings suggest that the mathematics learning process should accommodate the necessity of 21st-century skill learning abilities. Incorporating technology and 4C skills through the use of digital books STEM-PjBL could thus be one alternative solution to accustom teachers to facilitating students' needs. However, due to the limitations of this study, there is a need for additional research to broaden the research sample and expand the mathematical topics in the junior high school curriculum.

Author contributions: ASP: made substantial research design including research procedures, design of instrument test of mathematical literacy, project activity of STEM PjBL, & digital book content, analyzing & interpreting data, & drafting work; **RDS:** designed instrument test of mathematical literacy, implemented design product, & analyzed data; **SNA:** contributed to designing instrument of mathematical literacy, implementation of project activity, analysis, & interpretation of data; **UN:** contributed to designing instrument of mathematical literacy & implementation of project activity; **JPA & WW:** contributed to developing software for digital books & software for students' activities; **IDA:** contributed to implementation of project activity, analyzing & interpreting data; **NZ:** contributed to implementation of project activity & analysis of data; & **US:** designed activities of STEM-PjBL project & digital book content. All authors have agreed with the results and conclusions.

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