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2D Exploration Game Developed with Unity Integrated with Challenge Based on STEM Context Learning on Critical Thinking Skill

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Abstract. Critical thinking skill is one of the 4C elements that are important in 21st century education. However, the facts show that the current condition of students' critical thinking skills in Indonesia is still relatively low. One of the innovative solutions that can be done is through the development of learning media in the form of 2D exploration game developed with Unity game engine. The use of a challenge based on STEM context learning model can create deep learning through solving real problems. This research aims to summarize conclusions related to the effect of 2D exploration games developed with Unity that integrates challenge based on STEM context learning on improving critical thinking skills. This research was conducted by reviewing relevant national and international literature. The results show that 2D exploration game developed with Unity have advantages such as flexibility in facilitating interactions that allow players to be actively involved in the learning process through exploration and increase students' interest in learning, so it has a positive effect on critical thinking skills. Furthermore, challenge based on STEM context learning can encourage students' ability to solve problems analytically through meaningful learning thus potentially encourage their critical thinking skills. The results of this study indicate that 2D exploration games developed with Unity integrated with challenge based on STEM context learning have potential to improve students' critical thinking skills through interactive and contextual learning experiences.

INTRODUCTION

Science and technology are increasingly developing in each century creating various challenges in dealing with changes in each time. The 21st century requires humans to adapt to existing developments with supporting abilities [1]. The provision of these abilities is realized in education, where there are 4 learning abilities that are emphasized in 21st century education called 4C, the elements are critical thinking, creative thinking, communicating, and collaborating [2]. The emphasis on these 4 elements in 21st century education is intended so that students have personal and social skills to face challenges in a rapidly changing world [3].

Dewi and Purwanti stated that in facing increasingly complex problems, the critical thinking skill as one of the 4C elements is needed by an individual in making decisions when faced with certain problems [1]. Critical thinking skill is defined as the expertise in reviewing and assessing information obtained from observation, implementation, reasoning, and communication in order to make decisions whether the information can be trusted or ignored [4]. Encouraging this ability has an influence in preparing them to become flexible and adaptive thinkers in facing future challenges, whether in a professional context or everyday life [5].

Although it is considered important to have, the current facts show that the critical thinking skills of students in Indonesia are still in the low category. Based on research conducted by Pertiwi, the critical thinking skills of students are still low, it can be seen from the number of students who meet the indicators of critical thinking skills below 50% [6]. In line with Firmansyah's research, states that of the four subjects who were given critical thinking test questions, only one was able to fulfill the four indicators of mathematical critical thinking skills [7]. This is also supported by Indonesia's acquisition of the mathematics element in the PISA score precisely in the last two publications. In PISA 2018, Indonesia's score showed 379 out of 489 in the world average score, and 366 out of 472 in the PISA 2022 average [8]. This shows a decrease in scores each year and the value is still far from the

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international average. In addition, the TIMSS 2015 publication results show that Indonesia is at a score of 397 from the international average score of 500 [9]. One of the PISA and TIMSS assessment indicators in the mathematics element is the critical thinking skill [10][11]. Based on these data, it can be concluded that the fulfillment of critical thinking skills in Indonesia is still a real challenge and an effort is needed to overcome this.

One of the alternatives in achieving the improvement of critical thinking skills is the innovation of learning media such as educational games in the form of 2D exploration games. 2D exploration games are designed as a virtual world innovation with 2 dimensional visuals as environmental objects in exploration activities in learning. Learning with exploration activities allows students to freely observe various things around them randomly and interactively in a wide environment [12]. Based on research conducted by Hussein et al, learning that is integrated into digital games can make the learning atmosphere fun so that it allows students to fully focus on the learning process which has an impact on improving their learning outcomes, including in learning that is focused on critical thinking skills [13]. The use of exploration games in learning can support an interesting learning process and have a positive influence on students' critical thinking skills [14].

Various types of game development software can be used in creating 2D exploration games that are interactive and support various activities in the game, one of them is Unity game engine. Unity is a game development software that has the advantage of creating very flexible features [15]. According to Creighton, Unity is a technology that makes it simple and easy for game developers to create games [16]. Therefore, it can be concluded that Unity can facilitate the development of 2D exploration games that will be focused as learning media oriented towards critical thinking skills.

The use of innovative learning media in the classroom is inseparable from the application of an appropriate learning model [17]. As an effort to improve critical thinking 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) context into each stage of CBL (Challenge Based Learning). The CBL model combines the concepts of contextual learning based on real problems and collaborative projects in the implementation process [18]. Learning with a contextual problem approach has an effect on improving students' critical thinking skills [19]. In an effort to support the concept of contextual learning, STEM elements are combined in the CBL syntax stages. The combination of CBL and STEM will present various math problems related to science in the daily lives of students [20]. 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 [20][21]. This is included in the indicator of encouraging students' critical thinking skills.

Based on this background, it can be concluded that the combination of 2D exploration game developed with unity game engine and integrated learning model of challenge based on STEM context learning can be a potential innovation in improving students' critical thinking skills. Therefore, this article will review relevant previous literature related to the potential of mathematics learning media in the form of 2D exploration games developed with unity and integrated learning challenge based on STEM context learning on critical thinking skills to the basic description of the media design that will be implemented in learning.

METHOD

The method used in this research is the literature review method, which examines various previous national and international literatures that are relevant to the topic discussed. The technique used involved three main stages, namely organize, synthesize, and identify. The first stage is organize, involved collecting relevant literature related to the development of 2D exploration games with Unity and its integration with challenge-based learning contexts in STEM to improve critical thinking skills. The literature collected included journal articles, books, and other reliable sources that discussed 2D exploration game development and challenge based on STEM context learning implementation. The second stage, synthesize, is the process of unifying and organizing information from the literature that has been collected. At this stage, various concepts and findings from related literature are combined to form a comprehensive framework of understanding regarding the effect of 2D exploration game development integrated with challenge based on STEM context learning on critical thinking skills. Finally, the identify stage aims to identify research gaps, current trends, and further development opportunities based on the literature analysis that has been carried out so as to obtain results that are in accordance with the research objectives. The initial result and discussion subchapter will focus on the synthesize stage, and the last subchapter will contain the identify stage of this research. The results of these three stages are expected to provide deep insight into the development of 2D

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exploration games developed with Unity integrated with challenge based on STEM context learning to improve students' critical thinking skills.

RESULT AND DISCUSSION

Critical Thinking Skill

The Partnership for 21st Century Skills has identified 4 abilities needed in the 21st century, one of them is critical thinking skills [22]. Critical thinking skills are defined as the ability to process information objectively, build links between various information, analyze information, evaluate and conclude [2]. Noer states that critical thinking is a process that leads to making conclusions about what we should believe and what actions we will take [23]. According to Anugraheni, critical thinking is the ability to analyze, connect, and create all aspects of a given situation or problem [24]. Based on those opinions, it can be concluded that the critical thinking skills is a person's ability to analyze information that is already known and use it to evaluate and develop solutions to existing problems. Critical thinking is one of the important competencies that need to be achieved in learning mathematics, because mathematics is not only about short solutions with numbers, formulas, and symbols, but also requires high analytical power in processing information and concluding it [25]. This is also in line with the description of the Profil Pelajar Pancasila, including; (1) Faithful, devoted to God Almighty, and Noble, (2) Globally Diverse, (3) Mutual Cooperation, (4) Independent, (5) Critical Thinking, and (6) Creative [2]. There are 5 indicators of critical thinking skills according to Ennis, including basic clarification, basic support, inference, advanced clarifications, and strategies/tactics. Table 1 below is a description of each indicator of critical thinking ability [26].

TABLE 1. Critical Thinking Skill Indicators

Indicators	Description
Basic Clarification	1) Focus on a question 2) Analyzing argument 3) Asking and answering questions of clarification
Basic Support	1) Judging the credibility of a source 2) Observing and judging observation reports
Inference	1) Deducting and judging deductions 2) Inducing and judging inductions 3) Making and judging value judgements
Advanced Clarifications	1) Define terms and judge definitions 2) Identifying assumptions
Strategy and Tactics	1) Deciding on action 2) Interacting with others

2D Exploration Game Developed with Unity Game Engine

2D exploration games have developed around us with various characteristics [27]. However, most of the existing exploration games were developed with the sole purpose of being a leisure game and fun media. Aula also explained that 2D exploration game is a type of game with characteristics in the form of a virtual world map with 2 dimensional visuals that allows interactive exploration activities in it [27]. Exploration game innovation as a learning media in the classroom can be a strategy that has a positive impact on the learning process, this is related to the exploration activities carried out by students. [28]. Exploration activities make students gather information and identify problems around them randomly [12]. It can be concluded that exploration activities in learning that are represented in a virtual environment can train students' ability to analyze problems and process them independently into new knowledge, which is in line with the definition of critical thinking skills. In this case, the game media to be developed is focused on learning mathematics. According to Lestari et al, 2D exploration game as a learning media is an innovative strategy in learning that can support various orientations of abilities in learning, in this case of

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course including critical thinking skills [14]. This is also supported by research by Arimbawa et al which states that exploration games in the form of virtual worlds in learning mathematics can improve students' critical thinking skills [29].

The developer software that can be used in developing interactive 2D exploration games as math learning media is Unity. Unity is a game engine or game developer tool with advantages in the form of creating features that are very flexible and fairly easy to use [15]. Creighton also stated that Unity is a form of technology that makes it simple and easy for game developers to create flexible games according to the user's preferences. Based on this description, the use of Unity as a 2D exploration game developer software can support the creation of good learning media with various interactive learning activities for students.

The innovation of mathematics learning media in the form of 2D exploration games developed with Unity can encourage student involvement in the learning process [30]. In addition, Rangga also stated that the media creates fun learning so that it attracts students' interest in learning and supports the development of learning media that focuses on the indicators of critical thinking skills that want to be addressed in learning.

Challenge Based on STEM Context Learning

Challenge based on STEM context learning is a learning model that combines the nuances of STEM context (Science, Technology, Engineering, and Mathematics) into the challenge based learning (CBL) model. STEM context is used to support the contextual concept in CBL. In its implementation, the learning model will make STEM context as a nuance that is presented at every stage of CBL learning.

CBL learning focuses on real-life problems by combining the concepts of project-based learning, problem-based learning, and contextual learning [31]. The CBL model can encourage students' critical thinking skills [32]. In line with research by Azis and Ardianyah, the CBL model has a positive impact on improving critical thinking skills because it encourages students to be active in learning [33]. It is also said that students gain learning experience in constructing their own knowledge through solving problems encountered, the problem-solving process involves high-level reasoning which is also called critical thinking. Yoosomboon and Wannapiroon also explained that the syntax in the CBL learning model includes main idea (Big Idea) as an initial concept in learning processes that will be implemented to raise some triggering question (Essential Question) that needs to be resolved by students [34]. Next, students are asked to solve the collaborative project (Challenge) with a guiding resource as an aid to solving the problem given. There are also some guiding questions that serve as a clue in the guiding activity during the learning process. Next, students develop solutions to be implemented for real challenges (Solution Action). After that, students carry out the result of their project (Assessment) by presenting the solution that has been found to be published and evaluated by the teacher. Students then self-reflect on the results of the evaluation (Publishing and Reflection). The representation of CBL syntax is shown in Fig 1.

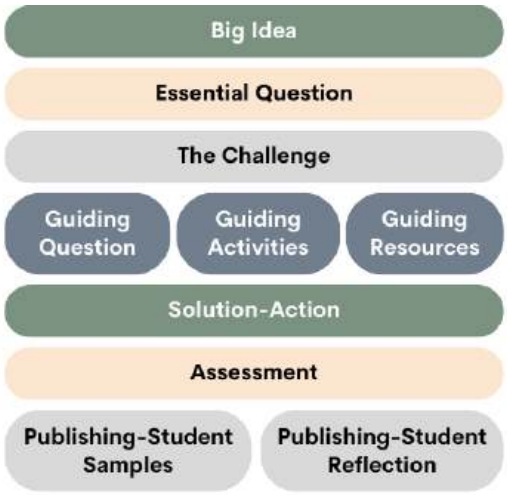

FIGURE 1. Syntax of Challenge Based Learning Model

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Furthermore, STEM is an approach that is formed based on a combination of several disciplines, namely science, technology, engineering, and mathematics. The STEM context focuses on integrating various concepts and problems that occur in everyday life [35]. According to Piaget's learning theory, participants' cognitive development must be considered through whether students actively interact with their environment or not [36]. Piaget also argues that children's knowledge is formed by children themselves through active exploration of the environment, this is in line with the application of STEM context as a real-life contextual element. In this 2D exploration game learning media innovation integrated with challenge based on STEM context learning, the STEM context element integrated is centered on the 'science' element focused on biological subfield. The implementation of STEM context in the learning process can encourage students' critical thinking skills [32][37].

The combination of CBL and STEM into a Challenge based on STEM context learning model will create a learning stage with deep involvement in students and the ability to construct a problem given to daily life. The combination of these two elements that have a positive influence on critical thinking skills can be an excellent strategy innovation in improving this skill.

Implementation of 2D Exploration Game Developed with Unity Integrated with Challenge Based on STEM Context Learning on Critical Thinking Skill

There are some plans related to the implementation of 2D exploration game developed with Unity integrated in challenge based on STEM context learning on mathematics. This innovation is focused on material of business mathematics, such as profit and loss. The media is planned to offers several features that support the learning process in order to improve students' critical thinking skills. There are several features plan contained in the game, which are listed in Table 2. In addition, Fig 2. shows the visual design plan of a 2D exploration game developed with Unity integrated with challenge based on STEM context learning to improve critical thinking skills.

TABLE 2. Features in 2D Exploration Game Developed with Unity

Feature Name	Description
Lobby	The initial place for students to gather, understand how to play, and a briefing place before entering into core learning activities.
Pretest	Teacher-activated mode, practicing students' initial skills and assessing their understanding of prerequisite materials.
Exploration Area	Class mode (only accessible during class learning). An environment for student exploration of the understanding of teaching materials and a place to collect xp from various objective activities.
Project Area	Where students work on group projects.
Inventory	Slots for storing various items that have been collected
Material Resumes	A place to review the material that has been previously learned (in the form of a collection of videos and a summary of the material).
Exercises Bank	A place for students to practice. This place contains a collection of practice questions (question bank)
Posttest	Teacher-activatable mode, student learning results training mode

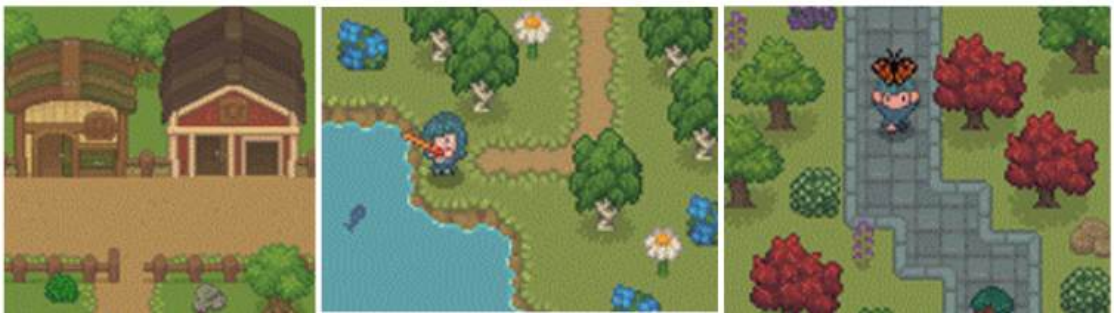

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FIGURE 2. Visual Design Plan

Furthermore, the features that are already offered will be integrated in the learning activities which means the learning model stages. Table 3 shows the implementation framework of the 2D exploration game developed with Unity integrated with challenge based on STEM context learning in the class. It is seen that the activities steps in challenge based on STEM context learning can support the five indicators of critical thinking skill by done a step by step activities that leads student to create a good strategy in solve problems with STEM especially in science context. These are clearly demonstrates that they will gain some new knowledges and information through their self-directed activities. Thus, this framework will be a strategic arrangement of the learning process oriented to critical thinking skills.

TABLE 3. Implementation Framework

CBL-STEM Context Syntax		Description of Learning Stages
Big Idea		Students are given big ideas to explore in 'lobby' and 'Exploration Area'.
Essential Question		Students are given essential questions related to the relationship between the science elements in the big idea and the math material to be learned.
The Challenge	Challenge	Students are given challenge related to big ideas and essential questions in the form of group projects that are done in the 'project area' in the game. The type of challenge will be a mathematics with science context
	Guiding Resource	Students are given materials in the exploration area 'exploration area'. The exploration area is a science nuanced environment.
	Guiding Activities	Students are given activities that related to science context and the material that can help students complete the project.
	Guiding Question	Students work on simple practice problems in the 'Exploration area' as a condition for collecting xp and continuing various game objectives. The problem is the type of mathematics with science context.
Solution Action		Students develop solutions to group project challenges that related to both mathematics and science context.
Assessment	Publishing	Students present project results and publish them
	Reflection	Students review the material in the 'material resumes' area, and work on questions in the 'posttest' mode. The questions are science context type of problems.

The focus of this research is to plan an innovative 2D exploration game developed with Unity integrated with challenge based on STEM context learning for business mathematics or social arithmetic material. A curriculum review was conducted to determine the learning outcomes and learning objectives of the media to be developed. The results of the curriculum review show that the learning outcomes that suitable for the material is “Peserta didik dapat menerapkan operasi aritmetika pada bilangan real, dan memberikan estimasi/perkiraan dalam menyelesaikan masalah (termasuk berkaitan dengan literasi finansial)”. Furthermore, learning objectives are also developed so the learning process will be well directed. The formulation of learning objectives was carried out by considering learning outcomes and indicators of critical thinking skills so that a description of the learning objectives was obtained as shown in Table 4. The learning objectives will be used as a reference in the development plan of 2D exploration game developed with Unity through challenge based on STEM context learning.

TABLE 4. Formulation of Learning Objectives

Learning Outcome	Learning Objectives

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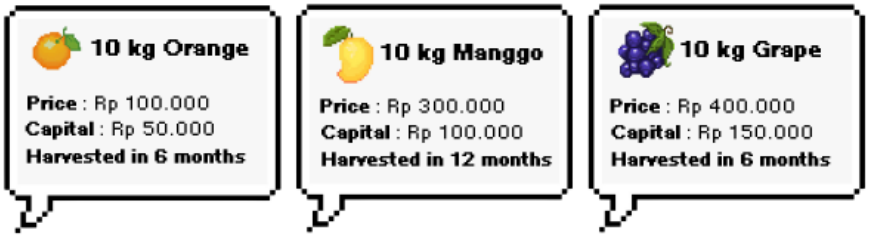
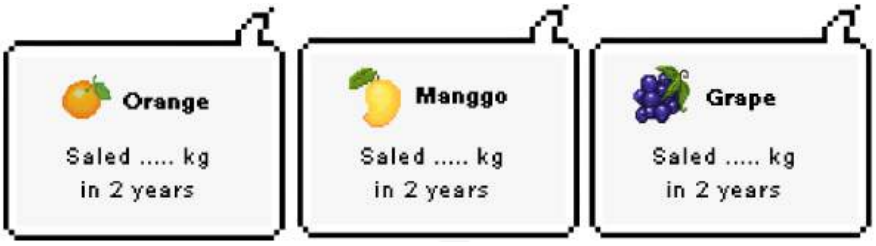
Peserta didik dapat menerapkan operasi aritmetika pada bilangan real, dan memberikan estimasi/perkiraan dalam menyelesaikan masalah (termasuk berkaitan dengan literasi finansial).	Through learning with 2D exploration games developed with Unity integrated with challenge based on STEM context learning, students can: 1. Determine the formula of selling price, buying price, profit and loss (along with the percentage value of profit and loss) correctly. 2. Calculate the selling price, buying price, profit and loss (along with the percentage value of profit and loss) well, and 3. Solve contextual problems related to selling price, buying price, profit and loss (along with the percentage value of profit and loss) appropriately.

The learning activity is planned to train student's critical thinking skill. On the Challenge stage in learning with 2D exploration game developed with Unity integrated with challenge based on STEM context learning, a mathematical problem as collaborative project that will be done by students by team was developed and became one of the benchmarks of training their critical thinking skills in the learning process. The development of the collaborative project design was considered by fulfillment of the five indicators of critical thinking skills such as basic clarification, basic support, inference, advanced clarifications, as well as strategies and tactics also considering its suitability with the learning objectives. In Table 5, the project problem is presented complete with detailed description of the analysis between each indicator of critical thinking skill with some parts on the problem. It is clearly seen that each stage in the project work will encourage student to conduct a deep analysis related to the steps they need to take as a strategy in solving existing problems using previously given information. Thus, the innovation of 2D exploration game developed with Unity integrated with challenge based on STEM context learning is potential to enhance students' critical thinking skill.

TABLE 5. Mathematical Problem of Challenge Stage

The Learning Objective	Through learning with 2D exploration games developed with Unity integrated with challenge based on STEM context learning, students can solve problems related to selling price, buying price, profit and loss (along with the percentage value of profit and loss) appropriately.
Critical Thinking Indicators	The Parts of Challenge Problem
Basic Clarification : Students should focus on the problems' context and analyze the information given. Basic Support : Students have to observe the source to conclude and evaluate what are the importance information that will be used	Do this activity with your group members! Take a look at the information below! You are a fruit seller with 3 kinds of fruit for sale. Below is the information and conditions that you have compiled in selling these 3 types of fruit 
Inference : Students need to conclude what is being asked Advanced Clarifications : Students will use previous given information to determine a first step.	Based on this information, 1. Determine your sales target for each type of fruit over a 2-year harvest period! (fill in the blank column below!) 

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Strategy and Tactics : Students need to formulate the steps/strategies that need to be done to get other elements that are still unknown and use them on the next step in solving the given problem.	2. If you reach your sales target by the exact amount, determine the percentage of profit you will get from your sales target!  (Write down the detail steps on paper, take a picture/scan it, and submit it here!)

CONCLUSION

Based on the results and discussion previously described, it is found that the 2D Exploration Game learning media developed with Unity integrated challenge based on STEM context learning can potentially be a solution of an effort to improve students' critical thinking skills. The use of this media in the learning process can attract students' interest in learning by creating a fun learning condition. In addition, the integration of challenge based on STEM context learning into the game supports the realization of meaningful learning experiences with the concept of contextual problems and collaborative project work. Therefore, researchers expect further research to be conducted related to the development of learning media in the form of 2D exploration games developed with Unity integrated with challenges based on STEM context learning to improve students' critical thinking skills in the future.

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