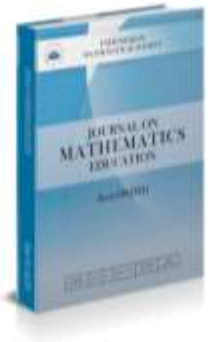

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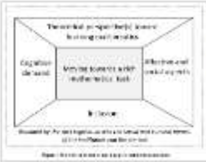

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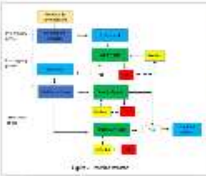

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Web-based realistic mathematics learning environment for 21st-century skills in primary school students

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Abstract

This study aims to develop a valid, practical, and which has potential effect web-based realistic mathematics learning environment with the six cultural contexts of the island of Sumatera. The learning environment has the potential to positively impact primary school students. The study employed design research method, which encompassed the preliminary, design, and assessment stages using the Kirkpatrick model. The research subjects consisted of three model teachers and 57 fourth-grade students. Research data was collected through observation, documentation, questionnaires, interviews, and tests. The web-based learning environment's validity level was found to be very high, with a score of 3.32, while practicality was rated at 3.86. The potential effects of the environment on mathematics learning were also deemed to be significant, with a score of 77.35. It was designed to facilitate the teaching and learning of mathematics by the PMRI approach, with a focus on topics such as numbering, geometry, and measurement, while also developing 21st-century skills.

Keywords: Learning Environment, The 21st Century Skills, Web-based Learning Environment Model, Web-based Realistic Mathematics

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Mathematics is a critical subject that plays a vital role in enhancing human life, as it enables students to develop a directed, logical, and flexible mindset to solve a range of mathematical problems (Sopiany & Rahayu, 2019). Kementerian Pendidikan dan Kebudayaan (2018) outlines three primary scopes of mathematics education at the primary school level: 1) numbers; 2) geometry and measurement; and 3) statistics. These areas of mathematics pose unique challenges in their application, particularly with regard to numbers and geometry and measurement, and require a comprehensive understanding of the underlying concepts (Meryansumayeka et al., 2022).

Students encounter various challenges when learning mathematics. For example, 1) students have trouble solving math problems that are relevant to real-world situations due to the prevalence of teaching formulas (Stacey, 2011), and 2) the inability of students to understand problems which is shown by their weaknesses in problem solving. Students experience difficulties in mathematical problem-solving because the learning process does not connect mathematical concepts to real life (Abdullah, 2017; Jupri & Drijvers, 2016). Moreover, the view that mathematics is an abstract concept disconnected from everyday life can hinder students' development of 21st-century skills, which are essential for meeting future challenges, regardless of cultural background (Prahmana et al., 2017).

The 4C framework of 21st-century skills encompasses creativity, critical thinking and problem-solving, communication, and collaboration, which are all essential skills for learning and innovation (Turhan & Demirci, 2021; Setiawan et al., 2018). In order to face the challenges of the future, it is crucial for students to develop 21st-century skills, which can be supported by technology and measured through assessment (Geisinger, 2016). With the constant change and ongoing learning in today's world, it is more important than ever for students to possess these skills, not only to succeed in the classroom but also in life (Mangiduyos & Subia, 2021).

Many studies have been conducted on the development of learning environments. For instance, Fauziah et al. (2020) developed a learning environment to enhance pedagogical abilities using a school campus model, professional development with a campus model, classes, and teacher working groups that involved teachers, students, and prospective teachers. Furthermore, research has explored the development of virtual learning environments and the analysis of teacher perceptions towards them (Rashid et al., 2021). Technology is increasingly utilized in virtual learning environments as it provides quick, efficient, and effective dissemination of knowledge to a broad range of individuals within the education sector. One form of technology that is ubiquitous in education is the internet. The ubiquitous use of the internet represents the presence of one type of technology (Faturrahman et al., 2018). Therefore, technology should be accessible to both teachers and students in the classroom. Web-based learning should not aim to replace face-to-face instructions with computer programs that overload students with excessive workloads. This is the rationale behind researchers' efforts to develop a model of a web-based learning environment for primary school teachers and students.

A web-based, realistic mathematics learning environment utilizing MOODLE (Modular Object-Oriented Dynamic Learning Environment) is one of the learning environments that academics develop in response to advancements in technology and google sites with culturals context of the island of Sumatera known as PMRI (Pendidikan Matematika Realistik Indonesia) VLEs (Virtual Learning Environments) (Pattanasith et al., 2015), using MOODLE (Mulhayatiah et al., 2019), using e-learning (Gunawan et al., 2018), VLEs using web-based (Hamzah et al., 2017), learning environment using gamification (Kirillov et al., 2016). The island of Sumatera is rich in various cultures ranging from historic buildings, traditional ceremonies, traditional clothes, traditional games, even to traditional clothing which varies in each region and the culture is used as a context in learning mathematics (Siregar et al., 2018; Nuh & Dardiri, 2016).

MOODLE is frequently used in language, science, and social studies, but its use in mathematics has been limited (Lisnani et al., 2020a; Malik & Rizvi, 2018; Breeze, 2014). The use of MOODLE suggests a need for interventions that can assist educators in creating a learning environment that aligns strongly with their personal, social, and professional visions, particularly in teaching and learning with MOODLE (Dhika et al., 2019; Khoza, 2016).

Google Sites is an educational tool used in the learning process and as a learning medium. (Bangun et al., 2022; Ramasundrum & Sathasivam, 2022). Google Sites are websites that can be created by teachers without the need for HTML coding and are used to distribute information and provide relevant links to help students better understand the content that will be covered in class. Google sites can be used as an interactive technology platform to exchange ideas, collaborate on assignments, and for teachers to design lessons and provide direct feedback to students (Al-Samarraie & Saeed, 2018; Wu et al, 2018).

VLEs are a learning environment that uses the internet as a learning tool (Zulkardi, 2002). PMRI (Pendidikan Matematika Realistik Indonesia) VLEs are a type of virtual-based mathematics learning environment that aims to introduce realistic teaching practices to both teachers and students through web-based learning. This approach aligns with the principles of industry 4.0, which stresses the integration of technology in education. MOODLE and Google Sites are examples of web-based learning tools that have been developed by researchers to facilitate the implementation of a realistic mathematics learning environment using the PMRI approach, cultural context of the Sumatera Island, learning media, and the Kirkpatrick model. I. The Kirkpatrick's model consists of four levels: level 1 - reaction, level 2 - learning, level 3 - behavior, and level 4 - results (Kirkpatrick, 2006; Kirkpatrick & Kirkpatrick, 2013). Kirkpatrick's model is commonly used in training for evaluating a person's competence (Supriyati & Abraham, 2021).

The idea of "Mathematics as a Human Activity" introduced by Hans Freudenthal has a significant influence on this method (Shanty, 2016; Prahmana et al., 2012). PMRI has five characteristics and three principles (Putri & Zulkardi, 2019). The effective teaching and learning of mathematics require students to have the right mindset and be deeply reflective about their learning preferences. Teachers must also possess the necessary skills and exhibit appropriate conduct in the classroom by fostering a supportive learning environment (Malik & Rizvi, 2018). In order to address the challenges faced by teachers and students in mathematics learning, a web-based realistic mathematics learning environment model should be developed using the PMRI approach with cultural contexts of Sumatera Island.

This research uses the six cultural contexts of Sumatera Island collected from the South Sumatera State Museum *Balaputera Dewa* in South Sumatera Province (Lisnani et al., 2020b), *Muaro Jambi* Temple in Jambi Province (Hardiarti, 2017), *Tabut* Ritual Ceremony in Bengkulu Province (Mahyudi & Yanti, 2020), *Tapis* Cloth from Lampung Province (Lisnani et al., 2022; Susiana et al., 2020; Maskar & Anderha, 2019), *Tak Tek/ Patek Lele* Game in Bangka Belitung Province (Gunawan & Suwarsono, 2019), and *Cekak Musang* Dress in the Riau Archipelago (Hasanuddin, 2017). The six cultures for learning mathematics are integrated in PMRI. The integration of the six cultures and mathematics is called 'ethnomathematics'.

The six cultural contexts of Sumatera Island provide the basis for mathematical contents, including: 1) geometry and measurement, covering 2D and 3D shapes, as well as measurements of length, time, and weight; 2) numbers, including arithmetic operations and social arithmetic. The six cultures of the Sumatera Island are incorporated into math comics called 'adventures on the island of Sumatera and learning instruments. The use of comics in the classroom is crucial to meet the demands of teaching mathematics in the 21st century, particularly in enhancing students' creativity and critical thinking abilities (Putra et al., 2021; Toh et al., 2017; van den Heuvel-Pahuizen et al., 2016; van den Heuvel-Panhuizen & Elia, 2011; van den Heuvel-Panhuizen & van den Boogaard, 2008).

Most studies focus on a specific topic, such as the learning environment, a particular topic in mathematics, ethnomathematics in one culture, web-based learning, and PMRI. However, no researchers have integrated various cultures and mathematics topics using web-based learning and comics to investigate 21st-century skills reflected in a web-based learning environment. Therefore, this study aims to develop a valid and practical web-based realistic mathematics learning environment for primary schools using the cultural contexts of Sumatera Island with MOODLE and Google Sites. The study also seeks to explore the potential effects of the learning environment on primary school students.

METHODS

In the initial stage, the researchers utilized an ethnographic approach to explore the integration of the six cultural contexts and mathematics. This integration was previously developed through twelve stages by Utami and Sayuti (2020). The stages begin with identifying informants and conducting interviews to gather information about the six cultures of Sumatera Island. This ethnographic approach is followed by the development of a realistic mathematics learning environment model using the design research method (Plomp, 2013; Sembiring et al., 2010; Plomp & Nieveen, 2007; Gravemeijer, 1994). Design research method consists of three stages: preliminary stage, prototyping stage, and assessment stage (Plomp, 2013).

The Preliminary Stage

In the preliminary stage, the researchers reviewed literature related to the 2013 mathematics curriculum for primary schools, particularly for fourth-grade students, to identify appropriate topics or materials that align with the culture of Sumatera Island. Additionally, they reviewed various studies on web-based learning, PMRI, math comics 'Adventure to Sumatera Island, and effective implementation strategies for educators to use with their students. The learning environment model was developed using primary school learning materials during the simulation. The researchers studied several topics of mathematics materials for primary schools in the curriculum. Interviews using Google Form were also carried out in preliminary research with educators from three primary schools with different accreditation standards. Interviews were conducted to 1) find out whether the educators have used technology in learning such as web-based learning; 2) find out whether the educators are familiar with the PMRI approach and explore their perceptions of learning mathematics; 3) find out whether the educators know the cultures of the island of Sumatera; and 4) find out whether the educators have used comics in mathematics learning. Then, the researchers analyzed the use of MOODLE for teaching and learning using questionnaires.

The Prototyping Stage

In the prototyping stage, the researchers conducted a formative study of the devices used and produced by the learning environment model by conducting self-evaluations, experts review, and one-to-one reviews, small groups, and field tests (Zulkardi, 2002; Tessmer, 1993). According to Van den Akker (1999) there are three criteria in development, namely validity, practicality, and effectiveness. First, validity refers to content, construct, and language. So, comics with cultural contexts of Sumatera Island and web-based learning content with models are said to be valid if they are appropriate in terms of content, construct, and language. Second, practicality refers to the attractiveness and convenience for the users. Comics with the cultural contexts of Sumatera Island and web-based learning contents with models are said to be practical if they are interesting and can easily be used by users, in this case students. Last, effectiveness refers to the achievement of the desired goal. Comics with the cultural contexts of Sumatera Island and web-based learning content with models are said to be effective if the learning objectives are achieved. In the self-evaluation stage, the researcher developed a learning design and learning tools (web-based learning in the form of MOODLE, cultural comics on Sumatera Island, and questions regarding cultural contexts of Sumatera Island using the PMRI Approach). Further, the learning tool was discussed with each fourth-grade teacher from the three schools who were appointed as model teachers. The results in the form of learning designs and learning tools are referred to as the first prototype.

In the expert review stage, the initial prototype was assessed by three experts specializing in the PMRI approach for learning instruments and three experts for comics. This process of expert validation involved reviewing the content, construct, and language of the PMRI learning tools (Zulkardi et al., 2020).

The results from the expert review and peer review were used to revise the product. Simultaneously, a one-to-one process was also carried out, namely testing the learning tools on several students individually. The results from one-to-one were also used to revise the products. After carrying out expert reviews, one-to-one, the first prototype can be said to be valid qualitatively, and the second prototype was produced.

The second prototype was tested in the small group stage by involving a small number of students consisting of six students who were not the subjects of the actual research. The students participating in small groups have varying abilities, which are categorized as low, medium, and high based on their pretest scores, and information gathered from their teacher. This stage was carried out to determine the practicality of the second prototype. If the learning process in the learning environment can be carried out and produces good outcomes, the second prototype could be said to be practical. The second prototype was revised based on the results of the small group trial and comments on PMRI tools. The result of this stage was the third prototype. Prototype 3 was subsequently subjected to a field test as the final stage in the development of a learning environment. The objective of this stage is to assess the potential impact of a web-based realistic mathematics learning environment in primary schools.

The Assessment Stage

The assessment stage was carried out to identify the potential effects of the implemented web-based realistic mathematics learning environment. The assessment stage involved four levels of development by Kirkpatrick and Kirkpatrick (2013), namely participants' reactions, participants' learning, participants' behavior, and participants' results obtained using questionnaires. The participants’ reactions toward the web-based learning environment model were measured through a web-based realistic mathematics learning environment development questionnaire which was distributed via the Google form containing 30 closed-ended questions. The 21st-century skills were measured using questionnaires developed by the researchers with four major indicators, namely 4C indicators.

The research subjects were 57 students from three primary schools and three teachers of fourth grade from three schools with different accreditations as Indonesia has A, B and C accreditation standards (Malik et al., 2021). The subjects were 24 students from a primary school with accreditation standard A (initial S1), 17 students from a primary school with accreditation standard B (initial S2), and 16 students from a primary school with accreditation standard C (initial S3).

Various methods were employed to collect data, including interviews, observations, video recordings, questionnaires, tests, walkthroughs, and documentation. The interviews were aimed at exploring the initial understanding of the fourth-grade teachers about PMRI and web-based learning. They were conducted orally with one teacher from each school, covering topics such as the technology used during the learning process amid the COVID-19 pandemic, the students' conditions, the appropriateness of the context and material used, the timing of the research, the teachers' opinions about the learning tools that had been designed, the difficulties faced by educators while teaching the material in class, the 21st-century skills possessed by students, and the experiences of educators and participants in using the PMRI approach. The researchers interviewed individuals who have knowledge about the six cultures of Sumatera Island as the contexts in this study. A written interview in the form of an introduction to the web-based realistic mathematics learning environment in primary schools was conducted with one fourth-grade teacher from each school. Oral interviews with one fourth-grade student from each school were conducted after learning to obtain more in-depth information about the strategies used and the mathematical activities carried out. The interviews were conducted with conversations or questions and answers either directly or indirectly to the teachers and students. A written interview was conducted with one fourth-grade teacher from each school on the introduction to the web-based realistic mathematics learning environment in primary schools.

Observations and video recordings were carried out to find out the lesson study process and the process of assessing the implementation plan. The students took a final exam in the form of an essay on task sharing with 64 questions in the student worksheet and an 18-question jumping exercise using the six cultural contexts of Sumatera Island. Questionnaires were given to the students aimed at identifying their satisfaction in web-based learning and the use of comics with the cultural contexts of Sumatera Island, how to implement 4C skills, and the students' responses to the four Kirkpatrick levels. Qualitative data analysis techniques were used to analyze the data obtained from interviews, observations, video recordings, questionnaires, tests, walkthroughs, and documentation. The validity and practicality criteria are presented in Table 1 (Andriyani et al., 2021). Whereas, effectiveness is assessed from the Minimum Completeness Criteria (MCC), where the MCC for each school is scored 75.

Table 1. Criteria for Validity dan Practicality

Score in percentage	Validity category	Practicality category
$80 < N \leq 100$	Very valid	Very practical
$60 < N \leq 80$	Valid	Practical
$40 < N \leq 60$	Somewhat valid	Practical enough
$20 < N \leq 40$	Less valid	Less practical
$0 < N \leq 20$	Invalid	Not practical

RESULTS AND DISCUSSION

The Preliminary Stage

During the preliminary analysis stage, the researcher conducted several preparations, including a review of the literature and the 2013 revised 2018 curriculum syllabus (Kementerian Pendidikan dan Kebudayaan, 2018) to develop an implementation plan for mathematics learning in the fourth grade of primary school. Then, the researchers analyzed the fourth-grade students in the form of an analysis of the introduction and use of the PMRI approach in learning, an analysis of the use of web-based learning during online learning, and an analysis of the use of a realistic mathematics learning environment for web-based learning using comics in learning mathematics.

The questionnaire distributed to students yielded information regarding their familiarity with and use of the PMRI approach. According to the questionnaire results, 79.3% of students had never heard of the PMRI approach, while the remaining 20.7% reported being familiar with it. Additionally, when asked about previous use of the PMRI approach in mathematics learning, 79.3% of students stated that they had never used the approach, while 20.7% reported previous use. These results indicate that the PMRI approach is a novel approach for the three primary schools. From the questionnaire distributed to students, information was obtained about the applications used during online learning, an introduction to MOODLE, and the use of MOODLE during online learning. The results revealed that 73.3% of students used WhatsApp during online learning, followed by zoom cloud meeting at 23.3%, and cloud at 3.4%. According to the questionnaire results, 41.4% of the students had not been previously introduced to MOODLE, while 58.8% had heard of it. In terms of the use of MOODLE during online learning, 75.9% of the students had never used it, while 24.1% had experience using MOODLE. Data from the analysis of the use of comics in mathematics learning show that 86.2% of students have never used comics in learning mathematics, while the remaining 13.8% stated that they have used comics in learning mathematics. The researchers' analysis of the 2013 revised 2018 curriculum (Kementerian Pendidikan dan Kebudayaan, 2018) shows mathematics subjects in the first to third grades are still thematically integrated, unlike in the fourth to sixth grades where mathematics is independent and not integrated with other subjects. The mathematics material in grades four to six focuses on geometry and measurement, numbers, and statistics. The focus of the research is mathematics subjects for fourth-grade students using the six cultural contexts of Sumatera Island presented in Table 2.

Table 2. Context analysis and mathematical materials

Context	Mathematics Subjects
Historical building: *Balaputera Dewa* State Museum of South Sumatera in South Sumatera Province	Geometry and Measurement: 2-D dimensional figure, 3-D dimensional figure, length measurement, and weight measurement
Architecture: *Muaro Jambi* Temple in Jambi Province	Geometry and Measurement: 2-D dimensional figure and length measurement
Traditional ceremonies: *Tabut* Ceremony in Bengkulu Province	Geometry and Measurement: 3-D dimensional figure and time measurement
Traditional cloth: *Tapis* Cloth in Lampung Province	Geometry and Measurement: 2-D dimensional figure and length measurement Numbering: Social arithmetic
Traditional game: *Tak Tek/ Patek Lele* game in Bangka Belitung Archipelago Province	Geometry and Measurement: length measurement Numbering: arithmetic operations
Traditional clothing: *Cekak* Musang Fashion in Riau Archipelago Province	Geometry and Measurement: length measurement Numbering: arithmetic operations

The Design Stage

In the design stage, an initial prototype was designed for a web-based realistic mathematics learning environment in the form of learning tools consisting of a Learning Implementation Plan, Student Worksheets consisting of sharing tasks and jumping tasks, math comics 'Adventure to Sumatera Island', MOODLE named Realistic Mathematics Learning Environment and Google Sites. The researchers designed a web-based learning environment using the PMRI approach and incorporating cultural context from the six different cultures on the island of Sumatera.

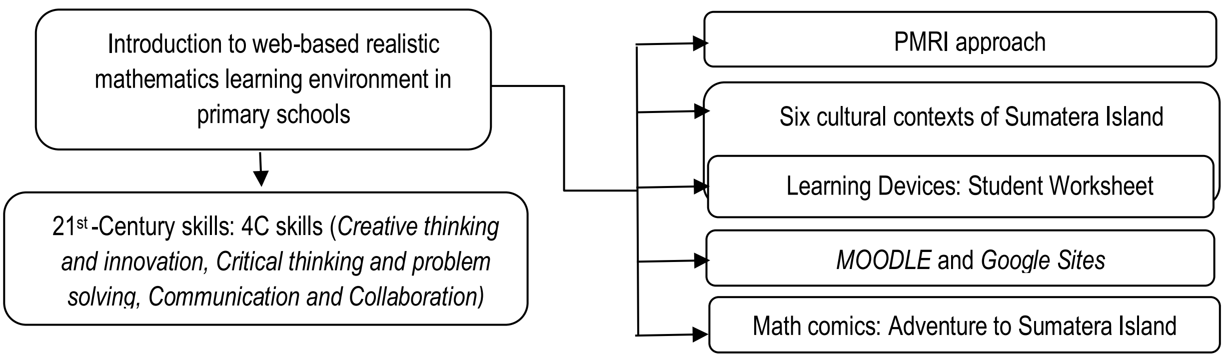


Diagram 1. The development of Web-Based Realistic Mathematics Learning Environment

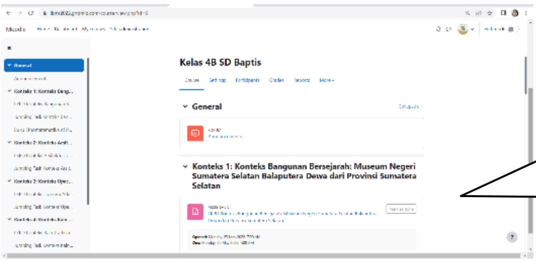
The learning tools included in the environment were MOODLE and Google Sites, along with student worksheets that contained ethnomathematical content from the six cultures, sharing tasks, and jumping tasks (Tanujaya et al., 2023; Gustiningsi et al., 2022; Putri & Zulkardi, 2019). The development process involved discussions between the researcher and the model teacher regarding the student worksheets and the overall concept of the research, as depicted in Diagram 1.

The Prototyping Stage

The prototyping stage consisted of four phases, namely the first prototype, one-to-one stage, the second prototype, and the third prototype phase. The explanation of all phases can be explained as follows.

The First Prototype

The web-based learning used MOODLE and Google Sites for mathematics learning for fourth-grade primary school students. In the initial stage, the researcher designed web-based learning using MOODLE and Google Sites to create a realistic mathematics learning environment (see Figure 1). The Google Site designed by the researcher is named ‘development of a web-based realistic mathematics learning environment using six cultural contexts on the Island of Sumatera’ (see Figure 2).



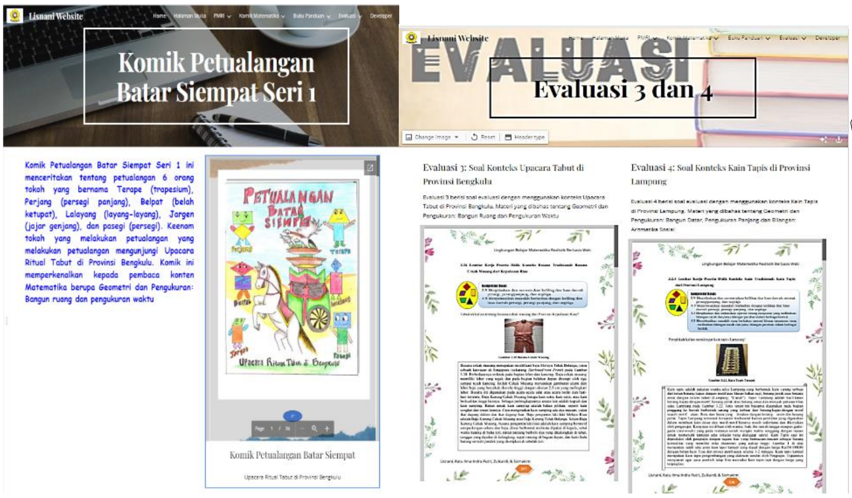
The content of MOODLE consists of classes, learning instruments such as student worksheets, comics, and evaluation for each cultural context of Sumatera Island from each school that is the subject of research. The URL of MOODLE: https://lbmr2022.gnomio.com/.

Figure 1. Realistic Mathematics Learning Environment using MOODLE

Figure 1 describes the realistic mathematics learning environment using MOODLE for students of fourth grade in primary school with accreditation A. In this learning environment, the students could do their activities using the six cultural contexts of Sumatera Island.

The Google sites contains content on "Development of a Web-Based Realistic Mathematics Learning Environment in Primary Schools" including PMRI, the cultural contexts of Sumatra Island, the comic ‘adventure to the island of Sumatra’ with a series of learning instruments, and the use of MOODLE as a web-based learning application.

This website is an application for researchers, educators, and students in learning primary mathematics using the cultural contexts of Sumatera Island using the PMRI approach. Various cultures on the island of Sumatera such as the *Balaputera Dewa* State Museum of South Sumatra, Lampung *Tapis* Cloth, *Muaro Jambi* Temple, the *Tabut* Ceremony, the *Tak Tek/Patek Lele* Game, and the *Cekak Musang* Fashion were also introduced on this page.



The URL of website: https://bit.ly/LingkunganBelajarMatematikRealistik Lisnani
The website consists of six student worksheets and three chapters of Math Comics: the adventure to Sumatra Island. The figure shows *Batar Siempat* adventure comic and evaluation 3 and 4.

Figure 2. Realistic Mathematics Learning Environment using Google Sites

Figure 2 describes realistic mathematics learning environment using google sites to introduce six cultural contexts of Sumatera using comics and ethnomathematics.

Math Comics: the adventure to Sumatra Island was validated by three validators and obtained an average score of 3.22 which indicates that the comics have a high level of validity. The experts' comments/suggestions are presented in Table 3.

Table 3. The experts' comment and revision decision

Experts	Learning Devices Comments and Suggestions	Revision Decision
E1	The sentences used are too long. One sentence is composed of several sub-clauses. It's best to use only one clause. Short and simple sentences to make it easier for students to read and understand. The displayed image should be in accordance with the actual. If the original image of the shape that appears is a square, then the image presented should not appear as a rectangle.	Suggestions are accepted, the researchers fix sentences that are too long, and pictures have been improved to make them clearer
E2	There needs to be a few improvements, such as: 1) in question 3, the word "each" should be "pole"; 2) in question 6, it is asked that the height of the statue is in the form of "human", while it is drawn "person", one should be replaced so that it is consistent; and 3) In question 12, they were asked to re-sketch, but the size of the answer box was too small, it needed to be enlarged. There needs to be a little improvement, such as: 1) in question 3, it says "Middle Line", but this word is not clear, it is possible that some students will be confused about the meaning of this middle line in what picture it looks like; 2) in question 6, the image of the part of the building being asked is not clear; and 3) in question 10, because Figure 3.4 has been written, it doesn't feel necessary to write the word "above" anymore. The images used need to be improved in	Suggestions are accepted, the researcher adds each word to question number 3. 1)The suggestion is accepted; the researchers replace the word "human" to "person." 2)Suggestions are accepted, researchers enlarge the answer box on 1)The suggestion is accepted; the researchers replace the word "diameter" with "diameter." 2)The researchers have clarified the picture to be painted 3)The researchers have made corrections according to feedback

	resolution so that they can be seen more clearly and are pleasing to the eye.	from the validator by removing the word "above"
E3	My suggestion, add a continuous question that can see his contribution in answering the question, and can describe his thoughts, you can add "how do you measure the height of the ladder? And what results do you get	The researchers still use the sentences because only the language is different

In this stage, the researchers designed the *PMRI* learning tool in the form of *student worksheets* using the cultural contexts of Sumatera Island based on the Basic Competencies of learning mathematics learning for grade IV students. Based on the results of validation by three validators of the learning tools, an average value of 4.50 is valid, indicating a very high level of validity as described in Table 4.

Table 4. Recapitulation of expert and peer validation of *PMRI* learning devices

No	Feasibility of material/content						Appearance						Language Suitability				AS
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	
V1	5	5	4	4	4	5	5	5	4	4	4	4	3	3	3	3	4.06
V2	5	5	5	5	5	5	5	4	4	5	5	5	5	4	5	4	4.75
V3	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	4.69
AS	4.66	4.66	4.33	4.33	4.33	5	5	4.66	4.33	4.66	4.66	4.66	4.33	4	4.33	4	4.50

AS= average score

The researcher and the model teacher discussed six activities that represent six cultural contexts of Sumatera Island in the six student worksheets. The students discovered mathematical concepts in the form of geometry and measurement and numbers which are one of the principles of mathematics with the activities.

The first activity is the context of the South Sumatera State *Museum Balaputera Dewa* on geometry and measurement. The second activity, the context of the *Muaro Jambi* Temple from Jambi Province, is about geometry and measurement. The third activity is the context of the *Tabut* Ceremony from Bengkulu Province on geometry and measurement. The fourth activity, the context of *Tapis* cloth from Lampung Province, is about geometry and measurement, and numbers. Fifth, the context of the *Tak Tek/Patek Lele* game from the Bangka Belitung Islands Province is about geometry and measurement, and numbers. Sixth, the context of the *Cekak Musang* dress in the Riau Archipelago Province is about geometry and measurement, and numbers.

One-to-One Stage

The student worksheets and test questions were then tested on three fourth-grade primary school students in each of the schools. The aim of the test is to identify the answers and challenges that students encounter when reading and responding to questions on the worksheets 1-6. The comments of three representatives (initial SO1 as a student in S1, SO2 as a student in S2, S3 as a student in S3) from each school related to student worksheets 1 to 6 are presented in Table 5. It presents the comments of the three students from the three schools with different accreditations. The students have difficulties in answering student worksheets 1-6.

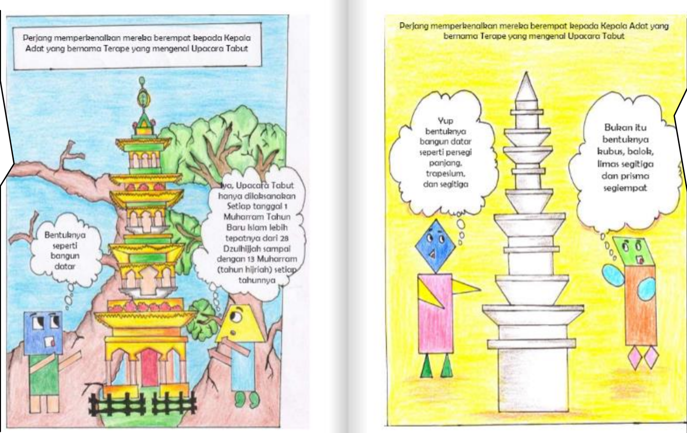
Table 5. Students' comments on worksheets 1-6

Student Worksheets	Comments		
	SO1	SO2	SO3
1	The student worksheets are interesting because they make me know about museums but there are some questions that I do not understand	I can do well on the questions on this student worksheets even though I still ask the teacher directly for things I don't understand	I do not like the worksheets because there are too many questions on the student worksheets
2	I do not like it because there are too many questions on the student worksheet	I do not like it because there are too many questions on the student worksheet	Because I can quite understand
3	I am not used to drawing shapes, so I had a little trouble and asked my friend to teach me about the volume of shapes	I am a little confused about which one is the Ark or the Tabut?	The calendar on the questions is not clear and I cannot work on the questions on this student worksheet
4	The material and questions in this student worksheets are easier for me to understand because it discusses the material for measuring the length and social arithmetic in everyday life.	I find it a little challenging to measure lengths because I do not understand measurements of length	I often see the shape of the cloth in my house because my mother is a tailor and for me student worksheet 3 about tapis cloth is interesting
5	Because it is easy to understand	When I went to Bangka, I was invited by my friends to play the *Tak Tek* game, so when working on questions on student worksheets 5, this made me understand more	The questions are easy to understand because we have learned about measuring length in the previous class
6	I have not been able to work on the pattern problem, while the others can	The fashion pattern makes me dizzy, but I can answer the others	I am having trouble understanding the pattern of this *Cekak Musang* dress, so there are several questions I cannot answer

The Second Prototype

The second prototype of the web-based realistic mathematics learning environment model in the form of a math adventure comic and the web-based PMRI learning tool are the results of a revision of the first prototype which has been valid and was tested on a small group consisting of six fourth grade primary school students from the three schools. Based on the validation from the validators, Math Comics: the adventure to Sumatra Island is converted to E-comics that are easy for students to read. The teachers directed the students to visit the link to the e-comic via WhatsApp chat and the students clicked on the link sent by the teacher (see Figure 3).

This comic describes the adventures of *Batar Siempat* to Bengkulu Province to see the *Tabut* ceremony. It describes the *Tabut* Ceremony held every 1st of *Muharram* of the Islamic New Year, more precisely from the 28th of *Dzulhijjah* to the 13th of *Muharram* (*Hijriyah* Year) every year. The content is about measurement of time.



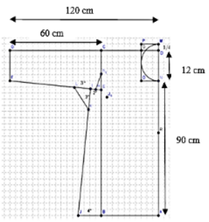
The shape of the *Tabut* describes geometric shapes in the form of cubes, beams, triangular pyramids, and rectangular prisms.

Figure 3. E-Math Comics: the adventure to Sumatra Island

Figure 3 describes one chapter of math comics, named *Batar Siempat* visiting the *Tabut* ceremony in Bengkulu Province. The e-comics describe the history of the *Tabut* ceremony. The characters in this comic are *Perjang, Jargen, Belpat, Terape, Lalayang,* and *Pasegi*. The characters in comics use the concept of a 2-D dimensional figure starting from the face to the feet. This comic also discusses mathematical materials about geometry and measurement, namely 3-D dimensional figures and time measurement.

The small group comprised six students from each elementary schools with different accreditations; they were two students with high abilities, two students with intermediate abilities, and two students with poor abilities. The students' answers in student worksheets (initial SC1, SC2, and SC3) with *Cekak Musang* dress context are presented in Table 6.

Table 6. Question and answers with *Cekak Musang* dress context

Subject	Question	
SC1, SC2, SC3	Gambar ilustrasi pola dapat dilihat pada Gambar 1. Untuk labuh baju dibuat dengan dasar bentuk geometris persegi panjang, dengan pola-pola yang sejajar seperti AB = CD yang diambil dari ukuran 1/2 lebar bahu. Sedangkan untuk labuh baju terdapat pola kesamaan AD = BC. Selain itu terdapat beberapa rumusan untuk membentuk pola leher, untuk 1/2 lebar bukaan kerah baju MP = DQ = NO = 1/6 lingkar leher - 1/4 inci, Sedangkan untuk tinggi bukaan kerah diperoleh dengan rumusan DN = QO = 1/6 lingkar leher + 1 inci  **Keterangan:** AB = CD = 1/2 lebar bahu AD = BC = labuh Baju CE = Lebar pangkal Lengan CG = EF = Labuh Lengan GF = 1/2 Bukaan Tangan EH = 1/2 inci EB= IJ = Panjang pesak EI = Lebar pesak atas (2 -2 1/2) inci (boleh ubah suai) BJ = Lebar Pesak Bawah (4-4 1/2) inci (boleh ubah suai) IK = IL = 3 inci ukuran kekek DM = naikkan 1/4 inci MP= DQ= NO= 1/6 leher - 1/4 inci DN= QO= 1/6 leher 1 inci = 2,54 cm **Gambar 6.1 Pola Busana Cekak Musang** **Pertanyaan 1: Pengukuran** Tentukan nilai dari DM dan MP! **Question 1:** Measurements Determine the value of DM and MP!	An illustration of the pattern can be seen in Figure 1. The shirt anchor is made on the basis of a rectangular geometric shape, with parallel patterns such as AB = CD taken from the size of 1/2 shoulder width. As for the clothes anchor, there is a similarity pattern AD = BC. In addition, there are several formulas to form a neck pattern, for 1/2 the width of the collar opening MP = DQ = NO = 1/6 neck circumference - 1/4 inch, while for the collar opening height, it is obtained by the formula DN = QO = 1/6 neck circumference + 1 inch **Information:** AB = CD = 1/2 shoulder width AD = BC = Seaport CE = Width at the base of the arm CG = EF = Arm Anchor GF = 1/2 Open Hand EH = 1/2 inch EB= IJ = Punch length EI = Width of top seam (2 -2 1/2) inches (customizable) BJ = Bottom Punch Width (4-4 1/2) inches (can be customized) IK = IL = 3 inches cake size DM = raise 1/4 inch MP= DQ= NO= 1/6 neck - 1/4 inch DN = QO = 1/6 neck, 1 inch = 2.54 cm

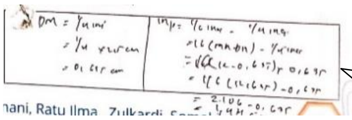
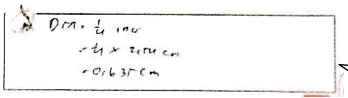
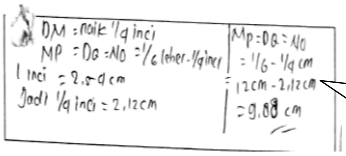
Subject	Answers		
SC1		DM = ¼ inch = ¼ x 2,5 cm = 0,625 cm	MP = 1/6 neck – ¼ inch = 1/6 (MN+DM) - ¼ inch = 1/6 (12+0,625) – 0,625 = 2,106 – 0,625 = 1,481 cm
SC2		DM = ¼ inch = ¼ x 2,5 cm = 0,625 cm	
SC3		DM = plus ¼ inch MP = DQ = NO = 1/6 neck – ¼ inch I inch = 2,54 cm Therefore, ¼ inch = 2,12 cm	MP = DQ = NO = 1/6 – ¼ cm = 12 cm – 2,12 cm = 9,88 cm

Table 6 shows the different answers of the students from the three schools. SC1 was able to answer the values from DM and MP correctly, which means that SC1 was able to solve problems critically, systematically, and directed based on the instructions from the questions given even though there are the differences are on the second decimal. SC2 was only able to complete the answers to DM but was unable to further analyze the MP value. It is different from SC3 which was able to answer DM and MP, but the answer was not quite right. From the three answers, it can be seen that the ability of SC1 is in first place followed by SC2 and then SC3. The use of the *Cekak Musang* dress context is the first step for students in reinventing mathematical models and developing their own models through the way the students answer each question given. The students are given freedom to construct and present their ideas and strategies in solving a problem from a real context.

The Third Prototype

The third prototype of the web-based realistic mathematics learning environment is the result of a revision from the small group stage. It was tested at the field test stage. This field test stage was conducted to see the potential effects of a web-based realistic mathematics learning environment on students in three primary schools through a series of tests.

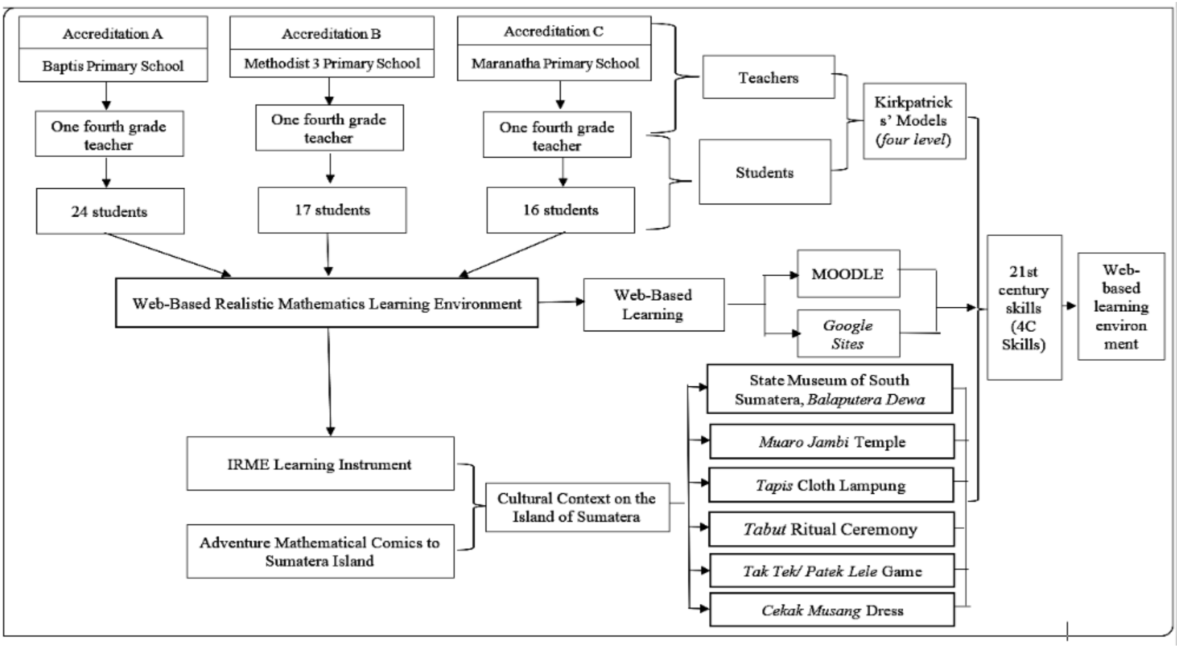


Figure 4. Web-based Learning Environment

All meetings in the learning process were carried out by teachers and students in three different schools. Based on this development process, the researcher concluded that the best model was the web-based learning environment model as shown in Figure 4. It depicts the web-based realistic mathematics learning environment using MOODLE and google sites as web-based learning environment with six cultural contexts of Sumatera Island. The web-based realistic mathematics learning environment was implemented in three primary schools with different accreditations using Kirkpatrick's models to measure 21st century skills.

The Assessment Stage

In this stage, an evaluation or assessment of the developed web-based realistic mathematics learning environment was carried out to identify whether it has a potential effect on teachers and students. Evaluation of the learning environment was carried out using four levels of development evaluation by Kirkpatrick and Kirkpatrick (2013).

1. *Participants' Reaction*

   At level 1, the participants' satisfaction with the web-based learning environment model was measured through a web-based realistic mathematics learning environment development questionnaire which was distributed via the Google form. There are 30 closed-ended questions in the form. The outcomes are shown in Table 7 and were determined using the measuring outcomes of a student satisfaction survey on a realistic mathematics learning environment model.

Table 7. Results of the Kirkpatrick's model of web-based realistic mathematics learning environment development questionnaire

Indicators	Statements	Average
Level 1: Participants' Reaction	1-8	3,32
Level 2: Participants' Learning	9-20	3,31
Level 3: Participants' Behavior	21-24	3,26
Level 4: Participants' Results	25-30	3,48
Average score level 1-4		**3,32**

   Table 7 shows that, on average, the students agree that the web-based learning environment model is interesting, useful, and new for the students at 3.32. Likewise, the learning instrument used include context, worksheets, sharing task questions, and jumping tasks which make students excited to take part in learning.

2. *Participants' Learning*

   At this level, the researchers measured the extent to which the participants acquire knowledge, skills, and attitudes based on the participation of teachers and students during activities in the web-based learning environment mode using PMRI approach. Students sit in groups during the learning process where there is an interaction between the teacher and students and students with each other.

3. *Participants' Behavior*

   The implementation of a web-based realistic mathematics learning environment in the form of MOODLE and Google sites received a positive response from the students of the three primary schools (PS1 includes 24 students in S1, PS2 includes 17 students in S2, and PS3 as includes 26 students in S3). This was identified using a questionnaire distributed to students, comprising 12 questions and 14 questions for math comics as shown in Table 8.

Table 8. Questionnaire of student responses to MOODLE and Google Sites and Math Comics

Schools	MOODLE and Google Sites		Math Comics	
	Average Score	Percentage	Average Score	Percentage
PS1	3.15	78.75%	3.13	78.25%
PS2	3.55	88.75%	3.39	84.75%
PS3	3.17	79.25%	3.44	86.00%
Overall average	**3.29**	**82.25%**	**3.32**	**83.00%**

Table 8 shows a positive response from the students towards the use of web-based learning using MOODLE and Google sites with an average participant of 82.25%. Based on the results, it can be seen that the most positive responses were from the students at PS2 because there were not too many students in one class so they could concentrate on learning. In addition to web-based learning in the form of MOODLE and google sites, this web-based realistic mathematics learning environment implemented math comics. Table 8 indicates that the students' responses to the use of math comics were very positive because the students at PS3 liked using the math comics in learning.

4. *Participants' Results*

   Most of the students were able to answer the questions on student worksheets 1, 2, 3, 4, 5, and 6. However, there were differences in the percentage of students' assessment results based on the assessment of students' work on each student worksheet in the three schools, as shown in Table 9.

Table 9. Recapitulation of assessment of student worksheet results

Schools	Average Score of *Sharing Task*	Average Score of *Jumping Task*
PS1	86.92	81.07
PS2	80.13	78.82
PS3	72.13	72.16
Overall average	79.72	77.35

Table 9 shows that the average student worksheets are in the very good category of 86.92, good at 80.13, and sufficient at 72.13. On average, there are differences in the assessment results of the three schools. Likewise, the jumping task assessment, even though it experienced a slight decrease due to the level of difficulty of the questions in the jumping task. The evaluation results of student worksheets were 79.72% and on the jumping tasks were 77.35%.

During the learning process, the researcher analyzed the 21st-century skills (4C skills) of the students and the results are described in Table 10.

Table 10. the 21st Century skills questionnaire (4C Skills)

21st-century skills (4C Skills)	Statements	PS1	PS2	PS3	Average Score 4C Skills
Creativity dan innovation	1-6	3.42	3.22	3.18	3.28
Critical thinking dan problem solving	7-15	3.41	3.37	3.33	3.39
Communication and Collaboration	16-20	3.04	3.25	3.24	3.27
Average 4C score each primary school		**3.29**	**3.38**	**3.32**	**3.33**

Table 10 shows the 21st-century skills of all students who are the subjects of the research from the three schools with different accreditations. The highest creativity and innovation abilities were found in students at PS1 of 3.42 (85.55%) followed by PS2 at 3.22 (80.50%) and PS3 3.18 (amounting to 79.50%). As with critical thinking and problem-solving skills, the results of the questionnaire assessment obtained a score of 3.41 for PS1 (85.25%), PS2 for 3.37 (84.25%), and PS3 with a not too high score, significantly different from PS2 of 3.33 (83.25%). PS2 obtained the highest score on the 21st century skills compared to the other two schools. This means that students at schools with A accreditation do not necessarily have better 21st-century skills compared to those of schools with B and C accreditations. On the other hand, students at schools that have B accreditation B have the best 21st-century skills based on the results of the questionnaire.

Overall, across the three schools, the abilities mostly possessed by students were creativity and innovation with a score of 3.29 (82.25%), communication and collaboration with a score of 3.32 (83.00%), and critical thinking and problem solving with a score of 3.38 (84.50%). Understanding critical thinking and problem-solving techniques is important for success, especially in the 21st- century competencies in the web-based realistic mathematical learning environment (Kivunja, 2015). Students of the three schools have the 21st-century skills (4C skills) with a score of 3.33 (83.25%). It means that the 21st-century skills of all students from the three schools can be categorized as 'good' (Collins, 2014).

This research has produced a web-based learning environment model that can be used in mathematics learning for teachers and fourth-grade students in three schools with different accreditations that are valid and practical; the model has potential effects on the students. The learning environment comprises a series of learning activities and their implementation in the three schools with different accreditations. Classroom learning activities consist of activities 1 to 6 which are realized in student worksheets 1 to 6.

The implementation in the three schools was done by the researchers based on the discussions with model teachers, covering 3 learning materials which include geometry in the form of plane shapes and geometric shapes, measurements in the form of measurements of length, weight, and time, and numbers in the form of social arithmetic. The learning environment model consists of web-based learning using MOODLE and google sites to introduce the learning environment, math comics, and PMRI learning instrument with a cultural context of Sumatera Island. The model is valid and practical, as well as has a significant potential effect on teachers and students of fourth graders. PMRI approach is an attractive approach for primary school students (Zulkardi, 2002).

When designing learning instruments, the researchers used contexts as a reference point and the PMRI approach to help students understand topics. Research on learning environment using lesson study to measure pedagogical abilities in using PMRI approach becomes serves as the basis for web-based mathematics realistic learning environment research; there are differences carried out by researchers, namely the use of six cultural contexts of Sumatera Island, leading 21st-century skills (Fauziah et al., 2020).

The research conducted by Fauziah, et al. (2020) did not raise ethnomathematics even though Indonesia is rich in culture. However, this opportunity was addressed by Risdiyanti and Prahmana (2018) who included the culture of Java in a particular topic of mathematics as a starting point for elevating various cultures of the island of Sumatera on several mathematical topics, such as numbers, geometry and measurement. Furthermore, the use of ethnomathematics in a virtual learning environment is still limited as is done by Rashid et al (2021) who used a web-based learning environment. This research resulted in a new finding, that is a web-based realistic mathematics learning environment for teaching and learning mathematics using PMRI approach with six local cultural contexts by using math comics: the adventure to Sumatera Island.

CONCLUSION

This study has produced a learning environment with a web-based realistic mathematics model. The web-based realistic mathematics learning environment provides a mathematics learning process comprising six learning activities using the PMRI approach with six cultural contexts of Sumatera Island using MOODLE and Google Sites. The validity level obtained from the questionnaire was 3.32 (83%), indicating that the development of the web-based realistic mathematics learning environment was very valid. The level of practicality obtained at the field test stage was obtained from the average value of the comic validation results of 3.22 and learning instruments of 4.50; therefore, a practicality value of 3.86 (96.50%) was obtained, indicating that the development of a realistic mathematics learning environment Web-based is very practical. The level of effectiveness (potential effect) obtained from the test results is 77.35 (77.35%) from the participants' results by Kirkpartrick's levels, indicating that the development of a web-based realistic mathematics learning environment is practical.

The potential effect, based on Kirkpatrick's level, is demonstrated by: 1) positive responses from students in the form of satisfaction and perceived benefits of the model based on the distributed questionnaires; 2) the utilization of the PMRI approach in mathematics learning process and familiarity of students with the said approach; 3) the attitudes and behaviors of teachers and students in support of the web-based realistic mathematics learning environment models; and 4) the achievement of learning outcomes by grade IV students in primary schools, meeting the average Minimum Completeness Criteria determined by the three standard deviations, which indicates that the students understand the two main scopes of mathematics - geometry and measurement, and numbers. It refers to materials from the web-based, realistic mathematics learning environment with model teachers acting as the facilitators. The model has a potentially significant impact on enhancing the students' 21st-century skills. This research is limited to 21st-century skills (4C skills). It is hoped that in the future, researchers can develop 21st-century skills (6C skills).

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Declarations

Author Contribution	:	L: Concept development, software/application development, research, formal analysis, first draft writing, and editing. RIIP: Assets, Data Curation, Validation, and Monitoring. Z: Supervision and methodology. S: Monitoring and formal analysis.
Conflict of Interest	:	The authors say they have no competing interests.

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