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ZPD Technological Learning Environment In Learning Computational Thinking Skill-Based Mathematics

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ABSTRAK

Penelitian ini dilakukan sebagai inovasi berkaitan dengan masalah pembelajaran yang sering terjadi pada siswa. Tujuan penelitian ini yaitu mengembangkan prototype teknologi lingkungan pembelajaran matematika-komputasi keterampilan bermain menggunakan pendekatan Zone of Proximal Development (ZPD) berbasis teknologi cerdas. Jenis penelitian ini adalah Research and Development dengan menggunakan alur model 4-D (Four-D Models). Teknik pengambilan sampel yaitu purposive sampling. Pengumpulan data dalam penelitian ini menggunakan sudut untuk sumber data lingkungan belajar dan pemikiran komputasi. Kemudian wawancaran digunakan untuk sumber data pengalaman belajar. Analisis data pada tipe data kuantitatif menggunakan statistik deskriptif dan statistik inferensial berupa independent sample t test dan model Miles and Huberman. Hasil penelitian ini ditemukan bahwa terdapat perbedaan kemampuan berpikir komputasi siswa laki-laki dan perempuan, dan yang dominan kemampuan berpikir komputasinya siswa laki-laki. Penelitian pengembangan ini telah menghasilkan produk lingkungan belajar online dimana produk tersebut valid menurut pendapat para ahli dengan kategori baik, menarik dan layak untuk diterapkan. Lingkungan belajar membantu dan memfasilitasi siswa dalam belajar matematika dengan menggunakan teknologi yang diarahkan pada pemikiran perbaikan.

ABSTRACT

This research was conducted as an innovation related to learning problems that often occur in students. This research aims to develop a technological prototype of the mathematics-computation learning environment for playing skills using the Zone of Proximal Development (ZPD) approach based on intelligent technology. This type of research is Research and Development using the 4-D model flow (Four-D Models). The sampling technique is purposive sampling. Data collection in this study uses angles for learning environment data sources and computational thinking. Then interviews are used as a source of learning experience data. Data analysis on quantitative data types used descriptive and inferential statistics in the form of independent sample t-tests and the Miles and Huberman model. This study found differences in the computational thinking abilities of male and female students, and the dominant computational thinking abilities were male students. This development research has produced an online learning environment product where the product is valid in the opinion of experts in the good category, exciting and feasible to implement. The learning environment assists and facilitates students in learning mathematics by using technology geared toward improving thinking.

1. INTRODUCTION

Education is an important topic that continues to be discussed in the world. Education is a means to advance all areas of human life, both in the economic, social, technological, security, skills, noble character, welfare, culture and progress of the nation nation (Aspi & Syahrani, 2022; Ilham, 2019; Yılmaz, 2020). The rapid change in technology demands that modern society be able to meet the educational needs of individuals who are trained in the education system who can later play an active role both on national and international platforms (Ak et al., 2022; Epçaçan, 2022; Steyn et al., 2018). Today the goal of education is to promote good people and good citizens who know how to access information, who can generate/compile information, and who can contribute to the development of the society in which they live (Erlistiana et al., 2022; González-calvo et al., 2022; Karagozoglu & Education, 2021). There are several issues, phenomena that are a challenge in the world of education today.

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First, the competency/skill needs that must be possessed, namely problem solving in relation to computing, or what is called Computational Thinking (CT), and secondly changes in student learning behavior, due to technological developments the need for integration in learning. This is evidenced by the fact that most countries that are part of the European Union have started to include CT from the 2016-2017 period and Asian countries such as Japan, Hong Kong, China, Taiwan, Singapore and Malaysia have included computer programming materials in their basic education curriculum (Bocconi et al., 2016; Ling et al., 2018; So et al., 2020). In Indonesia, the Ministry of Education and Culture has developed a prototype curriculum as an optional curriculum that can be applied to educational units starting in the new 2022/2023 academic year, which includes Integration of Computational Thinking (CT) in Indonesian, Mathematics and Natural Sciences subjects (Herman & Anwar, 2022; Rozady & Koten, 2021). Along with the development of technology today, it has an impact on learning trends that prioritize self learning and personalized learning (Bray & Mcclaskey, 2013; Ingkavara et al., 2022; Munshi & Biswas, 2019). Basically learning that is personalized learning focuses on individual characteristics and needs, theoretically one of the relevant learning is the Zone of Proximal Development (ZPD), where each individual has a domain of capacity/characteristic of each different potential.

As an innovation related to this research, a prototype learning environment technology for mathematics-computational tinking skills will be developed using the Zone of Proximal Development (ZPD) approach based on intelligent technology. Many studies regarding the integration of CT in education have been carried out and have become a trend nowadays by researchers in the field of mathematics and science education (Lee et al., 2020; Rich et al., 2020; Rodríguez-martínez et al., 2019). Given that CT is a basic 21st century ability to reformulate and solve problems via computers, educators are needed equipped with the knowledge, skills, and instructional strategies needed to teach computational thinking (Boom et al., 2022; Ezeamuzie & Leung, 2022; Rehmat et al., 2020). Then it has been confirmed by the Association of Computer Science Teachers that computational thinking equips students with essential critical thinking that enables them to conceptualize, analyze, and solve more complex problems (Bati & Ikbal Yetisir, 2021; Kusaka, 2021; Sovey et al., 2022). So it is necessary to integrate CT into learning.

One of them in mathematics lessons is that it requires the integration of computational thinking during the learning process. The integration of CT into mathematics lessons is useful for deepening and enriching mathematics learning and vice versa , acquainting students with real - world mathematical practices and growing students ' ability to acquire knowledge and apply it to new situations . Considering these advantages, many researchers and educators have started to integrate CT in mathematics classes as done by (Barcelos et al., 2018; Hickmott et al., 2018; Kalia et al., 2021).

The shift in people's behavior and technological advances also have an impact on the world of education. For example, now learning demands to be carried out online and or face-to-face (hybrid learning). Technology is certainly not used to completely replacing teachers, however, technology can help teachers carry out better learning. Today the application of technology, especially Artificial Intelligence in all fields, is very intense, one of which is education, and many studies have shown its effectiveness (Adamopoulou & Moussiades, 2020; Smutny & Schreiberova, 2020; Villegas-ch et al., 2020).

However, in practice, learning that provides services according to individual characteristics/needs is difficult to apply in conventional classes. This is because in conventional classes one teacher serves many students. So we need a learning innovation that is able to facilitate how different individual needs and allows it to be applied in conventional classes. For this reason, in this research, as an innovation related to this problem, a prototype learning environment technology for mathematics-computational tinking skills will be developed using the Zone of Proximal Development (ZPD) approach based on intelligent technology. For this reason, in this study, as an innovation related to this problem, this research aims to develop a learning environment technology prototype for math-computation playing skills using the Zone of Proximal Development (ZPD) approach based on intelligent technology.

2. METHOD

This type of research is Research and Development using the 4-D model flow (Four-D Models). Research and Development or Research and Development (R&D) is a series of processes or steps in order to develop a new product or perfect an existing product so that it can be accounted for (Masrukhin, 2014; Siregar & Harahap, 2019). The 4-D model stands for define, design, development and dissemination (Sari et al., 2022; Sohilait, 2020). The data obtained were in the form of explanatory quantitative and qualitative types. The population of this study were students of the Mathematics Education Study Program at the University of Jambi, Indonesia. The sampling technique is purposive sampling. using purposive sampling because it is sampling based on considerations from researchers on a particular matter (Crossman, 2020; Prasetia, 2022). The number of research samples as small group trial subjects was 15 students. The considerations in taking this sample were students of the mathematics education study program who were contracting basic mathematics courses with 100% class attendance.

Collecting data in this study uses a questionnaire as a source of data on the learning environment and computational thinking. Then interviews are used as learning experience data sources. Instrumen penelitian telah valid dengan nilai reliabilitas cronbach alpha 0,870. The lattice of learning environment character instruments in basic mathematics courses showed in Table 1.

Table 1. Lattice Learning Environment Instruments and Computational Thinking

Variables	Indicator	Statement number
Learning Environment	The role of teaching staff and peers	1,2,3,4,5
	Lecture facilities and infrastructure	6,7,8,9,10,11
Computational Thinking	Algorithm	1,2,3,4,5,6
	Pattern recognition	7,8,9

Responses to each statement were measured using a 5-point Likert scale. Point 1 for strongly disagree, point 2 for disagree, point 3 for neutral, point 4 for agree and point 5 for strongly agree. Then there are indicators in each category showed in Table 2. Then for the learning environment variable category there is also a learning experience and computational thinking interview grid showed in Table 3.

Table 2. Categories of Learning Environment Variable Indicators

Category	Learning Environment		Computational thinking	
	Teachers and peers	Lecture facilities and infrastructure	Algorithm	Pattern recognition
Not very good	5.0-9.0	6.0-10.8	3-5,4	6.0-10.8
Not good	9.1-13.0	10.9-15.6	5,5-7,9	10.9-15.6
Enough	13.1-17.0	15.7-20.4	8-10,3	15.7-20.4
Well	17.1-21.0	20.5-25.2	10,4-12,7	20.5-25.2
Very good	21.1-25.0	25.-30.0	12,8-15,1	25.-30.0

Table 3. Learning Experiment Interview Grid

Variable	Grille
Learning Experience	Teacher preparation Concrete experience

Data analysis on quantitative data types uses descriptive statistics and inferential statistics. Where descriptive statistics are used to identify students' computational thinking skills and identify student learning environments. Parametric inferential statistics using an independent sample t test were used to determine significant differences in students' computational thinking skills based on gender. Data that can be analyzed using parametric inferential statistics in the form of an independent sample t test is data that is normally distributed and is homogeneous (Dwi et al., 2022). Prerequisite tests that must be carried out before proceeding to the t test are the normality test (data is said to be normal if the sig. value is > 0.05) and homogeneity test (data is said to be homogeneous if the sig value is > 0.05) (Nawahdani et al., 2022; Zurweni et al., 2022). The basis for independent sample t test decision making, which can be seen from the Sig value. if < 0.05 then there is a difference (Darmaji et al., 2022). Then in the qualitative data the data analysis is based on the coding of each questionnaire item, then interpreted based on the context of the interview theme. Qualitative data analysis uses the Miles and Huberman model, namely data collection, data reduction, data presentation, and conclusion/verification (Ramli et al., 2022).

Referring to the research design in research and development (R & D), The stages in conducting this research consist of: Define (D-1)/Research and Information Collection. Analysis of theory/literature study, this stage analyzes theoretically the standards of e-learning content and learning including: (1) analysis of curriculum standards for calculus courses (3) analysis of student characteristics and resources, learning environment (2) analysis of standard content in the environment learning mathematics-computational thinking skills using the Zone of Proximal Development (ZPD) approach (3) system/ recruitment standard analysis (4) pedagogical strategy analysis. Requirement gathering and analysis program, in the form of software requirements (needs) from users (users) and customers (students and teachers) are collected, understood and defined. Where will be described in the objectives, functions and limitations (specifications) of the software to be developed.

Second, Design (D-2)/Planning. The design stage aims to provide a clear picture and a complete design of the system design that will later be used in making the program. The design phase activities include: Designing the program design: (1) preparing the design (2) making a Context Diagram (3) designing the Data Dictionary (4) making a flowchart (5) designing the File (master, input, process, temporary) (6) designing the Input Dialog (7) Designing Output Dialogs (8) Preparing system configuration. The role of designing content development (learning tools) is carried out by designing learning plans and student activity assignments. Third, Develop (D-3)/Develop Preliminary form of Product. In the program development section based on input from System Design (stage 2), the system is first developed in programs called Units, and integrated with the next stage. Each unit is developed and tested for functionality and used as a reference for unit testing. Fourth, Disseminate (D-4). This stage is carried out on the actual target implementation and when implementation is carried out measuring the achievement of goals. This measurement is carried out to determine the effectiveness of the product being developed which refers to the product development objectives.

3. RESULT AND DISCUSSION

Result

At the development stage, it is arranged in the form of a website system and content that can be accessed at the URL https://elematika.online/, and how to deliver it in learning. The product produced at this stage is called Prototype 1. Then Prototype 1 is validated by the Expert. Product validation was carried out by two experts. Based on expert suggestions and comments, website improvements are carried out by taking into account the suggestions for improvements. Improvements are made by also considering the direction and goals of website development. Improvements were made to the front page, namely: adding a slide show, login display, and language, listcourse and information for users. The display of repair results based on expert advice showed in Figure 1. The results of descriptive statistics on the learning environment variables and students' computational thinking showed in Table 4.

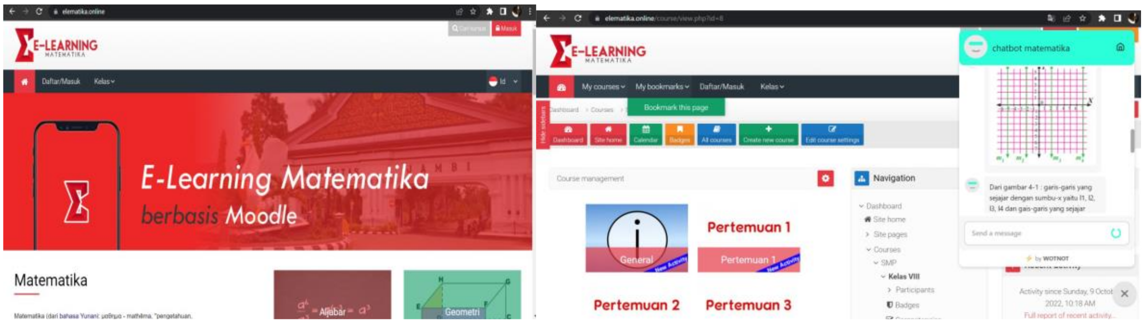

Figure 1. The Display of Repair Results Based on Expert Advice

Table 4. Description of the Learning Environment Variables on the Indicators of the Role of Teaching Staff and Peers as Well as Lecture Facilities and Infrastructure

Indicator	Category	Interval	F	%	Mean	Median	Min	Max
The role of teaching staff and peers	Not very good	5.0-9.0	0	0				
	Not good	9.1-13.0	0	0				
	Enough	13.1-17.0	8	53.3%	20.3	20,0	16.0	25.0
	Well	17.1-21.0	7	46.7%				
	Very good	21.1-25.0	0	0				
Lecture facilities and infrastructure	Not very good	6.0-10.8	0	0%				
	Not good	10.9-15.6	0	0%				
	Enough	15.7-20.4	5	33.3%	20.3	20,0	16.0	25.0
	Well	20.5-25.2	9	60.0%				
	Very good	25.-30.0	1	6.7%				

Based on the table above, it is known that the indicators for the role of teaching staff and peers are dominant in the sufficient category with a percentage of 53.3%. then the indicators of lecture facilities and infrastructure are more dominant in the good category with a percentage of 60%. Furthermore, a description of the variable computational thinking in the Algorithm and Pattern Recognition indicators is showed in Table 5.

Table 5. Description of Computational Thinking Variables in the Algorithm and Pattern Recognition Indicators

Indicator	Category	Interval	F	%	Mean	Median	Min	Max
Algorithm	Not very good	3-5,4	0	0				
	Not good	5,5-7,9	2	13.3%				
	Enough	8-10,3	10	66.7%	6.1	6.0	4.0	8.0
	Well	10,4-12,7	3	20,0%				
	Very good	12,8-15,1	0	0				
Pattern recognition	Not very good	6.0-10.8	0	0				
	Not good	10.9-15.6	1	6.7%				
	Enough	15.7-20.4	4	26.7%	19.8	20.0	16.0	25.0
	Well	20.5-25.2	9	60.0%				
	Very good	25.-30.0	1	6.7%				

Based on the table above it is known that the dominant algorithm indicator is in the sufficient category with a percentage of 66.7%. Then the pattern recognition indicator is more dominant in the good category with a percentage of 60%. Furthermore, the normality test of the learning environment and computational thinking showed in Table 6.

Table 6. Test for the Normality of the Learning Environment and Computational Thinking

Variable	N	Sig. (2-tailed)	Information
Learning environment	15	0.225	Normal
computational thinking	15	0.324	Normal

Based on the results of the table above, it can be concluded that the data is normally distributed. The normality test was obtained by the Shapiro-Wilk test, a significance value of > 0.05. Furthermore, the homogeneity test of the learning environment and computational thinking showed in Table 7.

Table 7. Test the Homogeneity of the Learning Environment and Computational Thinking

Variable	N	Sig.	Information
Learning environment	15	0.265	Homogeneous
computational thinking	15	0.276	Homogeneous

Based on the table above, it can be concluded that the learning environment variable data and computational thinking skills are homogeneous with a sig. > 0.05. The prerequisite test is in the form of a normality test to test whether the data is normal or not. The normality test is obtained by the Shapiro-Wilk test, a significance value of > 0.05 means that the data is normally distributed. The homogeneity test results obtained sig. > 0.05 where the learning environment variable obtained a sig. 0.265 > 0.05. Then the computational thinking skill variable is homogeneous with a sig. 0.276 > 0.05. So that it can be continued on parametric inferential statistical analysis with independent sample t test. From the independent sample t test, it was found that there were significant differences between male and female students related to their computational thinking skills. It is proven by the results of sig. (2-tailed) is smaller than 0.05. So that it can proceed to parametric inferential statistical analysis with the independent sample t test showed in Table 8.

Table 8. Learning Environment T Test and Computational Thinking Skills

Gander	t	Df	Sig. (2-tailed)	Mean Difference
Woman	16.145	15	.020	65.55553
Man	15.811	15	.024	65.55553

Based on the table above, it can be concluded that there are differences in the computational thinking skills of male and female students. It is proven by the results of sig. (2-tailed) is smaller than 0.05. In the interview, the first question is whether the teaching staff prepare learning tools every time they carry out teaching? Teaching staff 1 answered yes. Teaching staff 2 answered yes, it is very important to be prepared in my opinion, with learning tools the lecture or teaching process in class will be more focused. Teaching staff 3 answered rarely, because in my opinion it was enough to have a directed curriculum. Teaching staff 4 answered yes, but I often forgot to prepare them due to the many campus events that needed to be handled.

The second question is how do you mobilize students to gain concrete experience? Teaching staff 1 answered before the learning process I would ask students about the material that had been discussed before then I would ask how it is applied in everyday life?, are there any implications? Teaching staff 2 answered that during the presentation of the material, I would ask students about the material that was presented, did they ever experience it? Then ask him to retell and relate it to the material being studied. Teaching staff 3 by giving assignments. My teaching staff 4 will give group assignments to find the application of the material discussed, make a report and then present it.

Discussion

The learning experience from the interview results it was found that the teaching staff prepared learning tools before carrying out the lecture process in class. Learning tools are essential to prepare before learning begins (Anwar et al., 2016; Hernawati, 2016; Manalu et al., 2022). Learning tools can be a teacher's guide in carrying out teaching and learning activities. Learning tools can also improve teacher capabilities in teaching (Fahrurrozi et al., 2021; Lestari et al., 2016; Padmadewi, 2015). But there are also teaching staff who don't prepare it due to several obstacles. From the interviews it was also known that preparation in the form of learning tools such as syllabus, lesson plans and so on is very important for the direction of teaching activities and also as a reference in the success of classroom activities. Furthermore, in the concrete experiences of students, it is known that the teaching staff have given encouragement to students to gain concrete experiences. For example, before entering the next material the teaching staff will ask or repeat the previous material, and ask how it is applied in everyday life. Do not forget that the teaching staff will also give team assignments in the form of projects so that they can gain direct experience in which reports are linked to theory and presented in class.

The results of the small group trials show that the average user response to the display aspect is in the very good category with an average value range of 3-4, namely 3.56. Good media display has an impact on increasing student motivation (George et al., 2014; Ntshwarang et al., 2021; Poulova et al., 2022; Wulandari et al., 2020). Furthermore, based on the trial results, it can be concluded that the test of user perception of content subtnation, namely the VLEM system and its learning, shows that it is in the very good category, with an average of 3. The content presented must be adapted to the learning material so that it makes it easier for students to learn (Samir Abou El-Seoud et al., 2014; Sidiq & Nuswantoro, 2021; Sugiarto, 2020). Then in the small group trials there was an increase from the first day to the fourth meeting day. This development research has produced an online learning environment product. The results of the development conclude that the product developed is valid according to the expert's opinion, which is included in the good, interesting and feasible category and to be implemented. The learning environment can help students and facilitate students in learning mathematics using computational thinking-oriented technology (Al-Fraihat et al., 2020; Maudiarti, 2018; Ramkissoon et al., 2020).

Previous research that examined computational thinking skills, it was found that the direction of educational and cognitive mathematics activity is based on the principle of gamification and the authors classified the concept of "computational thinking", which includes a system of actions to activate patterns, connections between them from human memory, as well as devising effective algorithms to solve them: to obtain relevant information about development advanced technology; to state problems and models; to use software products with mathematical content (Soboleva et al., 2021). The difference is that computational thinking research is developed in the form of a website which hopes to help students improve their experience using technology and build students' computational thinking. The novelty of this study is in the form of research subjects and also the research variables studied. In this research, the development of testing the product was carried out. Recommendations for further research may be that more complex research can be carried out, such as being tested on large groups and maximizing the product again.

4. CONCLUSION

The conclusion of this study is that there are differences between the computational thinking skills of male and female students. This development research has produced an online learning environment product where the product is valid in the opinion of experts in the good category, interesting, and feasible to implement. The learning environment can help students and facilitate students in learning mathematics using technology that is oriented towards computational thinking.

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