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Development of Differentiate Learning Devices with Problem based Learning Models for Matrix Topics

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Abstract: ***This article presents a summary of research results that aim to produce differentiated learning tools in learning mathematics on the topic of the Matrix using the Problem Based Learning model for students of class XI IPA. The development process ends if all documents developed meet the valid, practical and effective criteria. The focus of the research is to develop learning tools consisting of Learning Implementation Plans (LIP), Student Worksheets (SW), Learning Outcomes Tests (LOT), and Learning Media (LM) to teach the Matrix with the Problem - Based Learning learning model based on Differentiated Learning. The development model used is the didactic mathematics research design Generic Research Design Model which explicitly describes an integrated cycle of research, design and output activities that interact directly and indirectly with development practices. The conclusion of this study is that all the products developed, namely lesson plans, worksheets, THB, and MP for teaching mathematics on the topic of Matrix based on Differentiated Learning have met the valid, practical and effective criteria.***

Keywords: Learning Tools, Matrix, Problem Based Learning, Differentiated Learning

1. Preliminary

Education is a seedbed for culture in society. To create civilized Indonesian people, education is one of the main keys to achieving it. Ki HadjarDewantara, a pioneer of the Indonesian education movement at the beginning of independence, stated that education guides all the nature that exists in children, so that they can achieve the highest safety and happiness both as humans and as members of society. Therefore, education can only lead to the growth or life of the natural strengths that exist in children, so that they can improve their behavior (not the basis) of life and the growth of the child's natural strengths. In fact, there are not a few educators who have not been able to free their students in learning. For example, educators still generalize the abilities of children in class, so that the learning styles in class are also generalized. Sanjaya (2007) mentions four teacher mistakes in teaching, namely: (1) The teacher does not try to find out students' initial abilities. The teacher often does not make a diagnosis of the student's condition, so he does not know whether the student understands the material to be taught, nor does he know whether the student has read the book or not. Students can understand better than their teacher about the subject matter to be taught. This is because students not only read the books used by the teacher, but students also learn from various other sources; (2) The teacher never invites students to think. The task of a teacher is not only to convey subject matter, but also to train students' abilities to think, use their cognitive structures in a full and directed manner. The subject matter should be used as a tool to train thinking skills, not as a goal; (3) The teacher does not try to get feedback. The teaching process is a purposive process. Therefore, what the teacher does should lead to an achievement of goals; (4) The teacher thinks that he is the most capable person and masters the lesson. In the current information age there should have been a change in the role of the teacher. The teacher no longer acts as the only source of learning (learning resources) but rather acts as a manager of learning (manager of instruction). In this kind of position, teachers and students can learn from each other.

Based on observations and interviews with teachers at SMAN 1 Tondano, it was found that only 35 - 40% of the 29 students in class XI IPA achieved a KKM score of 75 on the Matrix Material Daily Test. It is suspected that students have difficulty understanding and solving problems related to the Matrix material. According to Wibowo (2016) student activity makes learning run according to the lesson plans arranged by the teacher, the form of student activity can be in the form of activities on their own or activities in a group. In studying the matrix material, one of the learning models that is considered in accordance with the demands of the curriculum is differentiated learning with the Problem - Based Learning (PBL) model. Differentiated learning with problem solving makes student learning activities to increase active in learning activities Matrix and problem solving can help students know how to transfer their knowledge to understand problems in real life. Differentiated learning was originally introduced by Carol Ann Tomlinson (Tomlinson and Moon, 2013) who stated that differentiated learning is learning that accommodates, serves, and recognizes the diversity of students in learning according to students' readiness, interests, and learning preferences. Concern for students in paying attention to the strengths and needs of students is the focus of attention in differentiation learning. Learning profile that accommodates students' learning needs. Differentiated learning requires educators to pay attention and provide action to meet the special needs of students. Differentiated learning allows teachers to see learning from various perspectives. Differentiated learning is a cyclical process of finding out about students and responding to their learning based on differences. The

concept of differentiated learning is based on the teacher's need to differentiate learning in order to meet the needs of different students. Differentiated learning is built as a teacher's response to the different learning needs of students (Tomlinson, 2013). The teacher must understand all the students in the class, how students learn, and how students make their learning choices. The concept of differentiated learning is not interpreted as a separate, unrelated learning activity between students. Differentiated learning is learning that helps students with different academic needs and learning styles and guarantees that all students can achieve learning goals in different ways. There are three differentiation strategies, namely (1) content differentiation, (2) process differentiation, (3) product differentiation. Problem Based Learning (PBL) is a learning model that challenges students to "learn how to learn", work in groups to find solutions to real world problems. This problem is used to bind students to curiosity in the intended learning. Selanjutnya, MenurutArends (2007), Furthermore, according to Arends (2007), Problem Based Learning (PBL) is a learning approach in which students are faced with authentic (real) problems so that they are expected to construct their own knowledge, develop high - level skills and inquiry, make students independent, and increase confidence himself. Problem Based Learning is a teaching strategy in which students are actively confronted with complex problems in real situations.

Table 1: The Syntax of the Problem Based Learning Model and the Role of the Teacher

Phase	The Role Of The Teacher
Phase I Student orientation on the problem	The teacher explains the learning objectives, describes the various characteristics and needs of students, presents a problem and motivates students to engage in problem solving activities.
Phase II Organizing students to study	The teacher divides students into groups based on the results of the initial assessment. The teacher assists students in defining and organizing learning tasks related to problems.
Phase III Assist independent and group investigations	Teachers encourage students to get the right information, carry out experiments, and seek explanations and solutions.
Phase IV Develop and present the work	The teacher assists students in planning and preparing suitable works, such as reports, media, and models, and helps them to convey them to others.
Phase V Analyze and evaluate the problem solving process	The teacher helps students to reflect on the investigation and the processes used.

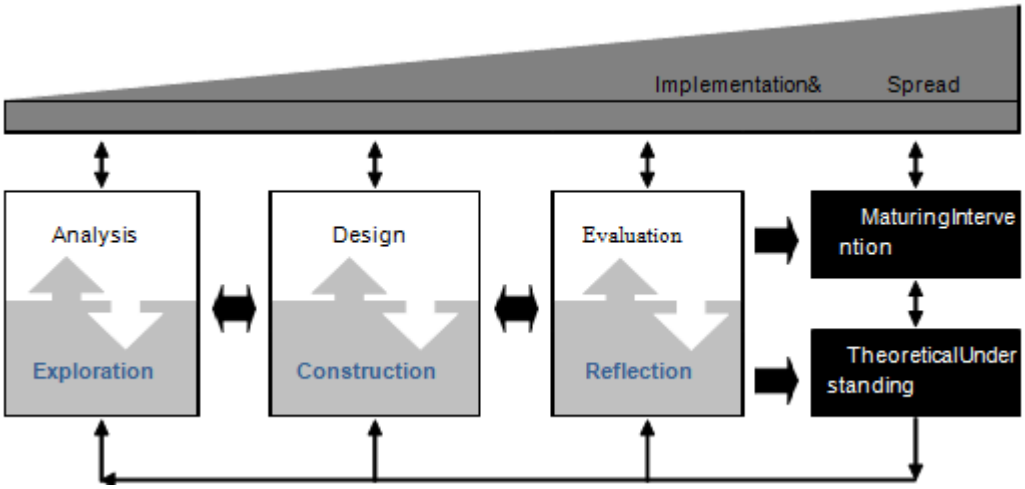
(Arends, 2007)

As a learning model, Problem Based Learning has several advantages (Sanjaya, 2007), including: (1) Challenging students' abilities and providing satisfaction to discover new knowledge for students; (2) Increasing students' motivation and learning activities; (3) Assist students in transferring student knowledge to understand real - world problems; (4) Helping students to develop their new knowledge and be responsible for the learning they do. Besides that, PBL can encourage students to self - evaluate both the results and the learning process; (5) Develop students' ability to think critically and develop their ability to adapt to new knowledge; (6) Provide opportunities for students to apply the knowledge they have in the real world; (7) Developing students' interest in continuing to learn even though studying in formal education has ended; (8) Facilitate students in mastering the concepts learned in order to solve world problems.

The disadvantages of the Problem Based Learning (PBL) model according to Sanjaya (2007) are as follows: (1) When students have no interest or do not have confidence that the problem being studied is difficult to solve, they will feel reluctant to try it; (2) For some students think that without understanding the material needed to solve the problem why should they try to solve the problem being studied, then they will learn what they want to learn. To overcome the shortcomings of the Problem Based Learning (PBL) model, it is necessary to design learning activities properly accompanied by adequate preparation. Prior to learning, a heterogeneous study group was prepared in advance in terms of learning profiles and student learning readiness based on the results of the initial assessment. This grouping is intended to accommodate the characteristics and needs of students with less academic ability and the management of large numbers of classes. In addition, the preparation of learning tools is also maximized to help students gain meaningful learning experiences.

2. Research Procedure

The development model used to develop learning tools in this research is the didactic mathematics research design model Generic Research Design Model (McKenney and Reeves, 2012) which explicitly describes an integrated cycle of research activities, design and output that interact directly and indirectly with practice. (Picture 1).



Picture 1: Generic models for conducting educational design research

The Generic Design Research model only represents the core elements of a flexible process featuring three main stages, which take place in interaction with practice and produce multiple outputs from knowledge and intervention (Spector et al.2014). In this model there are three distinct concepts of each form: (1) Squares: Three phases of research and development activities, (2) Rectangles: Two main outputs of design research, and (3) Triangles: Interaction with practice is shown to increase from time to time. McKenney and Reeves (2012) divides the generic model for research design in education into three stages, namely Analysis, Design and Evaluation. Analysis Phase – Exploration with activities (1) Initial orientation towards the problem. Presentation of research issues by explaining and formulating problems, research context, and stakeholders (parties involved); (2) Scientific and practical literature review/actualities in the field and linking them properly/structured; (3) Carry out field investigations (in the context of/to make plans, field work and meaning making; (4) conduct exploration regarding the 3 steps above through the implementation of site visits, professional meetings/discussions, and networking activities. Construction Phase with activities (1) The researcher starts designing through exploring ideas and mapping solutions; (2) Conduct discussions with several sources who are competent in finding solutions to problems that arise in the learning process; (3) Conduct literature studies either through print media, source books, reference books, or online media such as Google and YouTube about learning media; (4) Designing/designing instructional media based on theory and implementation in the field. Evaluation Phase – Reflection with the activity of carrying out an iterative process to test and improve solutions practically. After the product is developed, the researcher then conducts an initial trial which aims to validate the teaching material development design. Validation is carried out by material experts and media experts to determine the feasibility level of the media in learning. There are 5 (five) stages of activity in the Research Design Generic Model, namely (1) Analysis – Exploration, (2) Design – Construction, (3) Evaluation – Reflection, (4) Intervention - Theoretical Intervention Maturation, and (5) Implementation/Dissemination (Spread). The products produced go through stages 1 and 2, then in stage 3 an evaluation is carried out to measure the achievement of valid, practical and effective criteria. In stage 4, revisions or improvements to the media product are carried out according to the results of the trials and the considerations of the supervisor or assessor. After the revision is complete, the test is carried out again. This process will continue to repeat if the product has not shown a good level of feasibility. However, if the trial results show good feasibility results, the device testing will be stopped and a hypothetical model that is feasible to use in the learning process will be found. The intervention matures with the completion of each design research cycle. Stage 5 is actually inclusive in this stage of development. The implementation phase of this model starts from the analysis, design, evaluation and intervention - theoretical stages. In other words, every time the steps in this model are carried out, the results are directly implemented.

3. Results and Discussion

At the end of the Analysis - Exploration phase which includes interviews with teachers and other exploratory activities which can be summarized as follows: (1) The 2013 curriculum has not been implemented as it should. One of the most frequently encountered examples in the field is that learning is still teacher - centred; (2) During the Covid - 19 pandemic, the learning system changed from face - to - face learning to distance learning (online), but the tools used by teachers remained the same; (3) The application of restrictive policies that changed in a short span of time, causing problems for both the teacher and (LKS); (4) Teachers have not developed themselves optimally in the application of learning models, methods, teaching materials, selection of tools and materials (learning media) and assessment; (5) There is still a lack of teacher innovation and creativity in using digital technology for learning activities; (6) Online learning that takes place from March 2020 to the end of 2021, causes motivation and interest in learning to decrease, which impacts on learning outcomes; (7) The data from the interviews show that for class XI teaching materials that need to be developed, one of them is the matrix material. students find it difficult in the sub - matrix multiplication operation sub - matrix with a matrix and solving applied questions using the concept of determinants and matrix inverses. At this stage, after the data has been analyzed and explored, the researcher collaborates with colleagues at school, in this case the MGMP Mathematics of

SMAN 1 Tondano, the vice principal for curriculum affairs and the development supervisor to discuss and find solutions to the problems that occur. In addition, researchers conduct literature studies / literature studies to develop the right product, by carrying out technological innovations that are currently developing rapidly.

At the end of the Design - Construction stage a Differentiated Learning Toolkit with the PBL Model has been designed which includes lesson plans, worksheets, THB and MP which are ready to be validated.

At the end of the Evaluation - Reflection stage, the following results were obtained: (1) The device was valid after two validation stages; thus ready to be tested to obtain practicality and effectiveness data. In Tables 2, 3, 4 and 5, data from the validation results in the second stage of each device document are presented.

Table 2: Results of *Learning Implementation Plan* (LIP) Validation

Assessment Aspects of the LIP Section	The average validator value for all indicators	Remark
Part I. Identity of LIP	5.00	Very Valid
Part II. Indicators and Objectives	4.17	Valid
Part III. Material Selection	4.08	Valid
Part IV. Selection of Learning Approaches and Models	4.00	Valid
Part IV. Compatibility of Learning Activities with the PBL Model	3.93	Valid Enough
Part VI. Learning Resources and Assessment of Learning Outcomes	4.07	Valid
Percentage	0.84	Very high

Category Validation Formula Aiken's percentage of the total mean value of RPP Validation obtained V = 0.84 = 84% in the range 0.80 <V ≤ 1.00 with a very high rating. Based on these results, the lesson plans that have been developed by researchers are declared valid and can be used with slight revisions based on suggestions in the comments column. The results of the assessment from the LKS validator team which include LKS format, LKS content, language and concept accuracy, there are several parts that need to be improved. In making improvements to the LKS, it is presented in the following table:

Table 3: Student Worksheet Validation Results

Assessment Aspects	The average validator value for all indicators	Remark
Part I. Formats	4.38	Valid
Part II. Fill	4.19	Valid
Part III. Language and Writing	4.53	Valid
Part IV. Illustrations, Layouts and Diagrams/ Images	4.25	Valid
Benefits/Uses	4.25	Valid
Total Average	4.50	Valid
Percentage (%)	0.87	Very high

Based on Aiken's formula validation category (Susanti, 2021), the results of the average percentage of the total LKS Validation value obtained V = 0.87 in the range 0.80 <V ≤ 1.00 with a very high predicate. So it was concluded that the worksheets compiled by researchers were valid and could be used with revisions at the Implement stage. Formative (quizzes) and summative (daily tests) Learning Outcomes Test (THB) validation results which include THB Content, THB Construction, and Language, are presented in Table 4 below.

Table 4: Results of Learning Outcomes Test Validation

Assessment Aspects	Average validator value	Keterangan
Part I. Contents	4, 67	Valid
Part II. Construction	4, 83	Valid
Part III. Language	4, 80	Valid
Total Average	4, 77	Valid
Percentage (%)	0, 95	**Very high**

Category Aiken's Formula Validation the average percentage of the total online THB Validation value obtained V = 0.96 = 96% in the range 0.80 <V ≤ 1.00 with a very high rating. Based on these results, the THB that has been developed by researchers is declared valid and can be used.

Table 5: Learning Media Validation Results

Assessment Aspects	Rating Score		
	V1	V2	V3
Video Contents			
1) Clarity of learning objectives.	4	5	5
2) Conformity of learning indicators with the level of student development.	4	4	4
3) The video contains stimuli so that students respond to the video (prepare stationery, listen to material, answer questions)	5	4	5
4) The problems presented are authentic problems.	4	4	4
5) The material presented is in accordance with the subject matter.	5	5	5
6) Systematic presentation of material in the video according to the curriculum.	4	4	5
7) The suitability of the content of the material with the learning objectives.	4	4	4
8) The suitability of the illustrations presented with the material.	4	4	4
9) Explanation of the material in the video is displayed clearly.	4	4	4
10) The language used is in accordance with Indonesian rules and is easy to understand (communicative).	4	4	4
Video View			
11) Display of interesting learning videos.	4	4	4
12) Grow students' interest in learning.	4	4	4
13) The suitability of choosing the size and shape of the letters.	5	4	5

14) Accuracy of music or songs accompanying learning videos.	4	4	4
15) Readability of the text on the video.	4	4	4
16) Layout of the text on the video.	4	4	4
17) Image quality on video.	4	5	5
18) Sound quality on videos.	4	4	4
Average Aspect Rating	**4.22**		
Percentage	**0.84**		

Category Aiken's Formula Validation The average percentage of the total online THB Validation value obtained V = 0.84 = 84% in the range 0.80 < V ≤ 1.00 with a very high rating. Based on these results, the THB that has been developed by researchers is declared valid and can be used.

(2) Practical and effective devices after going through two stages of field trials. Each stage of learning is carried out in 4 meetings. Practicality data is shown by the results of observing the implementation of learning by the teacher using the developed learning tools. Observational data obtained a total average value for 4 meetings, namely 4.92 and with the criteria quoted from Nurdin (2007) in Ilyas (2015), the results of these observations are in very high criteria. This criterion indicates that the level of the teacher's ability to process learning is very high. So that it can be concluded, the learning tools developed by researchers, namely the development of learning tools with the PBL model based on Differentiated Learning, meet the Practical criteria.

Table 6: Observation Results of Learning Implementation in the 2nd Trial

No	Assessment Aspects	Average Value of Each Aspect
1	Part I. Introduction	5.00
2	Part II. Open Lesson	4.92
3	Part III. Core activities:	
	a) Syntax	4.38
	b) Mastery of Subject matter	4.92
	c) Learning Approach/Strategy	4.64
	d) Utilization of Learning Resources/ Learning Media	4.75
	e) Learning that Triggers and Maintains Student Engagement	5.00
	f) Assessment of Learning Processes and Outcomes	4.63
	g. Use of language	5.00
4	Part IV. Closing	5.00
	Average Aspect Rating	4.92
	Percentage	98.38

Furthermore, the effectiveness data is shown by student learning outcomes and student responses to learning that applies the developed tools. Table 7 presents data on student responses to Matrix Learning with Differentiated Learning - based PBL Models.

Table 7: Data on student responses to learning

Serial number	Observed Aspects	Student Response Percentage	
1	Students' feelings while participating in learning differ from the PBL model in the Matrix material	Happy	Not happy
		89, 66 %	10, 34
2	Students' feelings towards the learning component.	Happy	Not happy
	a) Subject matter	89, 66	10, 34
	b) Student worksheet	93, 10	6, 90
	c) Learning Media	96, 55	3, 45
	d) Learning Outcome Test	86, 21	13, 79
	e) Classroom Learning Atmosphere	93, 10	6, 90
	f) How to learn	89, 66	10, 34
	Average	**91.38**	**8.62**
3.	Student opinion on the learning components of the PBL model	New	Not New
	a) Subject matter	89, 66	10, 34
	b) Student worksheet	93, 10	6, 90
	c) Learning Media	96, 55	3, 45
	d) Learning Outcome Test	86, 21	13, 79
	e) Classroom Learning Atmosphere	96, 55	3, 45
	f) How to learn	93, 10	6, 90
	Average	**92.53**	**7.47**
4.	Student opinion on understanding the language used in:	Clear	Unclear
	a) Student worksheet	93, 10	6, 90
	b) Learning Media	96, 55	3, 45
	c) Learning Outcome Test	93, 10	6, 90
	Average	**94.25**	**5.75**
5.	Opinions of students about appearance (writing, illustrations or pictures and the location of the pictures)	Attractive	Unattractive
	a) Student worksheet	93, 10	6, 90
	b) Learning Media	96, 55	3, 45
	c) Learning Outcome Test	89, 66	10, 34
	Average	**93.10**	**6.90**

The data in Table 7 shows that most of the students gave a positive response to the learning they participated in in this study. Previously it was also obtained data that the learning outcomes of students who studied matrix with learning that used the tools developed had an average value higher than the learning outcomes of the same material in classes with other learning. This shows that the learning tools developed meet the criteria of being effective.

4. Conclusions and Suggestions

The conclusions of this study can be formulated as follows: (1) The results of the assessment on the validation aspect of different learning tools using the Problem Based Learning (PBL) model which includes RPP, LKS, THB and MP in the second development stage obtained an average value that belongs to the category very high; thus all the learning devices resulting from the development meet the Valid criteria; (2) Data on students' responses to differentiation learning based on the PBL model on the Matrix material with the developed tools obtained positive responses and were in the strong category; with these results it can be concluded that learning with the developed device received a positive response. The learning outcomes test shows that there is a significant difference in the average learning outcomes of the two classes, so it is concluded that the learning tools that have been developed meet the criteria of effectiveness. Based on the conclusions obtained through these indicators, it can be concluded that the tools developed are in the effective category; (3) Criteria for the practicality of the developed learning tools, seen from the level of the teacher's ability taken through the observational data of the implementation of learning assessed by the observer obtained a score with very high criteria. Based on these results, it can be concluded that the development of mathematics learning tools, especially the Matrix material with the PBL model based on differentiated learning meets the Practical criteria; (4) The results of the development of mathematics learning tools, especially matrix material with a differentiated learning - based PBL model including lesson plans, worksheets, THB and MP, meet the good category because they meet the criteria of Valid, Practical and Effective. It is suggested to other teachers and researchers to: (1) be able to facilitate students in understanding the concept of mathematics as a new learning experience in improving learning outcomes both in face - to - face learning and distance learning; (2) providing alternative online mathematics learning tools to teachers to improve, develop and improve the quality of mathematics learning; (3) make a positive contribution to teaching and learning activities, so that schools are more creative and innovative in developing mathematics learning tools to improve the quality of education.

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