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Jurnal Pendidikan Matematika

Optimizing Algebraic Thinking using the Area Model Algebra Worksheet based on PhET Interactive Simulation

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ABSTRAK

Penelitian ini bertujuan mengembangkan, memvalidasi dan menguji lapangan *Area Model Algebra Worksheet* berbasis *Phet Interactive Simulation* sebagai upaya optimalisasi berpikir aljabar siswa. Metode penelitian ini mengadaptasi prosedur penelitian pengembangan model ADDIE, terdiri dari fase *Analysis*, *Design*, *Development*, *Implementation*, dan *Evaluating*. Pengambilan data uji ahli menggunakan kuesioner dengan aspek substansi konsep aljabar, struktur lembar kerja yang dinilai, dan penggunaan bahasa. Pengambilan data uji coba terbatas dilakukan dengan pengisian lembar kerja yang telah divalidasi dan dinyatakan layak oleh validator ahli. Data uji ahli dianalisis menggunakan Statistika Q-Cochran dan data penggunaan lembar kerja oleh subjek penelitian dianalisis dengan Cronbach Alpha. Dari hasil uji Q-Cochran validasi lima orang ahli diperoleh nilai *Asymp.Sig.* = 0.539 > 0.05 untuk validitas muka dan nilai *Asymp.Sig.* = 0.707 > 0.05 untuk validitas isi yang mengindikasikan kelima orang validator menunjukkan pertimbangan yang seragam pada *Area Model Algebra Worksheet* berbasis *Phet Interactive Simulation*. Implikasinya, *worksheet* yang disusun memenuhi kelayakan untuk digunakan dalam membantu menyelesaikan masalah siswa pada konsep perkalian aljabar sekaligus menstimulasi kemampuan berpikir aljabar siswa. Adapun dari hasil uji terbatas dan uji lapangan pada 15 dan 65 orang siswa diperoleh perhitungan nilai r hitung > r kritis yang disimpulkan kelima butir *worksheet* valid dan reliabel.

Kata Kunci: Kemampuan Berpikir Aljabar; Konsep Luas Persegi; Lembar Kerja Aljabar; Perkalian Aljabar; Simulasi Interaktif PhEt.

ABSTRACT

The aim of this research is to develop, validate, and field test an Area Model Algebra Worksheet based on PhET Interactive Simulation as an effort to optimize students' algebraic thinking. The research method adapted the ADDIE model development procedure, which consists of the phases of Analysis, Design, Development, Implementation, and Evaluation. Data collection for expert validation used questionnaires assessing aspects of algebraic concept substance, worksheet structure, and language usage. Limited tests data were collected through the completion of validated worksheets considered appropriate by expert validators. Expert validation data were analyzed using the Q-Cochran statistic, and worksheet usage data by research subjects were analyzed using Cronbach's Alpha. The results of the Q-Cochran validation by five experts generated an Asymp.Sig. value of 0.539 > 0.05 for face validity and an Asymp.Sig. value of 0.707 > 0.05 for content validity, indicating that the five validators had consistent evaluations of the Area Model Algebra Worksheet based on PhET Interactive Simulation. The implication is that the developed worksheet meets the criteria for use in helping students solve algebraic multiplication problems while stimulating their algebraic thinking skills. Additionally, the results of limited and field tests with 15 and 65 students showed that the coefficient r values were greater than the critical r values, leading to the conclusion that the five items in the worksheet are valid and reliable

Keywords: Algebraic Multiplication; Algebraic Thinking Ability; Algebra Worksheet; PhET Interactive Simulation; Rectangle Area Concept.

Article Information:

Accepted Article: 20 Mei 2024, Revised: 22 Juni 2024, Published: 30 Juli 2024

How to Cite:

DOI: https://doi.org/10.31980/plusminus.v4i2.1465

Artasari, A., Oktaviyanthi, R., Zahwatuzzukhrufiah, & Delvianingsih. (2024). Optimizing Algebraic Thinking using the Area Model Algebra Worksheet based on PhET Interactive Simulation. *Plusminus: Jurnal Pendidikan Matematika, 4*(2), 241-254.

1. INTRODUCTION

Algebra is one of the branches of mathematics included in the junior high school curriculum with the primary basic competency being that students can solve problems related to algebraic forms and operations (Brahier, 2020; Barbieri & Miller-Cotto, 2021). Moreover, the importance of learning algebra for students is teaching them basic skills in logical problem solving (Melhuish, Lew, & Hicks, 2022; Zainudin & Utami, 2022). By understanding algebraic concepts, students can follow logical steps to solve various mathematical problems. This allows them to develop a better understanding of how numbers work together in equations and how to apply them in everyday life contexts (Darmayanti, Baiduri, & Sugianto, 2022; Manandhar, Pant, & Dawadi, 2022). Algebra is not only about manipulating mathematical symbols but also a fundamental base for advanced learning in many fields of science, including mathematics, science, engineering, medicine, and economics. With a strong understanding of algebra, students will be better prepared to explore more complex concepts and apply them in various real-life situations (Lehtonen, 2022). This helps prepare students for success in advanced studies and future careers that require a deep understanding of mathematics (Kwon & Capraro, 2021). Thus, the urgency of learning algebra for students lies not only in their ability to solve mathematical problems but also in preparing them for future challenges and opportunities in various fields of science and professions.

In practice, preliminary study results indicate that students often face several challenges in understanding algebraic concepts. One of these is the difficulty in developing and justifying methods for using area models to determine the product of monomials and binomials or the product of two binomials. This difficulty is partly due to errors in understanding factor expressions, especially those involving variables (Barbieri & Booth, 2020; Heffernan & Koedinger, 2022). Another issue is that students face challenges in recognizing that area represents the product of two numbers and is additive. As Cai and Hwang (2022) indicate, the problem of multiplication as the area of a rectangle, whether proportionally or using a generic area, is complicated for some students learning algebra. Additionally, students tend to struggle with translating words into algebraic expressions or vice versa. They also often misinterpret algebraic expressions and when changing signs. Namkung & Bricko (2021) noted that the misuse of algebraic concepts to solve common mathematical problems is also a frequent difficulty. Other difficulties recorded in the preliminary study include understanding pattern generalization problems, recalling mathematical facts, concepts, rules, formulas, sequences, and procedures. Inconsistent mastery of mathematical facts, difficulty with left and right orientation, and difficulty following sequential procedures and instructions in mathematical steps are also commonly faced by students (Janviskt & Niss, 2020; Tong, Yip, & Wong, 2023).

Vlassis and Demonty (2022) reviewed that the barriers to students' algebraic proficiency may be due to low algebraic thinking skills. In the context of learning algebra, algebraic proficiency becomes an important foundation for the development of algebraic thinking skills (Yang & Sianturi, 2022). When students have strong algebraic proficiency, they can effectively manipulate algebraic equations and enable students to identify patterns and relationships between variables in various mathematical situations (Lourens, 2022). Moreover, good algebraic proficiency also helps students develop algebraic intuition, allowing them to more easily generalize the algebraic principles they learn to new situations (Litke, 2020). Problems with algebraic thinking skills, such as difficulties in understanding algebraic concepts, applying algebraic principles in problem solving, and generalizing algebraic concepts, can be addressed using guided worksheets as a learning solution (Barana, 2021; Erisson & Sumpter, 2021; Keels, 2022). Guided worksheets are tools designed to help students develop their understanding of mathematical concepts, including algebra, through a series of structured and guided steps (Akbaş, 2021; Oktaviyanthi & Agus, 2023). In guided worksheets, each step or activity is designed to provide clear direction to students on how to solve specific algebraic problems. These worksheets may include steps such as understanding concept definitions, performing a series of progressive exercises, applying concepts in real-life contexts, and reflecting on their understanding (Sholahudin & Oktaviyanthi, 2023). Thus, guided worksheets help students build a strong foundation in algebraic thinking skills by providing organized and supportive structure in their learning.

2. METHOD

The research and development (R&D) method was employed to conduct this study using the ADDIE development model, which consists of the phases of Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009; Spatioti, Kazanidis, & Pange, 2022). The flowchart of the development process for this educational media is shown in Figure 1.

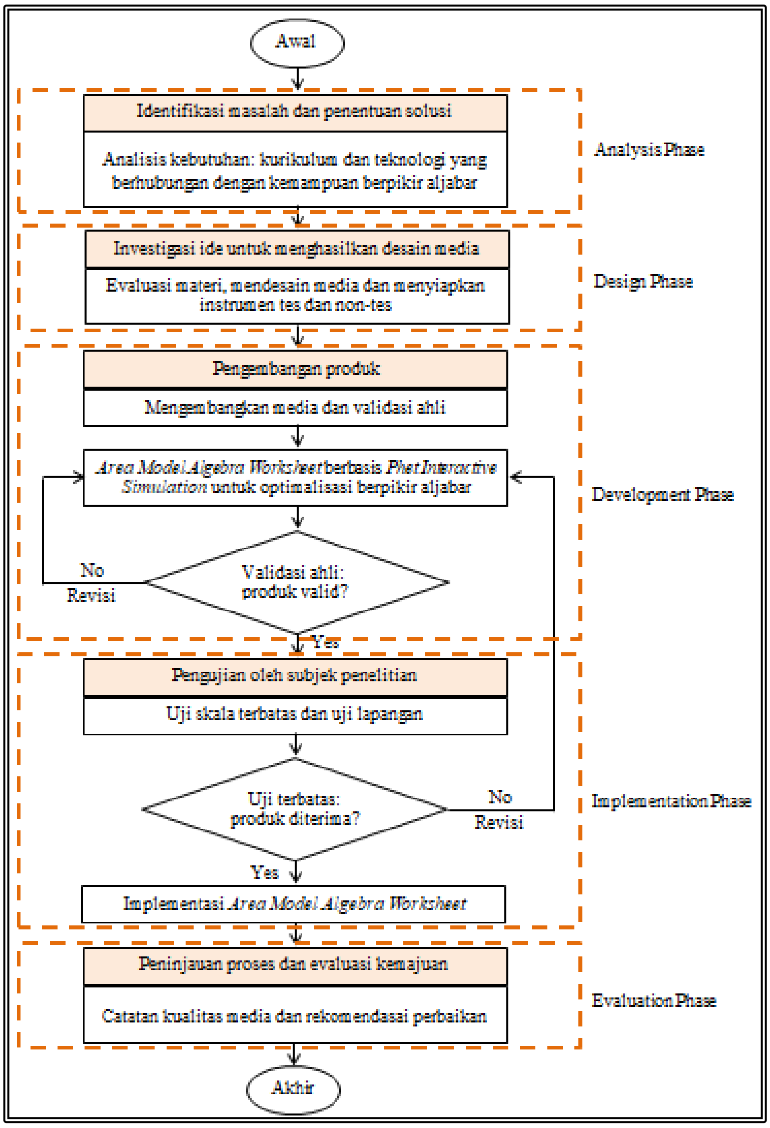

Figure 1. Development Flowchart of the Area Model Algebra Worksheet

The Analysis phase involves identifying problems aimed at discovering key issues related to students' algebraic thinking abilities and determining design solutions through needs analysis, curriculum analysis, and technology utilization analysis. In the subsequent Design phase, the process of investigating ideas is carried out to produce an appropriate and relevant problem-solving design through material review, product design, and the development of test and non-test instruments. The third phase, Development, focuses on the creation of the product, namely the Area Model Algebra Worksheet based on PhET Interactive Simulation. Additionally, in this phase, product validation is conducted by media experts and mathematics experts. Product revisions are made based on recommendations and feedback from the experts until the product meets the validity and reliability standards of the media. The next phase, Implementation, involves testing the product on subjects, specifically eighth-grade students, both on a small scale (limited) and in field trials. The Evaluation phase is the final stage of the product development procedure, which includes a review of the overall process and assessment of improvements recommended by validators and field trials to examine and ensure that the produced product meets the quality standards of the media and addresses the problems.

Data collection for expert validation was conducted using a questionnaire covering aspects of algebraic concept substance, worksheet structure, and language usage (Oktaviyanthi & Agus, 2021). Meanwhile, data collection for limited trials was carried out through the completion of validated worksheets deemed appropriate by expert validators. Expert validation data were analyzed using Q-Cochran statistics, and data on worksheet usage by research subjects were analyzed using Cronbach's Alpha. The criteria for worksheet assessment in this study are presented in Table 1 below.

Table 1. Criteria for Assessing Substance, Structure, and Language of the Worksheet

Criteria	Indicators
Substance of algebraic concepts	Alignment of worksheet content with the concept of decomposing algebraic expressions, including those containing variables
	Alignment of worksheet content with procedures for determining the product of a monomial and a binomial or the product of two binomials
	Alignment of worksheet content with the representation of multiplication problems as the proportional area of a rectangle
	Alignment of worksheet content with the strategy that the area or sum of areas is determined from the product of two multi-digit numbers
	Alignment of worksheet content with the logical flow that area represents the product of two numbers and is additive
Worksheet Structure	Alignment of the algebraic expression breakdown design with the worksheet layout that transforms multiplication into addition notation
	Alignment of the procedure for determining the product of a monomial or binomial with the worksheet construction that directs towards the area model method
	Alignment of the multiplication problem representation format with the worksheet flow that shows multiplication as the proportional area of a rectangle
	Alignment of the illustration presentation pattern with the worksheet concept that guides towards algebraic generalization or facts
	Alignment of real-world problem contexts with the worksheet format that emphasizes the idea that area represents the product of two numbers and is additive
Language Usage	Appropriateness of sentence usage with the worksheet structure
	Consistency in the use of symbols, terms, and notations within the worksheet
	Coherence of language and logical flow of the worksheet

3. RESULT AND DISCUSSION

a. Analysis Phase

In the initial phase, an exploration of the primary issues faced by students when learning algebra, particularly the concept of multiplication, was conducted. The research identified five key problems students encounter in learning algebra:

1) Errors in interpreting algebraic expressions and in changing signs
2) Difficulty in understanding the generalization of patterns, recalling mathematical facts, concepts, rules, formulas, sequences, and procedures
3) Difficulty in translating words into algebraic expressions or vice versa
4) Difficulty in developing and justifying methods for using the area model to determine the product of monomials and binomials, or the product of two binomials
5) Lack of recognition that area represents the product of two numbers and is additive

b. Design Phase

Next, in the design phase, ideas were explored regarding the structure of the worksheet that corresponds to the main problems faced by students and is relevant to the indicators of algebraic thinking skills. The designed worksheet structure is described in Table 2.

Table 2. Worksheet Development Ideas

Students' Problem	Algebraic Thinking Indicator	Worksheet Item Design	Item No.
Errors in interpreting algebraic expressions and changing signs.	Generalization Able to understand generalizations arising from the multiplication of monomials, binomials, trinomials, or polynomials.	Decomposing an expression, including expressions containing a variable.	1
Difficulty in understanding the generalization of patterns, recalling mathematical facts, concepts, rules, formulas, sequences, and procedures.		Developing and justifying a method for using the area model to determine the product of a monomial and a binomial or the product of two binomials.	2
Difficulty in translating words into algebraic expressions or vice versa.	Transformational Able to transform the multiplication of monomials or binomials into an algebraic area model or vice versa.	Representing a multiplication problem as the proportional area of a rectangle or using a generic area.	3
Difficulty in developing and justifying methods for using the area model to determine the product of monomials and binomials, or the product of two binomials.		Developing and justifying strategies for determining the product of two multi-digit numbers by representing the product as an area or a sum of areas.	4
Lack of recognition that area represents the product of two numbers and is additive.	Meta-global level Able to use the algebraic area model to solve real-world contexts.	Recognizing that area represents the product of two numbers and is additive.	5

c. Development Phase

The third phase, development, consists of activities related to the development of the worksheet and product validation by experts. The following is a recap of the worksheet development initiated in the previous phase.

1) Item 1: Addresses the problem of errors in interpreting algebraic expressions and changing signs.

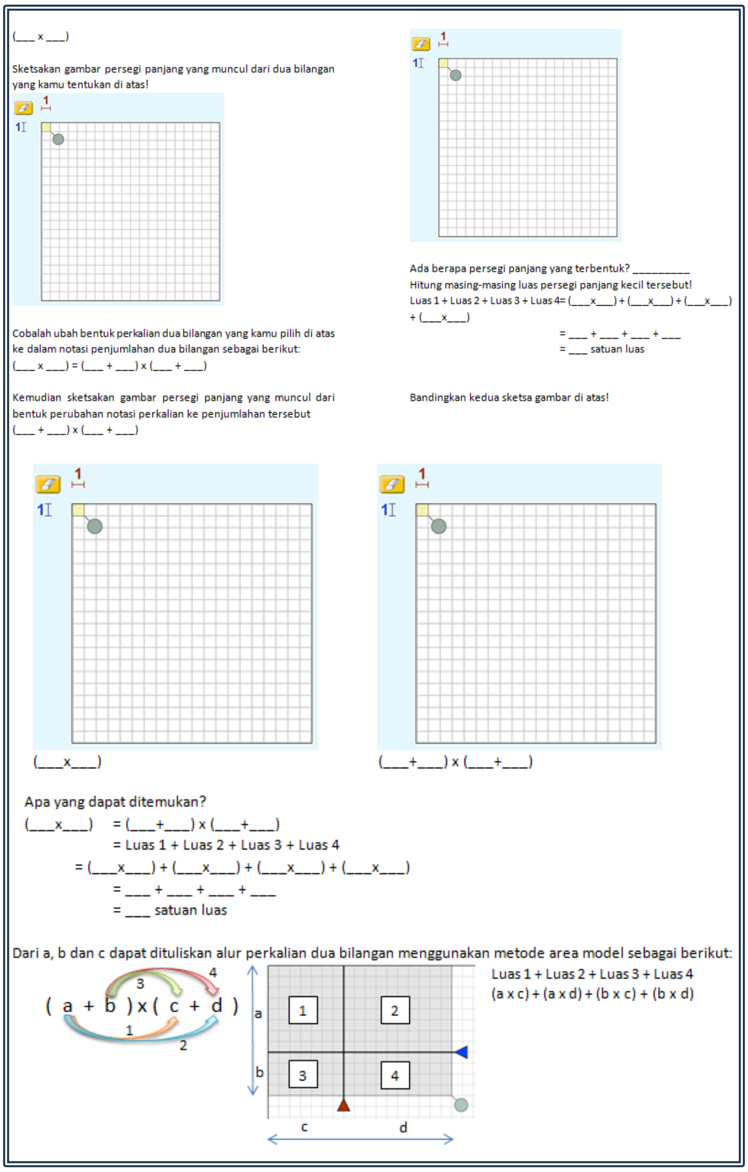

Figure 2. Worksheet Item 1

2) Item 2: Addresses the problem of difficulties in understanding the generalization of patterns, recalling mathematical facts, concepts, rules, formulas, sequences, and procedures.

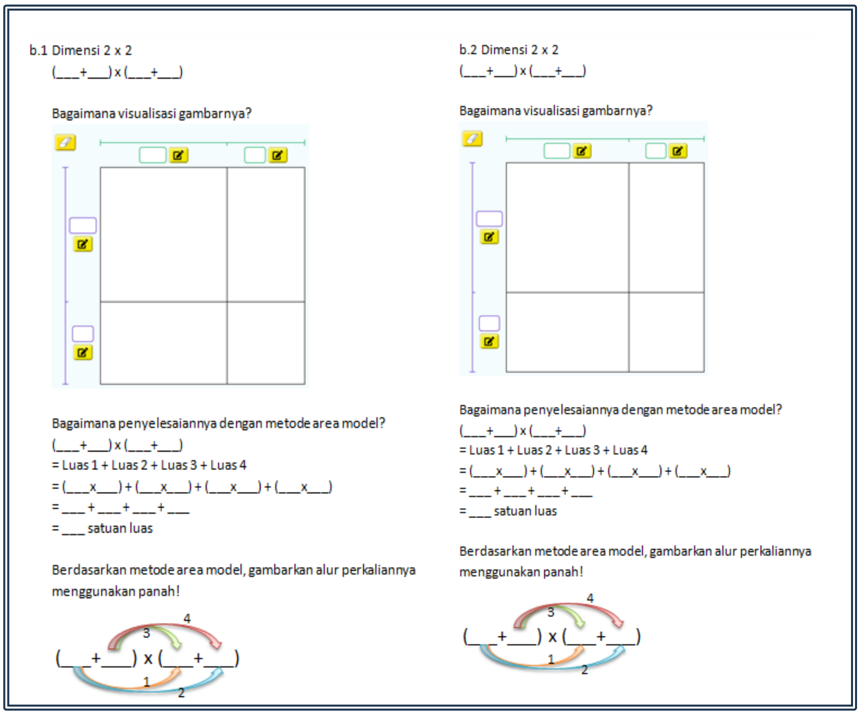

Figure 3. Worksheet Item 2

3) Item 3: Addresses the problem of difficulties in translating words into algebraic expressions or vice versa.

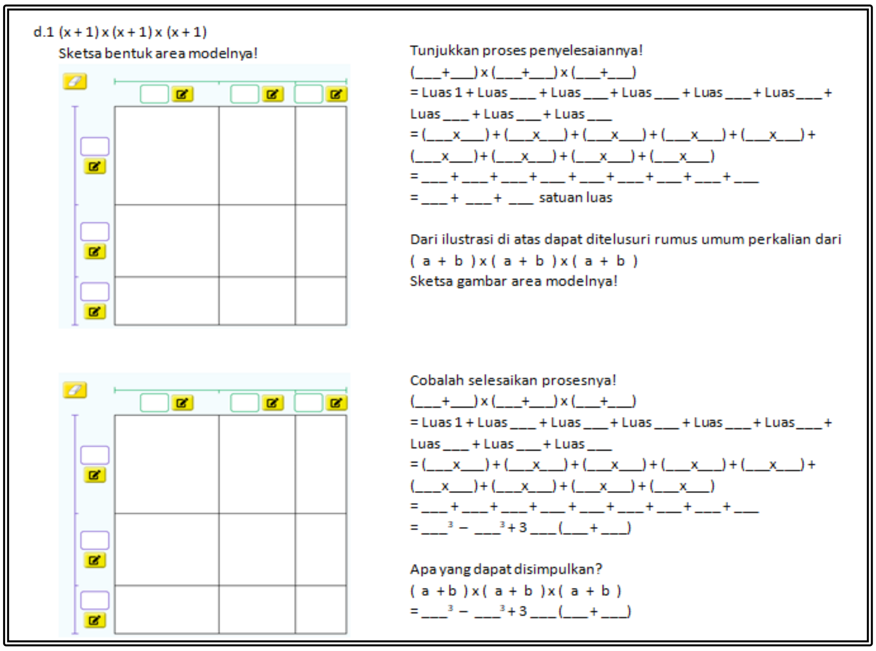

Figure 4. Worksheet Item 3

4) Item 4: Addresses the problem of difficulties in developing and justifying methods for using the area model to determine the product of monomials and binomials, or the product of two binomials.

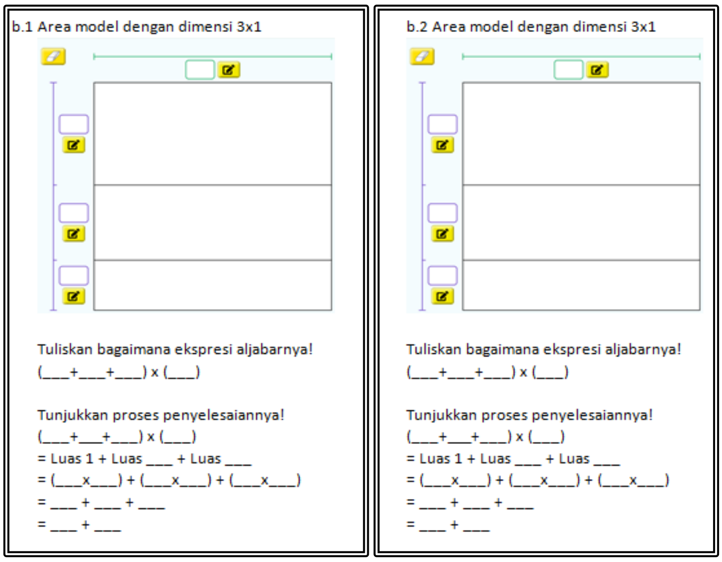

Figure 5. Worksheet Item 4

5) Item 5: Addresses the problem of not recognizing that area represents the product of two numbers and is additive.

(i) Pak Andi memiliki sebuah kebun berbentuk persegi panjang dengan panjang x+6 meter dan lebar x−5 meter. Dia ingin menanam berbagai jenis tanaman di kebunnya, dan dia juga ingin mengetahui luas total kebun tersebut untuk menentukan berapa banyak bibit yang perlu dibeli.

a. Tentukan luas kebun Pak Andi dengan menggunakan model aljabar dari dimensi yang diberikan.
b. Dengan bantuan PhET *Interactive Simulation*, gambarkan model area untuk menghitung luas total kebun.
c. Hitung produk parsial dari setiap bagian model area.
d. Jumlahkan produk parsial untuk menemukan total luas kebun dalam bentuk polinomial.

(ii) Bu Santi memiliki sebuah petak tanah yang berbentuk persegi panjang. Luas total petak tanah ini dapat dinyatakan dengan persamaan polinomial $6x^2+6x-24$. Bu Santi ingin menentukan panjang dan lebar petak tanah tersebut dengan menggunakan model area aljabar.

a. Tentukan panjang dan lebar petak tanah Bu Santi berdasarkan model area yang diberikan.
b. Dengan bantuan PhET *Interactive Simulation*, gambarkan model area yang sesuai untuk memecahkan masalah ini.
c. Hitung panjang dan lebar petak tanah tersebut dengan menggunakan faktorisasi dari polinomial yang diberikan.

Figure 6. Worksheet Item 5

Next, the validation of the worksheet by five validators involved readability and consistency tests using a questionnaire consisting of 13 items with a 2-point scale: 1 for agreement and 0 for disagreement. The questionnaire data were analyzed using the Q-Cochran statistical test, as shown in Table 3.

Table 3. Q-Cochran Test Results for Expert Validation

Instrument	Q-Cochran Value (*Asymp. Sig.*)	
	Face Validity	Content Validity
Area Model Algebra Worksheet Based on *Phet Interactive Simulation*	0.539	0.707

P-ISSN: 2798-2904, E-ISSN: 2798-2920

The information in Table 4 indicates that the Q-Cochran test results with Asymp.Sig. values greater than 0.05 suggest that the five expert validators showed uniform judgment regarding both the face validity and content validity of the Area Model Algebra Worksheet based on PhET Interactive Simulation. This indicates that the worksheet is suitable for use according to the research objectives.

d. Implementation Phase

The fourth phase involved limited and field tests with junior high school students in Serang City. The limited test was conducted with 15 students, while the field test involved 65 students. Data from the limited and field tests were analyzed using Cronbach's Alpha, with the calculation results summarized in Table 4.

Table 4. Cronbach's Alpha Analysis Results for Limited and Field Tests

Item Number	Corrected Item-Total Correlation (r coeeficient)	Validity Category	Cronbach Alpha (r critical)	Reliability Category
Limited Test				
1	0.654	Valid	0.588	Reliable
2	0.542	Valid	0.876	Reliable
3	0.699	Valid	0.815	Reliable
4	0.641	Valid	0.635	Reliable
5	0.711	Valid	0.593	Reliable
Field Test				
1	0.475	Valid	0.542	Reliable
2	0.348	Valid	0.488	Reliable
3	0.325	Valid	0.296	Reliable
4	0.528	Valid	0.315	Reliable
5	0.418	Valid	0.542	Reliable

The criteria for a valid and reliable worksheet item were met if the coefficient r-value exceeded the critical r-value. For the number of respondents (N) 15 and 60 at DF = N - 2 with a significance level of 5%, the critical r-values were 0.514 and 0.254, respectively. Based on the critical and coefficient r-values in Table 5, it can be concluded that all five worksheet items are valid and reliable.

e. Evaluation Phase

The refinement of the worksheet was carried out in the evaluation phase if needed. One of the recommendations from the validators was to enhance Item 1 by adding the generalization of binomial multiplication, which had been presented in points a-c previously. This was intended to ensure that Item 1's objective aligned with the indicator of algebraic thinking ability, namely the ability to understand generalizations arising from monomial or binomial multiplication.

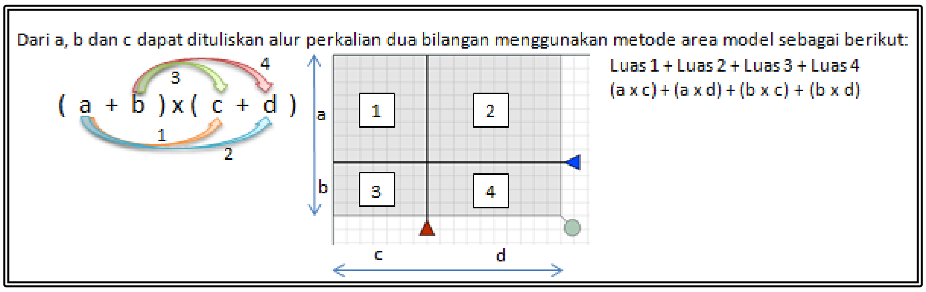

Figure 7. Refinement of Worksheet Item 1

The findings of this study include a worksheet structure tailored to students' problems in learning algebraic multiplication and aligned with the indicators of algebraic thinking ability. The design of Worksheet Item 1 encourages students to break down algebraic expressions, including those containing variables, to form a framework for generalizing binomial multiplication, thereby minimizing errors in interpreting algebraic expressions (Barana, 2021; Oktaviyanthi & Agus, 2021). The design of Worksheet Item 2 guides students to use the area model to determine the product of a monomial and a binomial or the product of two binomials, aiming to help students recognize patterns and avoid procedural errors in algebra (Barbieri & Booth, 2020). Worksheet Item 3 directs students to represent a multiplication problem as the area of a rectangle, building the concept of transforming multiplication into the area model, thus addressing difficulties in translating words into algebraic expressions (Keels, 2022; Oktaviyanthi & Sholahudin, 2023). Worksheet Item 4 helps students develop strategies for determining the product of two multi-digit numbers by representing the product as an area or the sum of areas, optimizing their ability to justify the area model method (Eriksson & Sumpter, 2021). Worksheet Item 5 focuses on the idea that area represents the product of two numbers and is additive, aimed at stimulating students' meta-global thinking level when using algebra in real-world contexts (Peker & Acar, 2022).

4. CONCLUSION

Based on the procedures and discussion of the research results, five items of the Area Model Algebra Worksheet based on PhET Interactive Simulation were developed, each with different achievement indicators. The Q-Cochran validation test with five experts resulted in Asymp.Sig. values of 0.539 > 0.05 for face validity and 0.707 > 0.05 for content validity, indicating that the validators had uniform judgments on the worksheet. This implies that the developed worksheet is feasible for use in addressing students' problems with the concept of algebraic multiplication while also stimulating students' algebraic thinking abilities. Additionally, limited and field tests with 15 and 65 students, respectively, showed that the coefficient r-values exceeded the critical r-values, confirming that all five worksheet items are valid and reliable.

Future research recommendations include (1) development in other algebraic concepts and contexts to ensure the worksheet structure remains relevant, (2) integration and collaboration with other learning media or technologies to validate the worksheet's universality, and (3) implementation and comparative studies across various levels of research subjects to identify opportunities for worksheet development.

BIBLIOGRAPHY

Agus, R. N., & Oktaviyanthi, R. (2023). Worksheet Graphing Quadratics Berbantuan PhET Simulation Untuk Optimalisasi Mathematical Visual Thinking Mahasiswa. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika, 12*(2).

Akbaş, E. E. (2021). Examining The Structure of Observed Learning Outcomes of Associate-Degree Vocational School Students in A CAS-Supported Environment: Limit-Continuous Sample. *Education Quarterly Reviews, 4*(2).

Barana, A. (2021). From Formulas to Functions Through Geometry: A Path To Understanding Algebraic Computations. *European Journal of Investigation in Health, Psychology and Education, 11*(4), 1485-1502.

Barbieri, C. A., & Booth, J. L. (2020). Mistakes on Display: Incorrect Examples Refine Equation Solving and Algebraic Feature Knowledge. *Applied Cognitive Psychology, 34*(4), 862-878.

Barbieri, C. A., & Miller-Cotto, D. (2021). The Importance of Adolescents' Sense of Belonging to Mathematics for Algebra Learning. *Learning and Individual Differences, 87*, 101993.

Brahier, D. (2020). *Teaching Secondary and Middle School Mathematics*. Routledge.

Branch, R. M. (2009). *Instructional Design: The ADDIE Approach (Vol. 722).* New York: Springer.

Cai, J., & Hwang, S. (2022). Seeing Algebra in Arithmetic Through Mathematical Problem Posing. *Journal of Educational Research in Mathematics, 32*(3), 309-329.

Darmayanti, R., Baiduri, B., & Sugianto, R. (2022). Learning Application Derivative Algebraic Functions: Ethnomathematical Studies nd Digital Creator Books. *Jurnal Cendekia: Jurnal Pendidikan Matematika, 6*(2), 2212-2227.

Eriksson, H., & Sumpter, L. (2021). Algebraic and Fractional Thinking in Collective Mathematical Reasoning. *Educational Studies in Mathematics, 108*(3), 473-491.

Heffernan, N. T., & Koedinger, K. R. (2022, May). *A Developmental Model for Algebra Symbolization: The Results of Difficulty Factors Assessment*. In Proceedings of the twentieth annual conference of the cognitive science society (pp. 484-489). Routledge.

Keels, K. (2022). *Early Algebra Instruction for Elementary Students with Mathematics Learning Difficulties*. Doctoral dissertation: University of Georgia.

Kwon, H., & Capraro, M. M. (2021). Nurturing Problem Posing in Young Children: Using Multiple Representation Within Students' Real-World Interest. International Electronic Journal of Mathematics Education, 16(3), em0648.

Lehtonen, D. (2022). *Now I Get it!': Developing A Real-World Design Solution for Understanding Equation-Solving Concepts*. Doctoral dissertation: Tampere University.

Litke, E. (2020). Instructional Practice in Algebra: Building from Existing Practices to Inform an Incremental Improvement Approach. *Teaching and Teacher Education, 91*, 103030.

Lourens, I. (2022). *A Systematic Analysis of The Generalisation Concept in Early Algebra for Young Learners – Some Ideas for The Classroom*. Doctoral dissertation, Stellenbosch: Stellenbosch University.

Manandhar, N. K., Pant, B. P., & Dawadi, S. D. (2022). Conceptual and Procedural Knowledge of Students of Nepal in Algebra: A Mixed Method Study. *Contemporary Mathematics and Science Education, 3*(1), 1-10.

Melhuish, K., Lew, K., & Hicks, M. (2022). Comparing Student Proofs to Explore a Structural Property in Abstract Algebra. *PRIMUS, 32*(1), 57-73.

Namkung, J. M., & Bricko, N. (2021). The Effects of Algebraic Equation Solving Intervention for Students with Mathematics Learning Difficulties. *Journal of Learning Disabilities, 54*(2), 111-123.

Oktaviyanthi, R., & Agus, R. N. (2021). Guided Worksheet Formal Definition of Limit: An Instrument Development Process. *AL-ISHLAH: Jurnal Pendidikan, 13*(1), 449-461.

Oktaviyanthi, R., & Sholahudin, U. (2023). PhET Assisted Trigonometric Worksheet for Students' Trigonometric Adaptive Thinking. *Mosharafa: Jurnal Pendidikan Matematika, 12*(2), 229-242.

Oktaviyanthi, R., & Agus, R. N. (2023). Evaluating Graphing Quadratic Worksheet on Visual Thinking Classification: A Confirmatory Analysis. *Infinity Journal, 12*(2), 207-224.

Peker, B., & Acar, S. (2022). *Algebra and Algebraic Thinking*. Current Studies in Social Sciences, 191.

Roni, S. M., Merga, M. K., & Morris, J. E. (2020). *Conducting Quantitative Research in Education*. Berlin/Heidelberg, Germany: Springer.

Sholahudin, U., & Oktaviyanthi, R. (2023). The Trigonometric Adaptive Worksheet Performance in Optimizing Trigonometric Thinking of Prospective Mathematics Teacher: Single Subject Research. *Jurnal Didaktik Matematika, 10*(2), 250-265.

Spatioti, A. G., Kazanidis, I., & Pange, J. (2022). A Comparative Study of the ADDIE Instructional Design Model in Distance Education. *Information, 13*(9), 402.

Tong, C. K. Y., Yip, E. S. K., & Wong, T. T. Y. (2023). *Examining The Unique Contributions and Developmental Stability of Individual Forms of Relational Reasoning to Mathematical Problem Solving*. Contemporary Educational Psychology, 73, 102181.

Vlassis, J., & Demonty, I. (2022). The Role of Algebraic Thinking in Dealing with Negative Numbers. *ZDM – Mathematics Education, 54*(6), 1243-1255.

Yang, D. C., & Sianturi, I. A. J. (2022). Analysis of Algebraic Problems Intended for Elementary Graders in Finland, Indonesia, Malaysia, Singapore, and Taiwan. *Educational Studies, 48*(1), 75-97.

Zainudin, M., & Utami, A. D. (2022). The Sequence of Algebraic Problem-Solving Paths: Evidence from Structure Sense of Indonesian Student. *Journal on Mathematics Education, 13*(3), 437-464.

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