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Development of a Student Worksheet Using a Pedagogical Deep Learning Approach for a High School Mathematics Studies Course

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ABSTRACT

Learning mathematics in higher education requires students not only to master mathematical concepts and procedures but also to understand conceptual meanings, connect concepts to real-life contexts, engage in reasoning, and reflect on their learning. Therefore, learning materials that facilitate meaningful, mindful, and joyful learning are needed to support active and reflective learning. This study aimed to develop a Student Worksheet for the High School Mathematics Studies course using Deep Learning as a pedagogical approach. This Research and Development study employed the 4-D development model, consisting of Define, Design, Develop, and Disseminate stages. The participants were 32 students of the Mathematics Education Study Program, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Sumatera Utara. Data were collected using expert validation sheets, student response questionnaires, and pre-test and post-test instruments. The developed worksheet incorporated meaningful, mindful, and joyful learning activities, supported by reflection and concept generalization. The results showed that the worksheet obtained validation scores of 91.75% for content, 89% for language, and 92% for media, indicating a high level of validity. The worksheet also achieved a practicality score of 92.59%. Students' mean learning outcomes increased from 68.25 on the pre-test to 91.53 on the post-test, with an N-Gain score of 0.71, indicating a high improvement in learning outcomes. Of the 32 students, 17 (53.13%) achieved a high N-Gain, 14 (43.75%) achieved a medium N-Gain, and 1 (3.12%) achieved a low N-Gain. The developed Student Worksheet demonstrated high validity and practicality and showed improved student learning outcomes.

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1. INTRODUCTION

Education is a crucial aspect of efforts to enhance the quality of human resources. In higher education, learning is directed not only toward mastering theoretical concepts but also

toward developing critical, creative, and logical thinking skills and problem-solving abilities. In Mathematics Education, students are therefore expected not merely to master mathematical procedures but also to develop deep conceptual understanding that enables them to explain, connect, and apply mathematical concepts in various problem-solving situations [21]. Such understanding is essential to ensure that students do not simply know how to solve problems but also comprehend the meaning and interrelationships among mathematical concepts.

One course that supports this development is the High School Mathematics Studies course, which prepares prospective mathematics educators to master mathematical concepts, principles, and procedures relevant to the high school level [24]. However, students continue to experience difficulties in the course. This is reflected in their Midterm and Final Examination results, which remain below the expected mastery standard. Insert preliminary learning-outcome data here, such as the mean scores and/or percentage of students who did not meet the mastery standard.

Student learning outcomes can be influenced by the instructional process. As noted by [9], lecturer instruction is an important factor affecting student learning outcomes. Preliminary observations in this study indicate that instruction in the High School Mathematics Studies course tends to be lecturer-centered, resulting in limited opportunities for active student engagement. The availability of appropriate learning materials is also important in supporting students' learning. Etika and Aini [4] reported that Student Worksheets can support the learning process. However, observations in this study indicate that a Student Worksheet specifically designed for the High School Mathematics Studies course is not yet available. Consequently, students have limited structured learning materials to guide them in exploring and understanding mathematical concepts independently.

One strategy to address these issues is to develop a Student Worksheet that facilitates active and structured learning. A Student Worksheet provides students with information, tasks, instructions, and learning activities that guide them toward the achievement of learning competencies [25]. Previous studies have shown that Student Worksheets can support systematic learning through structured activities [16], facilitate independent exploration and problem solving [7], and help students connect theoretical concepts with real-world contexts. However, these studies primarily emphasize the use of worksheets as structured learning materials and do not specifically address the integration of a pedagogical Deep Learning approach into a Student Worksheet for the High School Mathematics Studies course. Learning materials play an important role in facilitating active and meaningful learning experiences. Student worksheets can provide structured learning activities that encourage students to actively engage with learning content and develop critical thinking skills [6].

To provide a deeper learning experience, Student Worksheets need to be supported by a pedagogical approach that encourages students to actively construct, connect, and reflect on mathematical knowledge. In this study, Deep Learning refers to a pedagogical approach that emphasizes three interconnected principles: mindful, meaningful, and joyful learning. Mindful learning encourages students to be aware of their thinking processes and engage attentively in mathematical exploration; meaningful learning connects new

mathematical concepts with prior knowledge, real-life contexts, and meaningful problem situations; while joyful learning creates engaging learning experiences that encourage students to participate actively in mathematical activities. These principles provide a foundation for moving learning beyond memorization toward deeper conceptual understanding, reasoning, and reflection [8]–[13].

Although previous studies have developed Student Worksheets and discussed the potential of Deep Learning to support deeper mathematical learning, the integration of these principles into a Student Worksheet specifically designed for the High School Mathematics Studies course remains limited. Therefore, the novelty of this study lies in integrating a pedagogical Deep Learning approach through mindful, meaningful, and joyful learning into a Student Worksheet designed specifically for the High School Mathematics Studies course. The developed worksheet is intended to provide structured opportunities for students to explore mathematical concepts, connect concepts with meaningful contexts, solve problems, and reflect on their learning. Accordingly, this study aimed to develop a Student Worksheet for the High School Mathematics Studies course using a pedagogical Deep Learning approach and to examine its validity, practicality, and improvement in student learning outcomes.

2. METHOD

This study employed a Research and Development (R&D) approach to develop a student worksheet for the High School Mathematics Studies course using a Deep Learning approach. The development procedure adopted the 4-D Model developed by Thiagarajan, Semmel, and Semmel, which consists of four stages: define, design, develop, and disseminate. The study was conducted during the even semester of the 2025/2026 academic year in the Mathematics Education Study Program, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Sumatera Utara. The trial participants consisted of 32 third-semester students from Mathematics Education Class 2 (PMM-2) who were enrolled in the High School Mathematics Studies course. The participants were selected using purposive sampling because they represented the intended users of the developed student worksheet. The research data consisted of qualitative and quantitative data. Qualitative data included criticisms, suggestions, and recommendations provided by the validators, while quantitative data included expert validation results, student responses, and student learning outcomes obtained through pre-test and post-test assessments.

The define stage involved front-end analysis, learner analysis, concept or material analysis, and formulation of learning objectives. These analyses were conducted to identify learning problems, examine students' characteristics, determine the scope of the material covered in the High School Mathematics Studies course, and formulate the competencies to be achieved. The design stage involved developing the initial student worksheet based on the results of the preceding analyses. This stage included the preparation of criterion-referenced tests, selection of media, selection of the worksheet format, and preparation of the initial product design. The student worksheet was designed by integrating learning activities that support the Deep Learning approach, particularly activities that facilitate

meaningful understanding of mathematical concepts, problem exploration, mathematical reasoning and generalization, and reflection on the learning process.

The development stage consisted of expert validation, product revision, and student trials. The validation process involved six expert validators, consisting of two material experts, two media experts, and two language experts. The validators were lecturers with relevant expertise in their respective fields. Each feasibility aspect was assessed by two validators. The validation instruments were used to assess the feasibility of the student worksheet in terms of material, media or presentation, and language. The instruments employed a 1–10 rating scale, and the number of items was determined according to the dimensions assessed in each validation aspect. The material validation addressed the appropriateness and accuracy of the mathematical content and its alignment with the learning objectives, the media validation addressed the presentation and design of the worksheet, and the language validation addressed the clarity, appropriateness, and readability of the language. The validation results, together with the criticisms and suggestions provided by the validators, were used as the basis for revising the student worksheet.

Following expert validation and revision, the student worksheet was tested with 32 students to examine its practicality and effectiveness. Practicality was assessed using a student-response questionnaire administered to the trial participants. The questionnaire employed a 1–10 rating scale and covered five aspects: ease of use, clarity of presentation, attractiveness, usefulness, and implementation of the Deep Learning approach. The questionnaire was used to obtain students' responses regarding the practicality and usability of the developed student worksheet. The effectiveness test consisted of six essay questions designed to measure students' mathematical abilities based on the relevant mathematical ability indicators. The pre-test and post-test consisted of different but equivalent sets of questions to minimize the possibility of students answering the questions based on prior exposure. The test instruments were reviewed by experts to assess the appropriateness of the items in relation to the intended mathematical ability indicators, content, and level of difficulty. Students' answers were assessed using the predetermined scoring criteria. The effectiveness testing employed a one-group pre-test–post-test design, in which students completed a pre-test before using the developed student worksheet and a post-test after participating in learning activities using the worksheet.

The Deep Learning approach was operationalized through learning activities incorporated into the student worksheet. These activities were designed to facilitate students' meaningful understanding of mathematical concepts, encourage conscious and reflective engagement with mathematical problems, support problem exploration and reasoning, facilitate mathematical generalization, and provide opportunities for students to reflect on their learning process. The implementation of the Deep Learning approach was also assessed through an aspect of the student-response questionnaire, allowing students' perceptions of the implementation of the approach within the developed worksheet to be obtained.

The dissemination stage was conducted after the student worksheet had undergone expert validation, revision, and student trials. At this stage, the developed student worksheet was disseminated through the administration of the relevant test instruments and introduced as instructional material for the High School Mathematics Studies course. The dissemination

was intended to provide access to the developed and tested student worksheet for potential users in an educational setting.

The validation data and student-response data were analyzed using descriptive quantitative analysis by comparing the obtained scores with the maximum possible scores and expressing the results as percentages. The percentage score was calculated by dividing the obtained score by the maximum possible score and multiplying the result by 100%. The student worksheet was considered valid and practical if it achieved a minimum percentage of 81%, corresponding to the highly valid and highly practical categories, respectively. The improvement in students' learning outcomes was analyzed using the normalized gain (N-Gain) based on the pre-test and post-test scores. The N-Gain was calculated by comparing the difference between the post-test and pre-test scores with the difference between the maximum possible score and the pre-test score. N-Gain values were categorized as high ($g > 0.70$), medium ($0.30 \leq g \leq 0.70$), or low ($g < 0.30$). Ethical considerations were also addressed by informing the students about their participation in the research activities and obtaining their approval as indicated in the research instrument. Participation was voluntary, and the data obtained from the students were used for research purposes.

3. RESULTS AND DISCUSSION

3.1. Results

The results of this study include the development, validation, and practicality of the Student Worksheet using a deep learning approach. The development process followed the 4-D Model, consisting of the define, design, develop, and disseminate stages. The results are presented in three main aspects: the student worksheet development stage, validation results, and practicality assessment based on student responses.

3.1.1 Student Worksheet Development Stage

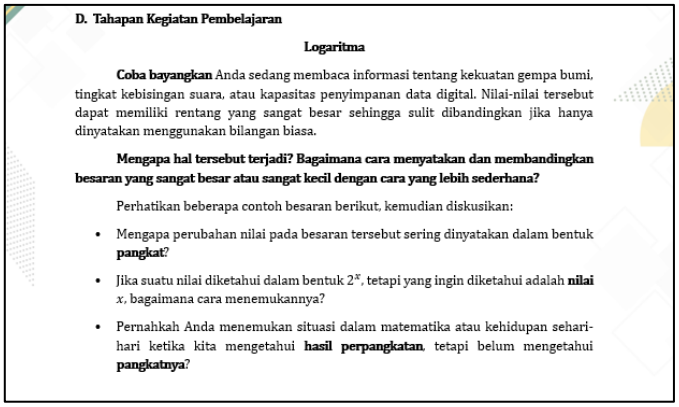
The development of the student worksheet for the High School Mathematics Studies course followed the 4-D Model, consisting of the define, design, develop, and disseminate stages. These stages were carried out systematically to produce a student worksheet that was aligned with students' learning needs and characteristics and integrated the principles of the Deep Learning approach. The developed worksheet covers 13 topics in High School Mathematics Studies: exponents and radicals, logarithms, sequences and series, quadratic equations and functions, composition and inverse functions, trigonometry, probability, matrices, vectors, limits, derivatives, integrals, and logic. Each topic was organized into a series of learning activities designed to facilitate students' understanding, exploration, reflection, and generalization of mathematical concepts.

In the define stage, front-end analysis, student analysis, concept analysis, and the formulation of learning objectives were conducted. The front-end analysis aimed to identify problems in the implementation of the High School Mathematics Studies course. The analysis indicated that the learning process tended to be lecturer-centered and that a student worksheet was not yet available to systematically guide students in studying the course materials. Student analysis was subsequently conducted to identify the characteristics of the intended users of the product. Concept analysis involved identifying, selecting, and

organizing the High School Mathematics Studies materials to be included in the worksheet. The findings from these analyses were used as the basis for formulating learning objectives and determining learning activities that were consistent with the Deep Learning approach. The design stage involved developing an initial draft of the student worksheet based on the identified learning needs, student characteristics, course materials, and learning objectives. The worksheet was designed to include identification information, learning objectives, instructions for use, supporting materials, learning activities, exercises, reflection sections, and evaluation activities. The learning activities were organized to provide opportunities for students to understand contextual problems, explore mathematical concepts, connect previously acquired knowledge with new concepts, formulate generalizations, and reflect on their learning experiences. These activities were designed to incorporate the principles of meaningful, mindful, and joyful learning within the worksheet. At this stage, the research instruments were also developed, including expert validation sheets, a student response questionnaire, and a learning outcome test, which were used to evaluate the quality, practicality, and learning outcomes associated with the developed product.

In the development stage, the initial draft was refined into a complete student worksheet and subsequently subjected to validation by subject matter, media, and language experts. The validation process assessed the suitability of the mathematical content, the quality of the presentation and design, and the appropriateness of the language used in the worksheet. The validators' assessments, comments, and recommendations were used as the basis for product revision. Following the revision process, the developed worksheet was piloted with students from the Mathematics Education Study Program. The trial was conducted to obtain information regarding the practicality of the worksheet, students' responses to the developed product, and changes in students' learning outcomes after using the Deep Learning-based worksheet.

Examples of learning activities that illustrate the integration of the Deep Learning approach in the developed student worksheet are presented in Figures 1, 2 and 3.



D. Tahapan Kegiatan Pembelajaran

Logaritma

Coba bayangkan Anda sedang membaca informasi tentang kekuatan gempa bumi, tingkat kebisingan suara, atau kapasitas penyimpanan data digital. Nilai-nilai tersebut dapat memiliki rentang yang sangat besar sehingga sulit dibandingkan jika hanya dinyatakan menggunakan bilangan biasa.

Mengapa hal tersebut terjadi? Bagaimana cara menyatakan dan membandingkan besaran yang sangat besar atau sangat kecil dengan cara yang lebih sederhana?

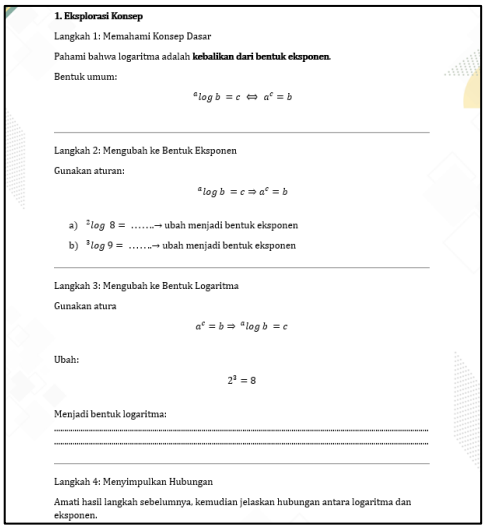
Perhatikan beberapa contoh besaran berikut, kemudian diskusikan:

- Mengapa perubahan nilai pada besaran tersebut sering dinyatakan dalam bentuk **pangkat**?
- Jika suatu nilai diketahui dalam bentuk 2^x, tetapi yang ingin diketahui adalah **nilai** x, bagaimana cara menemukannya?
- Pernahkah Anda menemukan situasi dalam matematika atau kehidupan sehari-hari ketika kita mengetahui **hasil perpangkatan**, tetapi belum mengetahui **pangkatnya**?

Figure 1. Example of a meaningful learning activity using the context of earthquake magnitude

The activity presents earthquake magnitude as a real-life context to encourage students to connect mathematical concepts with phenomena they may encounter in everyday

life. Students are prompted to estimate the difference in magnitude and relate their prior knowledge of powers and exponents to the use of logarithmic scales. This activity illustrates the meaningful learning aspect of the Deep Learning approach.



1. Eksplorasi Konsep

Langkah 1: Memahami Konsep Dasar

Pahami bahwa logaritma adalah **kebalikan dari bentuk eksponen**.

Bentuk umum:

$$^{a}\log b = c \Leftrightarrow a^{c} = b$$

Langkah 2: Mengubah ke Bentuk Eksponen

Gunakan aturan:

$$^{a}\log b = c \Rightarrow a^{c} = b$$

a) $^{2}\log 8 =$ ……→ ubah menjadi bentuk eksponen

b) $^{3}\log 9 =$ ……→ ubah menjadi bentuk eksponen

Langkah 3: Mengubah ke Bentuk Logaritma

Gunakan atura

$$a^{c} = b \Rightarrow {}^{a}\log b = c$$

Ubah:

$$2^{3} = 8$$

Menjadi bentuk logaritma:

……

……

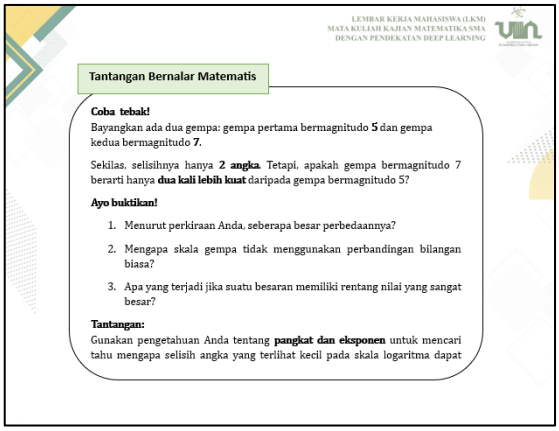
Langkah 4: Menyimpulkan Hubungan

Amati hasil langkah sebelumnya, kemudian jelaskan hubungan antara logaritma dan eksponen.

Figure 2. Example of a mindful learning activity through mathematical exploration and reflection

The worksheet also provides prompts that encourage students to examine and reflect on their mathematical thinking. In this activity, students are invited to consider why quantities are represented using powers and how an unknown exponent can be determined from an exponential form. These prompts provide opportunities for students to become aware of their reasoning processes and connect prior knowledge with the mathematical concept being developed.

Figure 3. Additional example of a mindful learning activity through mathematical exploration and reflection



LEMBAR KERJA MAHASISWA (LKM)
MATA KULIAH KAJIAN MATEMATIKA SMA
DENGAN PENDEKATAN DEEP LEARNING

Tantangan Bernalar Matematis

Coba tebak!

Bayangkan ada dua gempa: gempa pertama bermagnitudo **5** dan gempa kedua bermagnitudo **7**.

Sekilas, selisihnya hanya **2 angka**. Tetapi, apakah gempa bermagnitudo 7 berarti hanya **dua kali lebih kuat** daripada gempa bermagnitudo 5?

Ayo buktikan!

1. Menurut perkiraan Anda, seberapa besar perbedaannya?
2. Mengapa skala gempa tidak menggunakan perbandingan bilangan biasa?
3. Apa yang terjadi jika suatu besaran memiliki rentang nilai yang sangat besar?

Tantangan:

Gunakan pengetahuan Anda tentang **pangkat dan eksponen** untuk mencari tahu mengapa selisih angka yang terlihat kecil pada skala logaritma dapat

Figure 3. Additional example of a mindful learning activity through mathematical exploration and reflection

Another example of mindful learning is presented in Figure 3. The activity provides students with opportunities to examine the mathematical information presented consciously, explore the relationship between concepts, and reflect on the reasoning used to arrive at an understanding. Through these activities, students are encouraged not only to obtain the

correct mathematical result but also to pay attention to the process of thinking, questioning, and connecting ideas. This activity further demonstrates the integration of the mindful learning principle in the developed student worksheet.

3.1.2 Validation Results and Product Revision

Validation was conducted to assess the feasibility of the developed student worksheet before its implementation in the learning process. The validation covered three aspects: content, language, and media. Two experts assessed each aspect using the respective validation instruments. The results of the validation are presented in Table 1.

Table 1. Student Worksheet Validation Results

No.	Feasibility Aspect	Validator 1	Validator 2	Average Total Score of the Two Validators
1	Content feasibility	94.5%	89%	91.75%
2	Language feasibility	91%	87%	89%
3	Media feasibility	87%	97%	92%

The content validation resulted in an average score of 91.75%, which was categorized as highly valid. This result indicates that the mathematical content presented in the student worksheet was considered appropriate in relation to the learning objectives and the scope of the High School Mathematics Studies course. The assessment also considered the integration of Deep Learning activities within the worksheet.

The language validation resulted in an average score of 89%, which was categorized as highly valid. This result indicates that the language used in the worksheet was considered appropriate in terms of readability, clarity of instructions, and suitability for university students. Meanwhile, the media validation resulted in an average score of 92%, which was also categorized as highly valid. This result indicates that the presentation, layout, structure, and visual design of the worksheet met the established feasibility criteria.

Overall, the validation results showed that the developed student worksheet met the required feasibility criteria, with average scores of 91.75% for content, 89% for language, and 92% for media. The validators also provided feedback on the developed product. The student worksheet was considered usable with minor revisions. Based on this feedback, minor revisions were made to the worksheet before it was implemented in the student trial. The revised product was subsequently used in the next stage of the development process.

3.1.3 Results of the Student Worksheet Practicality Assessment Based on Student Responses

The practicality of the Deep Learning-based student worksheet was assessed through a response questionnaire administered to 32 students after they used the product during the learning process. The questionnaire consisted of five aspects: ease of use, clarity of presentation, attractiveness, usefulness, and implementation of the Deep Learning approach. The results of the student response analysis are presented in Table 2.

Table 2. Student Worksheet Practicality Results

No.	Assessment Aspect	Percentage Score per Aspect
1	Ease of Use	92.81%
2	Clarity of presentation	93.28%
3	Attractiveness	93.75%
4	Usefulness	92.81%
5	Implementation of the deep learning approach	90.31%
	Average overall percentage of all aspects	92.59%

As shown in Table 2, all five aspects obtained percentage scores above 90%. The ease-of-use aspect obtained a score of 92.81%, indicating that students perceived the worksheet as easy to use during the learning activities. The clarity-of-presentation aspect obtained the highest score of 93.28% among the first four aspects, indicating that students perceived the materials, instructions, and learning activities as clear and understandable. The attractiveness aspect obtained a score of 93.75%, reflecting positive student responses to the presentation and learning activities provided in the worksheet.

The usefulness aspect obtained a score of 92.81%, indicating that students perceived the worksheet as useful for supporting their learning activities and understanding of the course materials. Meanwhile, the implementation of the Deep Learning approach obtained a score of 90.31%. This result indicates that students perceived the learning activities in the worksheet as incorporating the intended Deep Learning approach, including activities that encouraged meaningful engagement, reflection, and deeper understanding of mathematical concepts.

Overall, the average percentage across the five aspects was 92.59%. Based on the predetermined practicality criteria, the Deep Learning-based student worksheet was categorized as highly practical according to student responses. These findings indicate that the developed worksheet received positive responses from students in terms of ease of use, clarity, attractiveness, usefulness, and the implementation of the Deep Learning approach.

3.1.4 Effectiveness of the Student Worksheet Based on Students' Learning Outcomes

The effectiveness of the Deep Learning-based Student Worksheet in the High School Mathematics Study course was measured by the improvement in student learning outcomes, based on pre-test and post-test scores. The assessment consisted of six essay questions administered before and after students engaged in instruction using the student worksheet. The pre-test and post-test scores were subsequently analyzed using Normalized Gain (N-Gain) to determine the level of improvement in student learning outcomes. The distribution of N-Gain categories is presented in Table 3 below:

Table 3. Distribution of N-Gain Categories

No.	Category	Number of Students	Percentage
1	High	17	53.13%
2	Medium	14	43.75%
3	Low	1	3.12%
	Total	32	100%

Based on Table 3, out of 32 students, 17 (53.13%) achieved N-Gain scores in the high category, 14 (43.75%) fell into the medium category, and 1 (3.12%) fell into the low category. Thus, the majority of students experienced improvements in learning outcomes ranging from the medium to high categories after participating in instruction using the Deep Learning-based student worksheet.

Overall, these results indicate that the use of the Deep Learning-based student worksheet led to improvements in student learning outcomes. The fact that the majority of students fell into the high and medium N-Gain categories demonstrates that the developed student worksheet effectively supports the achievement of learning outcomes in the High School Mathematics Study course.

3.2. Discussion

The development of the student worksheet in this study was motivated by the need for teaching materials that could support more active and in-depth engagement with High School Mathematics Studies. The preliminary analysis indicated that learning activities tended to be lecturer-centered and that existing materials did not sufficiently guide students through systematic learning activities. In this context, a student worksheet can function not merely as a collection of mathematical exercises, but as a structured learning environment that guides students through a sequence of activities toward conceptual understanding. This is particularly relevant in higher education, where students are expected to gradually develop greater independence in constructing mathematical knowledge. Previous studies have shown that well-designed worksheets can provide systematic guidance while creating opportunities for students to explore and discover mathematical concepts independently [3]–[15]. This finding is consistent with research on guided-discovery-based mathematics worksheets, which reported that structured learning activities can support students in engaging independently with mathematical concepts and facilitate the process of concept discovery and understanding [19]. Thus, the need identified in the preliminary analysis provides a meaningful rationale for developing a worksheet that goes beyond providing exercises by organizing students' learning experiences in a more guided and active manner.

The development process followed the 4-D Model, consisting of the define, design, develop, and disseminate stages. The relevance of this Model lies in its iterative and systematic structure, which allows the characteristics of the teaching material to be aligned with identified learning needs and subsequently refined through expert evaluation and user responses. In the context of mathematics teaching materials, this systematic process is important because the quality of a worksheet depends not only on the accuracy of its mathematical content but also on the clarity of its instructional organization and its suitability for students' learning needs. Previous studies have similarly applied the 4-D Model in developing mathematics teaching materials. Sutamrin and Sahid [22], for example, used the Model to develop open-ended problem-based calculus teaching materials and evaluated the resulting product in terms of validity, practicality, and effectiveness. Likewise, [11] developed Realistic Mathematics Education-based Analytic Geometry worksheets through stages involving validation, practicality testing, and effectiveness testing using pre- and post-tests. The consistency of these findings with the present study supports the relevance of the

4-D Model as a systematic framework for developing mathematics teaching materials. More importantly, the Model provides opportunities to refine the worksheet based on evidence gathered at different stages, thereby supporting the alignment between the intended pedagogical design and the actual characteristics of the final product.

A key characteristic of the developed student worksheet is the integration of Deep Learning as a pedagogical approach into its learning activities. In this study, Deep Learning refers to an approach that emphasizes mindful, meaningful, and joyful learning, rather than deep learning in the context of artificial intelligence. In mathematics education, this approach emphasizes students' meaningful understanding of concepts, connections between mathematical ideas and relevant contexts, and active engagement in the learning process [17]. These principles were operationalized in the worksheet through activities that guided students to understand concepts, explore problems, identify relationships, formulate generalizations, and reflect on their learning. Thus, the integration of Deep Learning was not limited to labeling the worksheet as a Deep Learning-based material; rather, its principles were embedded in the sequence and nature of the learning activities. This design provided opportunities for students to construct meaning from mathematical situations, examine their reasoning during exploration, and reflect on the concepts they had developed. The combination of these activities reflects the meaningful, mindful, and joyful dimensions of the pedagogical approach and distinguishes the developed worksheet from materials that primarily provide explanations and exercises [1]–[20].

The integration of this approach is particularly relevant to Mathematics Education students, who need not only to master mathematical content but also to understand the reasoning and processes underlying mathematical concepts. Rather than focusing solely on obtaining correct answers, the worksheet encouraged students to examine mathematical relationships, connect different ideas, and articulate the reasoning underlying their conclusions. This orientation is consistent with previous research suggesting that Deep Learning can support students' conceptual understanding and awareness of their own learning processes [12]–[14]. Similarly, research on metacognition-based Deep Learning among Mathematics Education students reported potential benefits for metacognitive awareness and understanding of fundamental mathematical concepts [10]. The present study extends this line of research by demonstrating how the principles of pedagogical Deep Learning can be translated into concrete worksheet activities for university-level mathematics learning. In this sense, the contribution of the study lies not merely in producing another mathematics worksheet, but in providing an example of how meaningful, mindful, and joyful learning can be embedded systematically within worksheet-based mathematics instruction.

Regarding validity, the developed student worksheet was considered appropriate by the subject matter, media, and language experts. The high level of content validity indicates that the mathematical material was considered consistent with the learning objectives and scope of the High School Mathematics Studies course. This appropriateness was supported by the organization of the content and the sequence of activities, which were designed to guide students from conceptual understanding toward exploration, generalization, and reflection. The positive assessment from media experts also suggests that the worksheet's

layout and structural organization supported the intended learning process, rather than merely presenting mathematical content in a static format. Meanwhile, the language assessment indicates that the instructions and explanations were sufficiently clear and appropriate for the characteristics of the intended users. The overall validity of the product was also supported by revisions made in response to expert feedback, allowing potential weaknesses in content, presentation, and language to be addressed before implementation. These findings are consistent with previous research emphasizing expert validation as an important stage in developing mathematics teaching materials because it helps ensure the appropriateness of the content, presentation, and instructional characteristics of the resulting product [23]. Thus, the validity findings suggest that the worksheet was not only mathematically appropriate but also sufficiently structured to support the pedagogical learning activities intended in its design.

The student responses indicate that the developed worksheet was perceived as practical for use in the learning process. Rather than reflecting only the technical usability of the product, the positive responses suggest that the organization and characteristics of the learning activities were accessible to students. The relatively high ratings for appeal, clarity, ease of use, and usefulness may be related to the worksheet's structured sequence of activities, clear instructions, and varied tasks that guided students through the learning process without relying entirely on lecturer explanations. The worksheet also provided opportunities for students to explore mathematical problems, identify relationships, formulate generalizations, and reflect on their understanding. These features may have supported students in engaging more actively with the material while maintaining a clear direction for completing each activity. The high response to the implementation of the Deep Learning approach further suggests that students were able to recognize the pedagogical characteristics embedded in the worksheet. Meaningful learning was reflected in activities that connected mathematical ideas with problems and contexts, mindful learning was encouraged through exploration and reflection, while joyful learning was supported through varied and engaging learning activities. Thus, the practicality of the worksheet can be understood not only in terms of ease of use but also in terms of how its design facilitated students' participation in the intended learning process. This interpretation is consistent with previous research showing that mathematics worksheets based on guided discovery can provide systematic support for students to learn independently and focus on the process of constructing mathematical understanding [19].

The positive student response to the implementation of the Deep Learning approach suggests that the pedagogical principles were recognizable within the learning activities provided in the worksheet. Rather than focusing solely on completing mathematical exercises, students were guided to understand concepts, establish connections between mathematical ideas, explore and analyze problems, formulate generalizations, and reflect on their learning. These activities provide concrete expressions of the mindful, meaningful, and joyful dimensions of the pedagogical Deep Learning approach described in previous research [17]. Meaningful learning was reflected in opportunities to connect mathematical concepts with relevant problems and prior understanding, while mindful learning was supported through exploration, reasoning, and reflection. The varied nature of the activities

also provided opportunities for joyful engagement with mathematical ideas. Thus, the findings suggest that the worksheet provided a feasible structure for translating the principles of pedagogical Deep Learning into concrete and systematic learning activities in university mathematics education.

The observed changes in student learning outcomes provide additional evidence of students' learning progress following the implementation of the Deep Learning-based student worksheet. The mean N-Gain score was 0.71, with 17 students (53.13%) categorized as having high gains, 14 students (43.75%) as having medium gains, and one student (3.12%) as having a low gain. This distribution indicates that most students demonstrated moderate to high improvement between the pre-test and post-test. The observed improvement may be related to the learning opportunities provided through the worksheet, particularly activities that encouraged students to actively process information, construct mathematical understanding, establish connections between concepts, and reflect on their learning. However, given the one-group design of the study, the observed gains cannot be attributed solely to the use of the worksheet. Other factors, such as regular classroom instruction, lecturer support during the learning process, students' prior mathematical knowledge, and familiarity with the assessment format through repeated testing, may also have contributed to the observed changes. Therefore, the N-Gain findings should be interpreted as evidence of learning progress following the implementation rather than as definitive evidence of the causal effectiveness of the developed worksheet.

The findings are broadly consistent with previous research on the development of mathematics student worksheets, which suggests that structured instructional materials can support students' engagement with mathematical concepts and learning processes. Muchsin [11], for example, developed an Analytic Geometry worksheet based on Realistic Mathematics Education and emphasized the role of contextual activities in connecting mathematical concepts with meaningful learning situations. Similarly, Sutamrin and Sahid [22] reported that systematically developed open-ended problem-based materials could support the quality of calculus learning. The present study extends these findings by demonstrating how a pedagogical Deep Learning approach can be embedded within a mathematics worksheet through activities that emphasize meaningful understanding, mindful exploration and reflection, and varied learning experiences. Thus, the contribution of the present study is not limited to confirming the value of structured mathematics teaching materials, but also illustrates how a specific pedagogical orientation can be translated into the design of worksheet-based learning activities at the university level.

At the same time, the variation in learning gains suggests that the use of a Deep Learning-based worksheet may not produce uniform learning experiences for all students. Previous studies have similarly indicated that students' responses and learning outcomes when using instructional materials may vary across individuals [5]–[26]. Differences in prior knowledge, engagement, pace of understanding, and capacity for reflection may be possible factors underlying such variation, although these factors were not directly examined in the present study. This finding highlights the continuing importance of lecturer support when implementing worksheet-based Deep Learning activities, particularly when students encounter tasks requiring complex analysis, conceptual connections, and deeper reflection.

In this approach, the lecturer's role shifts from primarily transmitting information toward facilitating students' learning through direction, questioning, feedback, and scaffolding that can be adjusted to students' needs [2]–[18].

Overall, the findings suggest that the Deep Learning-based student worksheet provides a feasible alternative for supporting learning in the High School Mathematics Studies course. Its contribution extends beyond providing mathematical content and exercises, as the worksheet organizes students' learning experiences through activities involving conceptual understanding, exploration, analysis, connection, generalization, and reflection. The theoretical contribution of this study lies in demonstrating how the principles of pedagogical Deep Learning can be operationalized within a worksheet-based learning environment in university mathematics education. In particular, the findings illustrate how meaningful, mindful, and joyful learning can be translated into concrete learning activities that encourage students to engage with mathematical concepts beyond obtaining procedural answers. From a practical perspective, the developed worksheet can provide lecturers with an instructional resource for facilitating more structured and active learning while supporting Mathematics Education students in developing conceptual understanding and reflective learning habits that are relevant to their future role as mathematics teachers.

4. CONCLUSION

This study developed a Deep Learning-based student worksheet for the High School Mathematics Studies course using the 4-D Model (Define, Design, Develop, and Disseminate). The developed worksheet integrates pedagogical Deep Learning principles into structured learning activities that support meaningful understanding, concept exploration and generalization, reflection, and varied learning experiences. The results indicate that the developed worksheet achieved high validity, with scores of 91.75% from subject matter experts, 89% from language experts, and 92% from media experts. The worksheet was also perceived as highly practical based on student responses, with an overall practicality score of 92.59%. Following its implementation, students demonstrated improvement in learning outcomes, with the mean score increasing from 68.25 on the pre-test to 91.53 on the post-test and a mean N-Gain score of 0.71.

These findings indicate that the developed worksheet was highly valid and practical, while students demonstrated substantial improvement in learning outcomes after its implementation. The theoretical contribution of this study lies in demonstrating how pedagogical Deep Learning can be translated into concrete worksheet-based learning activities in university mathematics education. In practical terms, the worksheet provides an alternative instructional resource for supporting more meaningful, active, reflective, and engaging mathematics learning among Mathematics Education students.

The findings should be interpreted within the limitations of the study. The implementation involved 32 students from one Mathematics Education class at a single institution and did not include a comparison or control group. In addition, the study did not examine the long-term retention of learning outcomes. Therefore, the observed improvement should not be interpreted as definitive evidence of the causal effectiveness of the developed worksheet. Future research should involve larger samples across multiple universities, comparison or control groups, and longer implementation periods. Further studies could also examine conceptual understanding, mathematical reasoning, reflective thinking, retention, and student engagement as distinct outcomes to provide more comprehensive evidence

regarding the contribution of pedagogical Deep Learning to university mathematics education.

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