Jurnal Gantang *10*(2) (2025): 315-328

JURNAL GANTANG

e-ISSN: 2548-5547
p-ISSN: 2503-0671

http://ojs.umrah.ac.id/index.php/gantang/index

Developing PBL-based worksheets on sequences and series to enhance mathematical connection skills of senior high school students

Nurhaliza Citra Puspita, Susda Heleni*, Elfis Suanto

Universitas Riau, Pekanbaru, Riau, 28291, Indonesia
*Corresponding Author: susda.heleni@lecturer.unri.ac.id

Submission: June 28th 2025; Accepted: November 23rd 2025; Published: November 30th 2025
DOI: https://doi.org/10.31629/jg.v10i2.7383

Abstract

This study was driven by students' low mathematical connection ability in learning Sequences and Series, a skill essential for understanding relationships among mathematical concepts. The purpose of this research was to develop a Problem-Based Learning (PBL)-based student worksheet designed to improve students' mathematical connection ability and to examine its validity and practicality. A development research approach was applied using the 4-D model—Define, Design, Develop, and Disseminate. The participants were tenth-grade students selected through purposive sampling. Data were collected using validation instruments, practicality questionnaires, interviews, and classroom observations. The validation process evaluated face, content, and construct validity. The developed worksheet demonstrated strong validity, with average scores of 89.29% for face validity, 89.29% for content validity, and 86.79% for construct validity. The overall validity score of 88.45% fell into the "very valid" category, indicating the product's suitability for field implementation. The practicality assessment, focusing on design, clarity of material presentation, and ease of use, produced an average score of 83.27%, classified as "practical." These findings suggest that the PBL-based worksheet is both valid and practical, offering potential as an effective instructional tool to support students in developing mathematical connection ability, particularly in topics related to Sequences and Series.

Keywords: student worksheet; problem-based learning; mathematical connection ability; sequences and series

How to cite: Puspita, N. C., Heleni, S., & Suanto, E. (2025). Developing PBL-based worksheets on sequences and series to enhance mathematical connection skills of senior high school students. *Jurnal Gantang, 10*(2), 315 – 328. https://doi.org/10.31629/jg.v10i2.7383

I. Introduction

Mathematics is a branch of science that serves as the foundation for the development of modern technology. Engelbrecht, Llinares & Borba (2020) state that mathematics is a tool for developing an individual's way of thinking. Mathematics is one of the essential subjects that must be taught from elementary school to higher education (Gravemeijer Stephan, Julie, Lin & Ohtani, 2017; Lina, Johar & Anwar, 2025; Ratuanik, Sainlia, Batkunde, Nifanngelyau, 2022). According to Purnama, Widyatiningtyas & Ridha (2019), mathematics is a systematically organized discipline that emphasizes the interrelation of mathematical ideas. The objectives of mathematics learning, as outlined in

the Merdeka Curriculum, include equipping students with mathematical understanding and procedural fluency, reasoning and proof, mathematical problem-solving, communication and representation, mathematical connections, and mathematical disposition (Permendikbudristek, 2022). Therefore, mastering mathematics is not only important for academic preparation but also serves as a foundation for logical and systematic thinking, which is essential for meeting the challenges of the 21st century.

One of the key objectives of mathematics education is to develop students' mathematical connection ability, which serves as a fundamental skill that every learner should possess. According to Putri (2017), mathematical connection ability refers to the capacity of students to identify relationships between mathematical concepts and procedures, recognize the interrelatedness among topics within mathematics, and apply mathematical ideas to other disciplines or real-life contexts. Albert and Antos (as cited in Permatasari, Asikin & Dewi, 2020) emphasize that when students can connect real-world experiences with mathematical concepts, mathematics becomes more meaningful and relevant to them. This sense of relevance enhances students' motivation and increases their engagement in the learning process. As a result, students become more curious and eager to explore the applications of mathematics in their everyday lives (Bernard & Senjayawati, 2019).

Despite the importance of mathematical connection ability, research conducted by Saputra, Armis & Maimunah (2022) revealed that students' mathematical connection skills remain low. The results showed that only 21.5% of the total students tested achieved the indicators of mathematical connection ability. Similarly, a study by Sudirman & Kadir (2018) found that the percentage of students who met the indicators was 46% for connecting objects with mathematics, 30% for connecting mathematics with real-life contexts, and 32% for connecting mathematics with other disciplines. Overall, the total achievement rate of students' mathematical connection ability was only 36%. Several international studies consistently report that students' mathematical connection skills remain low, as they struggle to link concepts, integrate multiple representations, and relate mathematical ideas to real-world contexts (Baiduri, Putri & Alfani, 2020; Haji, 2017; Hasbi, 2019; Hasibuan, 2020; Nuryanti, 2018; OECD, 2019; Retnawati, Apino & Santoso, 2020; Sholeha, Risnawati & Habibullah, 2021; Tasni, 2020). Interviews conducted by the researcher with a mathematics teacher at SMA Negeri 2 Tambang also revealed that many students struggle to learn mathematics because they do not understand previous material. As a result, students have difficulty linking mathematical ideas. These findings indicate that students' mathematical connection ability remains insufficient.

Putri & Santosa (2015) stated that the low level of students' mathematical connection ability may be attributed to the use of teacher-oriented instructional approaches. In such settings, students tend to be passive recipients of information, show a lack of responsibility, and are often reluctant or unmotivated to face challenges in solving mathematical problems. The learning process typically focuses on note-taking, reading, and writing, without involving the observation or analysis of real-world problems relevant to the students. As a result, students are not trained to solve everyday problems that are related to mathematical concepts. Observations conducted at several senior high schools namely SMAN 2 Tambang, SMAN 2 Siak Hulu, and SMAN 15 Pekanbaru also revealed that many students struggle with solving mathematical problems due to a lack of understanding of prior material. Therefore, a student-centered learning model is needed to address this issue.

Several prior studies have explored the use of Problem-Based Learning (PBL) to enhance students' mathematical abilities. Astuti (2023) developed a PBL-based electronic worksheet (E-LKPD) and demonstrated that the product achieved high validity and practicality,

contributing to improved mathematical connection skills. While Astuti's study focused on digital learning materials, the present study differs by developing a printed PBL-based worksheet aligned with the Merdeka Curriculum and focusing specifically on Sequences and Series, a topic identified as challenging at the senior high school level.

Juniati, Kartini & Maimunah (2021) developed PBL-based instructional tools, including lesson plans and worksheets, to support mathematical connection skills. However, their study employed the ADDIE development model and targeted junior high school content on Quadrilaterals and Triangles. In contrast, the present research employs the 4-D development model and addresses a different mathematical domain that requires higher conceptual abstraction.

Meanwhile, Tambunan & Khairuna (2022) developed a PBL-based worksheet for Arithmetic Sequences and series, reporting that it was valid, practical, and effective. However, their study did not specify a particular mathematical ability to be enhanced. The present study fills this gap by explicitly positioning mathematical connection ability as the core competency to be facilitated.

Based on this comparative analysis, the novelty of the present research lies in:

1. developing a printed PBL-based worksheet tailored to the Merdeka Curriculum framework,
2. focusing on the underexplored topic of Sequences and Series at the senior high school level, and
3. explicitly targeting mathematical connection ability, which has received limited attention in previous PBL-based worksheet developments.

This study, therefore, contributes a focused, curriculum-aligned, and pedagogically grounded instructional product designed to address a critical learning need in mathematics education.

Problem-Based Learning (PBL) is an instructional model that engages students in solving real-world problems through inquiry and questioning, thereby stimulating their thinking processes (Lestary, Zulfah & Astuti, 2023). According to research by Abidin (2020), in an experimental class that implemented the PBL model, the learning process became more dynamic and was not rigidly focused only on mathematical content. Nevertheless, the essence of mathematics remained central, allowing students to perceive that they were not only learning mathematical concepts but also engaging with other interdisciplinary elements. Supporting this, a study conducted by Atiningsih (2018) at SMA Negeri 11 Semarang demonstrated that the PBL model significantly improved students' mathematical connection ability. The average score on the mathematical connection ability test increased to 85.68%, with the percentage of mastery reaching 76.47%. Based on these findings and supported by empirical evidence, the PBL model can be considered an innovative approach that effectively facilitates the development of students' mathematical connection ability.

In the implementation of Problem-Based Learning (PBL), innovation is needed to support each stage of the learning process effectively. One important instructional innovation that can be utilized is the use of Student Worksheets (LKPD). According to Salirawati (as cited in Noprinda & Soleh, 2019), the use of LKPD assists teachers in managing the learning process, guiding students to discover concepts through individual or collaborative activities, developing process skills and scientific attitudes, and helping educators monitor students' achievement of learning objectives.

The development of student worksheets (LKPD) is an effort that supports students in achieving their mathematics learning objectives. According to Trianto (as cited in Effendi, Herpratiwi & Sutiarso, 2021), LKPD serves as a guide for students, developing their cognitive aspects while also functioning as a reference for the overall learning process. LKPD is designed to guide students in investigating or solving problems based on the learning achievement

indicators that must be met. Based on various studies, Student Worksheets (LKPD), particularly those developed using a Problem-Based Learning approach, have been proven effective in enhancing conceptual understanding, higher-order thinking skills, learning engagement, and student independence through the provision of structured and contextual learning activities (Aneliana, 2022; Eryani, 2025; Hayati, Astuti & Febrian, 2022; Masruroh, 2023; Satiti, Fajariah & Nasrulloh, 2023; Suryanti, 2023; Triwahyudianto, Isnani & Kumala, 2024; Tussholeha, 2023). Therefore, LKPD can be considered a learning tool designed to facilitate effective interaction and enhance students' learning activities and academic performance. To ensure that students can effectively utilize the LKPD, it must align with the current curriculum specifically, the *Merdeka* Curriculum and be consistent with the PBL framework designed by the researcher.

One of the topics taught in the *Merdeka* Curriculum is Sequences and Series. This topic is included in Phase E, where the learning objective is for students to apply arithmetic and geometric sequences and series in solving problems involving simple and compound interest. According to Hariyomurti, Prabawanto & Al Jupri (2020), the topic of sequences and series is essential for students to learn and master due to its wide range of applications and frequent occurrence in daily life. This is in line with Sumarmo's statement (as cited in Rohendi & Dulpaja, 2013), which outlines several indicators of mathematical connection ability: (a) identifying relationships among various representations of concepts and procedures; (b) understanding the connections among mathematical topics; (c) applying mathematics in other disciplines or real-life situations; (d) recognizing equivalent representations of concepts or similar procedures; (e) identifying relationships among different procedures within equivalent representations; and (f) utilizing connections between mathematical topics and between mathematics and other subjects. Therefore, the topic of sequences and series serves as a suitable context to facilitate students' mathematical connection ability, as it inherently incorporates these indicators.

II. Research Method

The type of research conducted in this study is development research (Research and Development), which focuses on producing a product in the form of a Problem-Based Learning (PBL) Student Worksheet (LKPD) on the topic of sequences and series to facilitate students' mathematical connection abilities. The development model used is the 4D model developed by Thiagarajan (Ayuningtyas & Setiana, 2019), which consists of four stages: Define, Design, Develop, and Disseminate.

The first stage, Define, involves needs analysis to identify problems and learning objectives. The second stage, design, includes the development of a conceptual framework and the preparation of learning tools. The third stage, Develop, encompasses the creation of the media and validation testing to assess its feasibility. The final stage, Disseminate, involves implementing the developed learning product in actual classroom settings with the research subjects.

The researcher employed interviews, classroom observations, expert validation questionnaires, and practicality questionnaires as data collection techniques. Based on the learner analysis, the sample of this study consisted of Grade X students at SMA N 2 Tambang. To explore the initial problems and conduct a preliminary analysis, data were gathered through interviews and observations. Interviews were conducted with the Grade X mathematics teacher to gain insights into the ongoing teaching and learning process. At the same time, observations were made to examine students' behaviors and engagement during mathematics lessons. In addition, data collection also included expert validation results and student response questionnaires to ensure the developed materials met the required quality standards.

In addition, other data collection techniques included expert validation and student response questionnaires. To determine the

percentage scores from the validators, the researcher used the data analysis technique proposed by Akbar (2017), using the formula.

$$\boldsymbol{V = \frac{T_{se}}{T_{sh}} \times 100\%}$$

Where:

V = validity percentage

T_{se} = Total empirical score from the validator

T_{sh} = Maximum expected score

Table 1. Validity level criteria

Validity Score (V)	Interpretation
80% < $V \leq$ 100%	Very Valid
60% < $V \leq$ 80%	Valid
40% < $V \leq$ 60%	Fairly Valid
20% < $V \leq$ 40%	Less Valid
0% ≤ $V \leq$ 20%	Not Valid

Source: Akbar, 2017

The LKPD is considered valid or very valid if it reaches a score above 60%. It is considered reasonably valid if it is equal to or below 60%. If the percentage does not reach 60%, the LKPD is deemed not valid and must undergo further validation testing by the researcher.

The formula used to calculate the practicality percentage of the LKPD based on student responses is adapted from Akbar (2017).

$$\boldsymbol{P = \frac{Q_{se}}{Q_{sh}} \times 100\%}$$

Where:

P = Practicality percentage

Q_{se} = Total empirical score obtained from student responses

Q_{sh} = Maximum possible score

The resulting percentage is then interpreted according to the following criteria:

Table 2. Practicality assessment criteria

Percentage (P)	Interpretation
85% < $V \leq$ 100%	Very Practical
70% < $V \leq$ 85%	Practical
50% < $V \leq$ 70%	Less Practical
0% ≤ $V \leq$ 50%	Not Practical

Source: Akbar, 2017

The LKPD is considered practical if it reaches a score above 70%, and is considered less practical if it is equal to or below 70%. If the percentage does not reach 70%, the LKPD is deemed not practical and must undergo a further practicality assessment by the researcher.

III. Results and Discussion

This development research resulted in a product in the form of a student worksheet (LKPD) designed to facilitate the mathematical connection ability of Grade X senior high school students on the topic of sequences and series. This study aimed to examine whether the developed LKPD met the criteria of validity and practicality in supporting students' mathematical connection skills. The research employed the 4D development model, which consists of four stages: Define, Design, Develop, and Disseminate.

Define

The define stage was carried out to determine and formulate the needs related to the learning process, as well as to gather the necessary information for designing the draft of the developed learning tools. This stage consisted of preliminary-final analysis, student analysis, task analysis, concept analysis, and specification of learning objectives, with the following results: (1) In the preliminary-final analysis, based on a literature review, it was found that students' mathematical connection ability, especially at the senior high school level, was still low. Interview results with teachers also indicated that the use of LKPD had not yet integrated experimental and observational activities aligned with the PBL model; (2) In the student analysis, it was discovered that students were more enthusiastic when learning through peer discussions and actively participating in problem-solving, and that students showed greater interest in learning involving visual elements such as images; (3) In the task analysis, the researcher analyzed the learning outcomes of Grade X Phase E on the topic of sequences and series according to the *Merdeka* Curriculum. The learning objectives

refer to BSKAP Regulation No. 033/H/KR/2022; (4) In the concept analysis, the topic of sequences and series was structured based on the 2022 *Merdeka* Curriculum student book and teacher's guide, which consists of arithmetic sequences, geometric sequences, arithmetic series, geometric series, and infinite geometric series; and (5) In the specification of learning objectives, information was obtained that was necessary for designing the draft of the developed learning tools.

The design stage involved the development of criterion-referenced tests, media selection, format selection, and the initial product draft, with the following results: (1) In developing the criterion-referenced tests, validation sheets and practicality questionnaires were created to assess the validity and practicality of the developed LKPD. The validation sheet was designed based on three aspects: face validity, content validity, and construct validity. The practicality questionnaire for the LKPD was developed based on three aspects: the appearance of the LKPD, the content/material presented, and the ease of use; (2) For media selection, the medium used in this study was print-based or hardcopy format; (3) In the format selection, the LKPD was structured to include steps for discovering concepts and solving problems related to the topic of sequences and series, enabling students to participate in the learning process actively; and (4) In the initial product draft, the subtopics for each LKPD were divided as follows: LKPD-1 covers arithmetic sequences, LKPD-2 covers arithmetic series, LKPD-3 covers geometric sequences, LKPD-4 covers geometric series, and LKPD-5 covers infinite geometric series. The result of this stage is referred to as Draft I. The following is the initial design of the developed LKPD.

1) LKPD Cover

Figure 1. Initial design of the LKPD cover

2) LKPD Contents

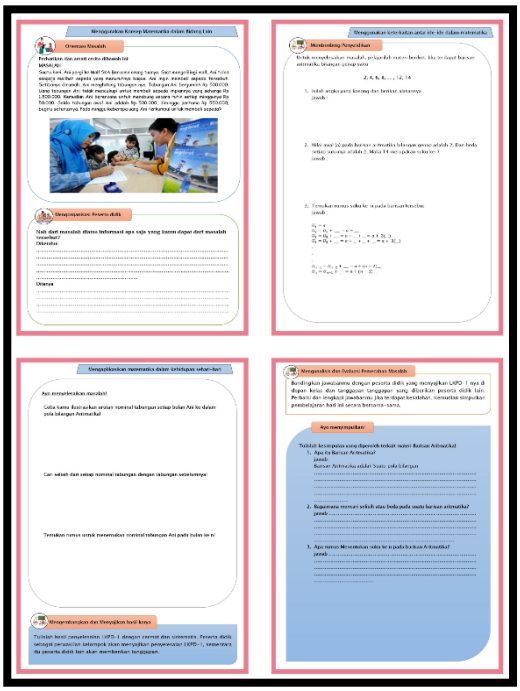

Figure 2. Initial design of the LKPD content

3) Practice Questions

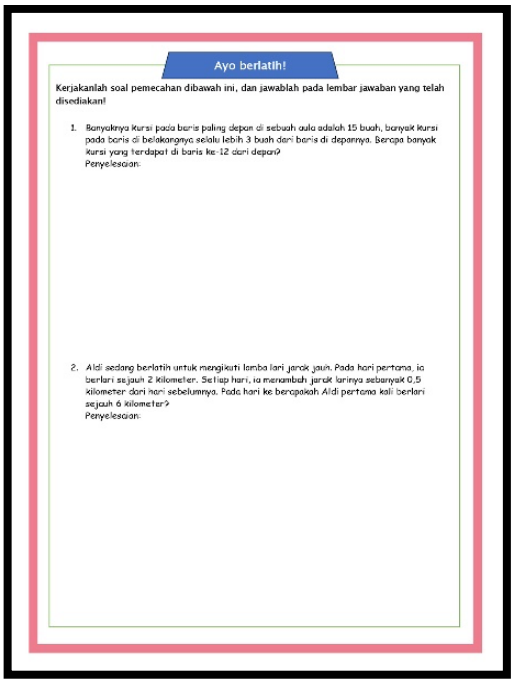

Figure 3. Initial design of the practice question

Develop

The development stage is divided into two main activities conducted by the researcher, namely expert appraisal, which consists of expert review and one-to-one evaluation, and development testing, which involves trying out the developed product.

Expert Review

The LKPD was validated by three validators: two university lecturers and one practitioner. The validation results are presented in Table 3 below:

Table 3. LKPD validation result

Student Worksheet	Assessment Aspects			Rata-rata
	Face Validity	Content Validity	Construct Validity	
LKPD-1	83%	83%	85%	84%
LKPD-2	93%	93%	86%	90%
LKPD-3	92%	92%	86%	90%
LKPD-4	88%	88%	89%	88%
LKPD-5	90%	90%	89%	90%
Average Validity Score				**88%**
Category				**Very Valid**

Based on the data in Table 3, the average validation score of the developed Student Worksheet (LKPD) reached 88%. Referring to the validity criteria listed in Table 3.3, this percentage falls within the range of 85% < V_a ≤ 100%, indicating that the LKPD is in the very valid category. This result shows that the developed LKPD has met the content feasibility standards and is suitable for field testing, provided that revisions are made based on suggestions and feedback from the validators. The suggested improvements from the validators, along with the corresponding revisions made to the LKPD, are presented in the following section.

1) The validator suggested revisions during the guiding phase of the investigation, recommending that several sentences be improved to help students complete the LKPD more easily and to avoid multiple interpretations.
2) The validator provided input to replace certain images with more relevant visuals.

One-to-One

The results of the one-to-one evaluation in this study indicated that several terms or sentences in the LKPD were difficult for students to understand. During the one-to-one evaluation, students also asked questions and provided comments and suggestions regarding the LKPD being developed. These comments and suggestions served as a reference for the researcher in revising the LKPD. The feedback and suggestions provided by the students are presented in Table 4 below:

Table 4. Comments and suggestions from the one-to-one evaluation

Student	Comments and Sugestions
1	The LKPD has a colorful design, which makes the learning process more enjoyable.
2	The explanation is clear, but it would be better if the tables in the LKPD were widened.
3	Some of the instructions in the LKPD are not clear.

Several parts of the LKPD that were included in the students' comments and suggestions were revised. The opinions and input

from students as users of the developed LKPD served as a reference for the researcher in refining the worksheet. The results of the revisions from the validation and one-to-one evaluation are presented as Draft-2.

Small Group

The small group trial was conducted with six Grade X students from SMAN 2 Tambang, selected based on the teacher's recommendation to represent students with heterogeneous abilities. The trial took place over three meetings, from May 19 to May 21, 2025. Based on the researcher's observations during the LKPD implementation, students were initially confused about how to complete the "known" and "asked" sections in the student organizing phase. At first, they did not understand what answers to provide in that section. After the researcher explained what should be written in the student organizing phase, the students began to understand and became more active in working on the developed LKPD. The researcher then distributed a practicality questionnaire (student response questionnaire) to assess the ease of use and gather students' opinions on the LKPD being developed. The results of the practicality questionnaire from the small group trial are presented in Table 5 below.

Table 5. Student response questionnaire results small group

Aspect	Average Score for LKPD (%)					Total Average Score (%)	Category
	1	2	3	4	5		
DA	96	94	96	96	94	95	Very Practical
CP	100	98	96	88	92	95	Very Practical
EU	94	92	93	88	86	91	Very Practical
Overall Average	97	95	95	91	91	94	Very Practical

Note:
DA: Display Aspect
CP: Content Presentation
EU: Ease of Use

Based on the data in Table 5, the results of the student response questionnaire in the small group trial for the LKPD, which was developed on the topic of sequences and series to facilitate students' mathematical connection ability, indicate that the LKPD is classified as very practical, with an overall practicality score of 94%.

Field Test

The field test in this study involved a larger group consisting of 36 Grade X.1 students at SMAN 2 Tambang with heterogeneous academic abilities. The field testing was conducted from May 23 to June 4, 2025. The results of the student response questionnaire from the field test are presented in Table 6.

Table 6. Student response questionnaire results–large group

Aspect	Average Score for LKPD (%)					Total Average Score (%)	Category
	1	2	3	4	5		
DA	87	92	91	85	85	88	Very Practical
CP	78	82	79	77	76	78	Practical
EU	85	86	83	79	84	83	Practical
Overal Average	83	87	84	80	82	83	Practical

Note:
DA: Display Aspect
CP: Content Presentation
EU: Ease of Use

Based on the data in Table 6, the student response questionnaire results from the large group field test show that the LKPD developed on the topic of sequences and series to facilitate mathematical connection ability in Grade X high school students is categorized as practical, with an overall score of 83%. After reaching this stage of practicality, the developed LKPD was finalized as a complete product.

Dissiminate

The dissemination phase consisted of two main activities: (1) packaging the final product, and (2) distributing the LKPD to users by delivering the teaching module to SMAN 2 Tambang. Below is the cover of the final packaged LKPD product.

Figure 4. Final LKPD cover packaging

In the definition stage, the researcher conducted a preliminary and final analysis, learner analysis, task analysis, concept analysis, learning objective specification, and literature review. The initial problem was identified as the low mathematical connection skills of students, which was confirmed through interviews during the needs analysis process. Interview results revealed that students experienced difficulties in connecting mathematical ideas, a finding that aligns with previous studies by Widiyawati (2020) and Sudirman & Kadir (2018), who also reported low levels of mathematical connection skills among students. Based on observations and interviews with the Grade X mathematics teacher at SMA Negeri 2 Tambang, it was found that students were not actively engaged in learning; instruction remained teacher-centered, and learning resources were not integrated with the PBL model, requiring extensive teacher explanation. As a result, students struggled to learn new topics because of their limited understanding of prerequisite materials. To address this issue, student-centered learning was deemed necessary, particularly the Problem-Based Learning (PBL) model, which has been shown to support mathematical connection skills through active participation and contextual problem solving (Chen et al., 2024; Ge et al., 2025; Lonergan, Cumming & O'Neill, 2022; Manuaba & Wu, 2024; Yew & Goh, 2016; Yu & Zin, 2023).

In the design stage, the researcher developed PBL-based worksheets (LKPD) to facilitate students' mathematical connection skills on the topic of Sequences and Series. The worksheets incorporated the phases of PBL: (1) problem orientation, (2) organizing students for learning, (3) guiding individual and group investigations, (4) developing and presenting solutions, and (5) analyzing and evaluating the problem-solving process. These phases were aligned with indicators of mathematical connection skills, including connecting mathematical ideas, applying mathematical concepts across disciplines, and relating mathematics to daily life. The developed worksheets consisted of five meetings: arithmetic sequences, arithmetic series, geometric sequences, geometric series, and infinite geometric series (Draft-1). Validation and practicality questionnaires were also developed; validation covered face, content, and construct validity, while practicality measured appearance, content presentation, and ease of use using a Likert scale.

In the development stage, Draft-1 was validated by three experts: two mathematics education lecturers and one mathematics teacher. The average validation score was 88%, categorized as "very valid" based on Akbar's (2017) modification criteria, indicating that the worksheets were suitable for facilitating mathematical connection skills. The draft was revised following expert feedback. A one-to-one evaluation involving three students of heterogeneous abilities indicated that the worksheets were visually appealing and clear, though some tables required enlargement, and specific instructions needed clarification. After revision, Draft-2 was administered in a small-group trial with six students. During implementation, students had difficulty

interpreting one instruction related to expressing opinions, prompting the researcher to provide clarification. Practicality scores from the small-group trial averaged 94% ("very practical"). A field test involving 36 Grade X students over five meetings produced an average practicality score of 83% ("very practical"). These results indicate that the PBL-based worksheets meet the criteria of validity and practicality. However, some students still struggled to relate mathematical ideas, which echoes findings by Khoirudin, Setyawati & Nursyahida (2017) regarding factors such as content selection, teaching methods, classroom environment, family support, test readiness, and individual student abilities.

In the disseminate stage, the researcher presented the study in a research seminar and packaged the final product into a book, which was then distributed to SMA Negeri 2 Tambang for classroom use, particularly to support mathematical connection skills in Sequences and Series.

The strength of this research lies in the development of empirically validated and practical PBL-based worksheets that effectively facilitated students' mathematical connection skills. This finding is supported by studies showing that PBL enhances students' ability to connect mathematical concepts (Juniati et al., 2021; Lestari, Mardiyana & Slamet, 2022; Mahendra, Husamah & Budiono, 2023; Mandasari, 2021; Mubarika, Firmansyah & Yuliane, 2020; Pradini, Lusiana & Kesumawati, 2022; Setiawan, Tahmir & Jafaruddin, 2024; Dalimunthe & Hasibuan, 2025). Thus, this study contributes further empirical evidence supporting the potential of PBL phases—implemented through PBL-based worksheets—to improve mathematical connection skills. Nevertheless, several limitations should be considered. Because the worksheets were designed to encourage student-generated ideas, some instructions were intentionally concise, which led to difficulties during small-group implementation. Additionally, although the study employed three indicators of mathematical connection skills, some tasks overlapped with indicators involving cross-disciplinary and real-life applications. Future researchers are encouraged to refine task alignment with specific indicators and address the noted limitations to improve subsequent development studies.

IV. Conclusion

The development research conducted by the researcher resulted in a mathematics Student Worksheet (LKPD) aligned with the *Merdeka Curriculum* and based on the Problem-Based Learning (PBL) model for the topic of Sequences and Series, aimed at facilitating the mathematical connection ability of Grade X high school students. Based on the findings and discussions, it can be concluded that the LKPD developed using the PBL model for the topic of Sequences and Series meets the criteria of being very valid, with an overall average validity score of 88%, and practical, with an overall average practicality score of 83%.

References

Abidin, Z. (2020). Efektivitas pembelajaran berbasis masalah, pembelajaran berbasis proyek literasi, dan pembelajaran inkuiri dalam meningkatkan kemampuan koneksi matematis. *Profesi Pendidikan Dasar*, *1*(1), 37–52. https://doi.org/10.23917/ppd.v1i1.10736

Akbar, S. (2017). *Instrumen perangkat pembelajaran*. Remaja Rosda Karya.

Aneliana, A. (2022). The development of a student worksheet based on Problem-Based Learning to improve critical thinking skills. *Brillo Journal*.

Astuti, N. W., & Octavia, B. (2023). Development of Problem-Based Student Worksheet on Environmental Change Material. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 10916-10922.

Atiningsih, S. M. (2018). Penerapan model problem-based learning untuk meningkatkan kemampuan koneksi matematika dan tanggung jawab peserta didik pada kelas XI semester 1 tahun 2015/2016 SMA N 11

Semarang. *Journal of Medives*, *2*, 77–86.

Ayuningtyas, A. D., & Setiana, D. S. (2019). Pengembangan bahan ajar matematika berbasis etnomatematika Kraton Yogyakarta. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *8*(1). https://doi.org/10.24127/ajpm.v8i1.1630

Baiduri, O. R., Putri, I. A., & Alfani, I. (2020). The mathematics connection process of students with low mathematical ability in solving contextual problems. *European Journal of Educational Research*, *9*(4), 1527–1541. https://doi.org/10.12973/eu-jer.9.4.1527

Bernard, M., & Senjayawati, E. (2019). Meningkatkan kemampuan koneksi matematik siswa SMP dengan menggunakan pendekatan metaphorical thinking berbantuan software geogebra. *Jurnal Mercumatika: Jurnal Penelitian Matematika Dan Pendidikan Matematika*, *3*(2). https://doi.org/10.26486/jm.v3i2.558

Chen, T., Zhao, Y.-J., Huang, F.-Q., Liu, Q., Li, Y., Alolga, R. N., Zhang, L., & Ma, G. (2024). The effect of problem-based learning on improving problem-solving, self-directed learning, and critical thinking ability for the pharmacy students: A randomized controlled trial and meta-analysis. *PLOS ONE*, *19*(12). https://doi.org/10.1371/journal.pone.0314017

Dalimunthe, Y & Hasibuan, I. S. (2025). Development of learning problem-based learning to increase mathematical connection ability students of SMK Darul Arqom Kerasaan. *International Journal of Humanities Education and Social Sciences (IJHESS)*, *4*(4). https://doi.org/10.55227/ijhess.v4i4.151

Effendi, R., Herpratiwi, H., & Sutiarso, S. (2021). Pengembangan LKPD matematika berbasis problem based learning di Sekolah Dasar. *Jurnal Basicedu*, *5*(2), 920–929. https://doi.org/10.31004/basicedu.v5i2.846

Engelbrecht, J., Llinares, S., & Borba, M. C. (2020). Transformation of the mathematics classroom with the internet. *ZDM*, *52*(5), 825–841. https://doi.org/10.1007/s11858-020-01176-4

Eryani, R. (2025). Needs analysis for PBL-based mathematics student worksheets. *JELE Journal*.

Ge, W.-L., Zhu, X.-Y., Lin, J.-B., Jiang, J.-J., Li, T., Lu, Y.-F., Mi, Y.-F., & Tung, T.-H. (2025). Critical thinking and clinical skills by problem-based learning educational methods: an umbrella systematic review. *BMC Medical Education*, *25*(1), 455. https://doi.org/10.1186/s12909-025-06951-z

Gravemeijer, K., Stephan, M., Julie, C., Lin, F.-L., & Ohtani, M. (2017). What mathematics education may prepare students for the society of the future? *International Journal of Science and Mathematics Education*, *15*(S1), 105–123. https://doi.org/10.1007/s10763-017-9814-6

Haji, S. (2017). Developing students' mathematical connection ability using outdoor mathematics learning. *Infinity Journal*.

Hariyomurti, B., Prabawanto, S., & Al Jupri, D. (2020). Learning obstacle siswa dalam pembelajaran barisan dan deret aritmetika. In *Journal for Research in Mathematics Learning) p* (Vol. 3, Issue 3).

Hasbi, M. (2019). Improving the mathematical connection ability of middle school students through problem-based learning. *Journal of Mathematics Education*, *11*(3), 123–136.

Hasibuan, S. A. (2020). Development of PISA mathematical problem model on the change and relationship content. *International Electronic Journal of Mathematics Education*, *15*(1), 1–9. https://eric.ed.gov/?id=EJ1235422

Hayati, H. S., Astuti, P., & Febrian, F. (2022). Electronic student worksheets based on rigorous mathematical thinking for sequence and series materials in senior high school. *Jurnal Gantang*, *7*(2).

Juniati, J., Kartini, K., & Maimunah, M. (2021). Perangkat pembelajaran materi segiempat

dan segitiga berbasis model pbl untuk memfasilitasi kemampuan koneksi matematis peserta didik SMP/MTs. *Jurnal Cendekia*, *5*(2), 1375–1389. https://doi.org/10.31004/cendekia.v5i2.545

Khoirudin, A., Setyawati, R. D., & Nursyahida, F. (2017). Profil kemampuan literasi matematika siswa berkemampuan matematis rendah dalam menyelesaikan soal berbentuk PISA (Vol. 8, Issue 2). https://doi.org/https://doi.org/10.26877/aks.v8i2.1839

Lestari, P., Mardiyana, M., & Slamet, I. (2022). Effectiveness of mathematics modules based on problem-based learning to improve students' reasoning ability in junior high school. *Muslim Education Review*, *1*(2), 198–213. https://doi.org/10.56529/mer.v1i2.77

Lestary, V. S., Zulfah, & Astuti. (2023). Analisis bibliometrik: Fokus penelitian problem based learnig dalam pembelajaran matematika. *Jurnal Ilmiah Matematika Realistik* , 120–125.

Lina, S. I., Johar, R., & Anwar. (2025). The role of mathematics education in shaping sustainable futures: A systematic literature review. *Jurnal Elemen*, *11*(3), 757–782. https://doi.org/10.29408/jel.v11i3.29706

Lonergan, R., Cumming, T. M., & O'Neill, S. C. (2022). Exploring the efficacy of problem-based learning in diverse secondary school classrooms: Characteristics and goals of problem-based learning. *International Journal of Educational Research*, *112*, 101945. https://doi.org/10.1016/j.ijer.2022.101945

Mahendra, Y. M., Husamah, H., & Budiono, B. (2023). Improving mathematical connection capability and learning outcomes through problem-based learning model. *AlphaMath: Journal of Mathematics Education*, *9*(1), 61. https://doi.org/10.30595/alphamath.v9i1.17308

Mandasari, N. (2021). Problem-based learning model to improve mathematical reasoning ability. *Journal of Physics: Conference Series*, *1731*(1), 012041. https://doi.org/10.1088/1742-6596/1731/1/012041

Manuaba, I. B. A. P., -No, Y., & Wu, C.-C. (2024). Correction: The effectiveness of problem-based learning in improving critical thinking, problem-solving and self-directed learning in first-year medical students: A meta-analysis. *PLOS ONE*, *19*(5), e0303724. https://doi.org/10.1371/journal.pone.0303724

Masruroh, V. (2023). Development of student worksheets oriented to Problem-Based Learning integrated 21st century skills. *Alishlah Journal*.

Mubarika, M. P., Firmansyah, E., & Yulianie, L. (2020). Implementasi dimensi connectedness dalam problem-based learning untuk meningkatkan koneksi matematis dan disposisi matematis. *Pasundan Journal of Mathematics Education: Jurnal Pendidikan Matematika*, *10*(1), 39–50. https://doi.org/10.23969/pjme.v10i1.2443

Noprinda, C. T., & Soleh, S. M. (2019). Pengembangan lembar kerja peserta didik (LKPD) berbasis higher order thinking skill (hots). *Indonesian Journal of Science and Mathematics Education*, *2*(2), 168–176. https://doi.org/10.24042/ijsme.v2i2.4342

Nuryanti, D., & al., et. (2018). Students' difficulties in solving PISA-like problems: implications for mathematical connections. *International Journal of Research & Method in Education*, *41*(2), 123–139.

OECD. (2019). *PISA 2018 Results (Volume I): What students know and can do*. OECD Publishing. https://doi.org/10.1787/5f07c754-en

Permatasari, S., Asikin, M., & Dewi, N. R. (2020). Potensi game edukasi untuk mengembangkan kemampuan koneksi matematis siswa pada pembelajaran daring. *Prosiding Seminar Nasional Pascasarjana*.

Permendikbudristek. (2022). *Permendikbud Nomor 008 Tahun 2022 tentang Capaian*

Pembelajaran Pada Pendidikan Anak Usia Dini, Jenjang Pendidikan Menengah Pada Kurikulum Merdeka.

Pradini, M. R., Lusiana, L., & Kesumawati, N. (2022). Problem based learning and self-regulated learning: Impact on mathematical reasoning ability in the circle material. *Desimal: Jurnal Matematika*, *5*(3), 235–246. https://doi.org/10.24042/djm.v5i3.12807

Purnama, D. M., Widyatiningtyas, R., & Ridha, M. R. (2019). Penerapan model pembelajaran learning cycle 5e untuk meningkatkan kemampuan koneksi matematis siswa SMK. *INTERMATHZO*, *4*, 9–18.

Putri, H. E. (2017). *Pendekatan concrete-pictorial-abstract (CPA), kemampuan kemampuan matematis, dan rancangan pembelajarannya*. UPI Sumedang Press.

Putri, R. I., & Santosa, R. H. (2015). Keefektifan strategi REACT ditinjau dari prestasi belajar, kemampuan penyelesaian masalah, koneksi matematis, self-efficacy. *Jurnal Riset Pendidikan Matematika*, *2*(2), 262–272. https://doi.org/10.21831/jrpm.v2i2.7345

Ratuanik, M., Sainlia, B., Batkunde, Y., Nifanngelyau, J., Matematika, P., Tinggi Keguruan Dan Ilmu Pendidikan Saumlaki, S., & Boediono-Saumlaki, J. (2022). Model Pembelajaran Problem Based Learning untuk Meningkatkan Pemecahan Masalah Matematika SMP Santo Paulus Saumlaki. *Leibniz: Jurnal Matematika*, *2*, 34. https://doi.org/https://doi.org/10.59632/leibniz.v2i1.139

Retnawati, H., Apino, E., & Santoso, A. (2020). High school students' difficulties in making mathematical connections when solving problems. *International Journal of Learning, Teaching and Educational Research*, *19*(8), 255–277. https://doi.org/10.26803/ijlter.19.8.14

Rohendi, D., & Dulpaja, J. (2013). Connected Mathematics Project (CMP) model based on presentation media to the mathematical connection ability of junior high school student. *Journal of Education and Practice*, *4*(4). www.iiste.org

Saputra, I., Armis, & Maimunah. (2022). Pengembangan perangkat pembelajaran matematika berbasis discovery learning untuk memfasilitasi kemampuan koneksi matematis peserta didik. *ANARGYA: Jurnal Ilmiah Pendidikan Matematika*, 43–52.

Satiti, W. S., Fajariyah, L., & Nasrulloh, M. F. (2023). Development of occupational-based-context worksheets of geometric sequences and series for senior high school students. *APPLICATION: Applied Science in Learning Research*, *2*(3), 143–149.

Setiawan, W., Tahmir, S., & Jafaruddin, J. (2024). The effect of problem-based learning on mathematical connection ability in the context of learning style at UPT SMAN 6 Jeneponto. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *14*(2). https://doi.org/10.30998/formatif.v14i2.28949

Sholeha, V. A., Risnawati, & Habibullah. (2021). An analysis of student difficulties in mathematics learning in terms of mathematical connection ability on Pythagoras theorem. *Prisma*, *10*(2), 45–60.

Sudirman, C., & Kadir. (2018). Analisis kemampuan koneksi matematis siswa smp pesisir ditinjau dari perbedaan gender. *Jurnal Pembelajaran Berpikir Matematika*, *3*, 656–680.

Suryanti, E. (2023). Development of student worksheets based on Problem-Based Learning with video-assisted approach. *JPPIpa*.

Tambunan, S. P. R., & Khairuna, K. (2024). Development of problem-based learning worksheets combined with the make a match cooperative model to enhance students' critical thinking skills in biology. *Jurnal EDUCATIO: Jurnal Pendidikan Indonesia*, *10*(1), 322-333.

Tasni, N. (2020). Students' difficulties in productive connective thinking to solve mathematical problems. *Beta: Jurnal Tadris*

Matematika, *13*(2), 45–58.

Triwahyudianto, T., Isnani, D. R., & Kumala, F. N. (2024). PBL-based liveworksheet e-LKPD to improve critical thinking ability in primary science learning. *Jurnal Bidang Pendidikan Dasar*, *8*(1), 96–104.

Tussholeha, Z. (2023). Student worksheets (LKPD) with problem-based learning model: Development and validity. *AlphaMath: Journal of Mathematics Education*, *7*(2), 92–100.

Widyawati, S., Rosydah, U., Setyawati, A., & Lestari, S. (2025). Evaluating the CMP model's impact on mathematical connection abilities: Insights through self-efficacy levels. *Al-Jabar: Jurnal Pendidikan Matematika*, *16*(1).

Widiyawati, W., Septian, A., & Inayah, S. (2020). Analisis kemampuan koneksi matematis siswa SMK pada materi trigonometri. *Jurnal Analisa,* *6*(1), 28–39. https://doi.org/10.15575/ja.v6i1.8566

Yew, E. H. J., & Goh, K. (2016). Problem-based learning: An overview of its process and impact on learning. *Health Professions Education*, *2*(2), 75–79. https://doi.org/10.1016/j.hpe.2016.01.004

Yu, L., & Zin, Z. M. (2023). The critical thinking-oriented adaptations of problem-based learning models: A systematic review. *Frontiers in education*, *8*. https://doi.org/10.3389/feduc.2023.1139987