

## Enhancing the Competence of High School Teachers in Implementing Deep Learning through Mathematical Connections

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| Article Info                                                                                                                                                                                                                                                                                                                                                                                                      | Abstract                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
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| <p><b>Article history:</b><br/> Received: November 17, 2025<br/> Accepted: March 12, 2026<br/> Published: March 28, 2026</p> <p><b>Keywords:</b><br/> Deep learning<br/> Mathematical connections<br/> Teacher training</p> <p>This article is licensed under a <a href="#">Creative Commons Attribution-ShareAlike 4.0 International License</a></p> <p>© 2026 Bubungan Tinggi: Jurnal Pengabdian Masyarakat</p> | <p>This community service program aimed to enhance the competence of senior high school mathematics teachers in Banjarmasin City in implementing the Deep Learning approach through the strengthening of mathematical connection skills. The program was conducted using a Community-Based Participatory Research (CBPR) approach, which actively involved the Mathematics Teachers' Association (MGMP) in the stages of needs identification, program planning, implementation, evaluation, and follow-up. The activity consisted of a 32-hour intensive training held from September 4 to 11, 2025, involving 59 teachers. Program effectiveness was evaluated using a pretest–posttest design comprising 10 multiple-choice items assessing teachers' understanding of Deep Learning dimensions (meaningful, mindful, and joyful learning) and mathematical connection competencies. The results indicated an increase in the mean score from 86.95 (SD = 8.96) to 90.85 (SD = 10.05), with an average gain of 3.90 points (4.48%). A paired sample t-test demonstrated a statistically significant improvement, <math>t = 2.806</math>, <math>p = 0.007</math>, with a moderate effect size (Cohen's <math>d = 0.41</math>). In addition to quantitative improvements, teachers demonstrated enhanced ability in designing contextual mathematical problems that integrate inter-topic connections and real-world applications aligned with Deep Learning principles. To promote sustainability, the program was extended through a structured three-month mentoring phase to support classroom implementation and reflective practice. Overall, the findings indicate that the CBPR-based training effectively strengthened teachers' conceptual understanding and instructional competence while reinforcing collaborative partnerships for sustainable professional development.</p> |
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### INTRODUCTION

The government, through the Ministry of Primary and Secondary Education (Kemendikdasmen), has established various policies to strengthen the Merdeka Curriculum, including the adaptation of the principles of Deep Learning (DL) as a foundation for improving the quality of education. This approach has been implemented in several countries, such as the United Kingdom, Finland, Japan, and Australia, with the aim

of creating more meaningful learning experiences that are exploration-based and oriented toward the mastery of cross-disciplinary skills ([Kemendikdasmen, 2025](#)).

However, the implementation of this approach still faces several challenges. First, there is a lack of pedagogical training that emphasizes mathematical connection skills. A preliminary survey involving 28 MGMP mathematics teachers showed that 75% of teachers experienced difficulty in designing mathematical connection-based assessment tasks aligned with Deep Learning principles. Second, the integration of technology in problem-based learning remains limited. Third, there are difficulties in designing assessments that align with the principles of the Deep Learning ([Sandi et al., 2023](#)). For example, in geometry, students often memorize formulas for area and volume without understanding their connections to other concepts or their applications in real-world contexts ([Kadarisma et al., 2020](#)). Similarly, in statistics, many teachers still focus on computational procedures without linking them to data analysis in fields such as science or economics ([Akhmad et al., 2023](#); [Maya Santi et al., 2024](#)). These challenges highlight the need for instructional strategies that foster mathematical connection skills, enabling students to relate concepts across different branches of mathematics in a more comprehensive and applicable manner ([Andini et al., 2021](#)).

In addition to pedagogical aspects, another challenge lies in the development of deep learning-based teaching modules and assessments that align with the principles of the Merdeka Curriculum. Several previous training programs, such as the development of 4C-based learning tools and workshops on constructing HOTS (Higher Order Thinking Skills) questions, have supported teachers in enhancing their competencies in designing competency-based instructional materials. However, the implementation of deep learning-oriented instructional strategies still requires further reinforcement, particularly in developing more exploratory and project-based teaching materials ([Zulkarnain et al., 2020](#)). From the perspective of higher education policy, this program aligns with the Key Performance Indicators (IKU) for universities established by the Ministry of Primary and Secondary Education (Kemendikdasmen). Specifically, it supports IKU 3, which encourages lecturers to engage in off-campus activities that contribute directly to the educational community, particularly to teacher professional groups (MGMP). In addition, the program supports IKU 5, which emphasizes that lecturers' outputs should provide tangible benefits to society, such as the development of teaching modules, instructional materials, and deep learning-based teaching methods. From an institutional standpoint, this activity is also consistent with the Strategic Plan (RENSTRA) for Community Service of Universitas Lambung Mangkurat (ULM) 2025–2029, which highlights the importance of empowering educators through research-based instructional innovation and strengthening academic engagement in building a more adaptive and transformative educational ecosystem ([LPPM, 2024](#)).

Although the Ministry of Primary and Secondary Education (Kemendikdasmen) has positioned deep learning as one of the key approaches in the implementation of the Merdeka Curriculum, a gap between policy and practice persists. This is evidenced by findings from a preliminary needs analysis conducted with mathematics teachers in the MGMP of Banjarmasin City, which revealed specific instructional challenges.

Based on a preliminary needs analysis conducted among MGMP members, most teachers have participated in various professional development programs related to deep learning and demonstrate an adequate conceptual understanding of its principles. However, they still experience significant difficulties in translating this understanding into assessment design, a critical component of curriculum implementation. Specifically, teachers struggle to construct mathematical problems that effectively measure students'

mathematical connection abilities (i.e., the capacity to link conceptual understanding, procedural knowledge, and real-world contexts) from a deep learning perspective.

Specifically, teachers report uncertainty in designing tasks that integrate conceptual understanding, contextual application, and inter-topic mathematical relationships in a way that aligns with the characteristics of deep learning. This gap between theoretical knowledge and practical implementation highlights the urgent need for targeted assistance focusing on the development of mathematical connection-oriented problem design.

Based on the agreement with the target partner, namely the Association of Mathematics Teachers (MGMP) for Senior High Schools in Banjarmasin City, the priority issue to be addressed is the need to enhance teachers' understanding and skills in preparing for the implementation of the Deep Learning approach, particularly in developing students' mathematical connection skills. Most teachers are still in the stage of learning the concepts and principles of deep learning, which emphasize deep conceptual understanding, inter-topic connections, and the application of knowledge in real-world contexts ([Levin, 2024](#)). At present, teaching methods still tend to rely on approaches oriented toward content mastery through standardized procedures, focusing primarily on basic understanding and procedural fluency. Therefore, a transition is needed toward approaches that emphasize the development of critical thinking and problem-solving skills ([Kanthimathi et al., 2025](#)).

In addition, teachers need effective strategies to develop students' mathematical connection skills, namely the ability to connect mathematical concepts in a comprehensive and applicable manner ([National Council of Teachers of Mathematic, 2000](#); [Zentgraf & Prediger, 2024](#)). At present, mathematics instruction remains fragmented, where students tend to understand concepts in isolation without recognizing their relationships to other topics or their applications in real-life contexts. This highlights the importance of mentoring and training programs for teachers to ensure they are well-prepared to meet the challenges of implementing the deep learning approach, particularly in integrating mathematical connection skills into the learning process ([Hamdani et al., 2025](#)).

As a solution to these challenges in understanding and implementing deep learning in mathematics education, this program will conduct an activity entitled "Enhancing the Competence of High School Teachers in Banjarmasin City in Implementing Deep Learning through Mathematical Connections." The training aims to equip teachers with an in-depth understanding of the principles of deep learning and strategies to integrate them with the enhancement of students' mathematical connection skills ([Ulya Akmal et al., 2025](#)).

In practice, teachers will be provided with examples of instructional materials and lesson plans that have been developed through research, including guidance on how to design lesson plans, select appropriate teaching methods, and implement assessments that effectively measure students' mathematical connection skills ([Cevikbas et al., 2024](#)). Teachers will also receive guidance on how to analyze and adapt learning materials to accommodate differences in students' levels of understanding, thereby creating a more adaptive and student-centered learning process focused on developing mathematical connections ([Purnomo et al., 2024](#)). The purpose of this training is to enhance teachers' conceptual understanding of the deep learning approach from the perspective of mathematical connections, as well as to improve their ability to design and implement deep learning-based instructional strategies.

## METHODS

This community service program employed a Community-Based Participatory Research (CBPR) approach, which emphasizes collaborative partnerships between academics and community members throughout all stages of the activity. In this approach, the partner community, namely the Association of Senior High School Mathematics Teachers

(MGMP) of Banjarmasin, was actively involved as an equal partner in identifying problems, planning the program, implementing activities, and reflecting on the outcomes.

The CBPR approach was selected to ensure that the program addressed real needs experienced by teachers and to promote shared ownership of both the process and outcomes of the activity. Through this approach, academic knowledge and practical classroom experiences were integrated to produce more meaningful, contextual, and sustainable improvements in mathematics teaching practices.

### **Work Procedure**

The implementation of the CBPR-based community service program was carried out through the following stages:

#### **1. Collaborative Needs Identification**

At the initial stage, the community service team conducted coordination meetings and interviews with representatives of the MGMP to identify priority issues related to the implementation of the deep learning approach in mathematics instruction. This process allowed teachers to express their challenges, expectations, and needs, particularly in developing mathematical connection skills. The results of this collaborative needs assessment served as the basis for designing the training program.

In this stage, the university team acted as facilitators and coordinators of the needs assessment process, while the MGMP teachers served as active partners who articulated their classroom challenges and professional needs. Thus, teachers were positioned not merely as program beneficiaries but as co-determiners of the training focus.

#### **2. Participatory Program Planning**

Based on the identified needs, the community service team and MGMP representatives jointly formulated the objectives, training materials, learning activities, and evaluation strategies. The training content focused on the principles of deep learning, meaningful, mindful, and joyful learning, and strategies for developing mathematical connection problems. This participatory planning process ensured that the program design was aligned with the teachers' professional contexts and classroom realities.

During the planning phase, the university team contributed theoretical foundations and research-based instructional frameworks, whereas the MGMP teachers provided contextual insights and practical considerations from their classroom experiences. This shared responsibility ensured that both academic and practical perspectives were integrated into the program design.

#### **3. Collaborative Implementation**

The training activities were implemented using participatory learning methods, including interactive presentations, group discussions, collaborative problem design, and guided practice. Teachers were actively involved not only as participants but also as contributors who shared experiences and ideas related to the implementation of deep learning in mathematics classrooms. This collaborative learning environment facilitated mutual knowledge exchange between the facilitators and the teacher community.

In the implementation stage, the university team functioned as facilitators and mentors, while teachers actively participated as co-learners and co-creators by designing contextual problems and engaging in reflective discussions. This division of roles reflects the collaborative nature of the CBPR approach.

#### 4. Participatory Evaluation and Reflection

Evaluation was conducted using a combination of pretest and post-test instruments to measure changes in teachers' understanding of deep learning concepts and mathematical connections. In addition, participants completed a satisfaction questionnaire to provide feedback on the training materials, delivery methods, and overall implementation. Reflective discussions were also carried out to capture participants' perspectives on the strengths of the program and areas for improvement. In this evaluation phase, the university team was responsible for instrument administration and statistical analysis, while teachers participated as respondents and reflective practitioners who provided feedback and interpreted the results collaboratively.

The pretest and post-test instruments consisted of 10 multiple-choice items with four answer options (A–E). Each correct response was scored 1, and each incorrect response was scored 0, resulting in a total possible score ranging from 0 to 10, which was subsequently converted into a 0–100 scale for ease of interpretation. The instrument was designed to measure teachers' conceptual understanding of deep learning principles and mathematical connection skills within the context of mathematics instruction.

The test items were developed based on clearly defined competency indicators related to deep learning dimensions and mathematical connection skills. The blueprint of the instrument is presented in Table 1.

Table 1 Competency indicators of the pretest–posttest instrument

| No | Competency Aspect                            | Indicator Description                                                                         |
|----|----------------------------------------------|-----------------------------------------------------------------------------------------------|
| 1  | Joyful Learning                              | Identifying instructional activities that promote enjoyable and engaging mathematics learning |
| 2  | Meaningful Learning                          | Recognizing contextual integration of mathematical concepts in real-life situations           |
| 3  | Mindful Learning                             | Demonstrating awareness in applying mathematical concepts appropriately in practical contexts |
| 4  | Mathematical Connection (intra-mathematical) | Connecting concepts across different mathematical topics                                      |
| 5  | Mathematical Connection (real-world)         | Linking mathematical concepts to authentic real-life problems                                 |
| 6  | Contextual Problem Construction              | Identifying essential steps in constructing contextual mathematical problems                  |
| 7  | Collaborative Learning                       | Understanding the purpose of collaborative learning in mathematics instruction                |
| 8  | Mathematical Modeling                        | Formulating mathematical models from contextual scenarios                                     |
| 9  | Data Interpretation                          | Interpreting statistical data in authentic contexts                                           |
| 10 | Project-Based Learning                       | Identifying joyful and reflective dimensions in mini-project activities                       |

The quantitative data obtained from the pretest and post-test were analyzed using a paired sample t-test to determine whether there was a statistically significant improvement in teachers' understanding after the training program. The level of significance was set at  $\alpha = 0.05$ . In addition to statistical significance, effect size was calculated using Cohen's *d* to determine the magnitude of the intervention effect. The effect size interpretation followed conventional criteria: 0.20 (small), 0.50 (medium), and 0.80 or higher (large effect). This analysis allowed the study to assess both the statistical and practical impact of the program.

### 5. Follow-Up and Sustainability

At the end of the training program, teachers were asked to complete a questionnaire evaluating the implementation of the training activities. The evaluation covered aspects such as training materials, facilitators, facilities, and suggestions for follow-up actions, using a scale of 1 to 5 (Table 2). The collected feedback was then analyzed and brought into the participatory reflection session with the MGMP.

Table 2 Categories of feedback questionnaire scores

| Score | Interpretation |
|-------|----------------|
| 1     | Very Poor      |
| 2     | Poor           |
| 3     | Adequate       |
| 4     | Good           |
| 5     | Excellent      |

As part of the CBPR approach, the results of the evaluation and reflection were discussed with the MGMP to identify potential follow-up actions. Teachers' products, such as mathematical connection problems developed during the training, were documented and shared to support continued professional learning. This stage aimed to strengthen the sustainability of the program outcomes and encourage ongoing collaboration between the university and the teacher community.

In the follow-up stage, the university team provided academic mentoring and guidance, whereas the teachers implemented and refined the developed instructional designs within their respective classrooms. The MGMP forum functioned as a collaborative platform for peer feedback and shared professional learning.

## RESULTS AND DISCUSSION

This community service program was implemented through a collaborative and participatory process involving the Mathematics Teachers' Association (MGMP) of Senior High Schools in Banjarmasin. The following stages illustrate how the CBPR approach was applied in practice, from needs identification to evaluation.

### 1. Collaborative Needs Identification and Program Planning

The initial stage involved intensive coordination with the MGMP to jointly identify the main challenges faced by mathematics teachers in implementing the deep learning approach. Through focus group discussions and interviews, teachers expressed the need for training that not only introduces deep learning theoretically but also provides practical guidance on designing mathematical connection problems. This collaborative needs assessment ensured that the program design was rooted in the real experiences and priorities of the teachers. Based on these inputs, the training objectives were formulated together with the MGMP representatives, focusing on:

- (1) Enhancing teachers' understanding and skills in implementing deep learning in mathematics instruction.
- (2) Equipping teachers with the ability to design mathematical connection problems aligned with the principles of Deep Learning (meaningful, mindful, joyful).
- (3) Fostering meaningful, critical, and reflective learning among students.
- (4) Strengthening collaboration between the university and the teacher community through participatory capacity building.

## 2. Collaborative Implementation and Active Participation

The training was conducted from 4 to 11 September 2025 and attended by 59 teachers. Using participatory methods, the training sessions were designed not as one-way knowledge transfer but as a collaborative learning space where teachers actively shared experiences, co-created problem examples, and engaged in reflective discussions.

Before the training, a pretest was administered to measure teachers' initial understanding of deep learning. The results (Figure 1) indicated that most teachers were still in the early stages of understanding the concept and its application in mathematics teaching.

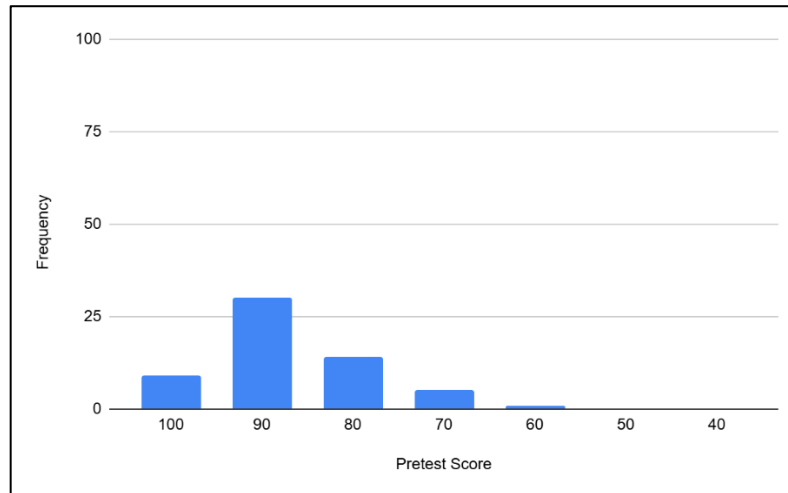


Figure 1 Pretest result

Through interactive sessions, teachers were introduced to the Deep Learning framework and the concept of mathematical connections. They then worked in groups to develop contextual problems based on real-life and wetland-themed scenarios, integrating the three pillars of deep learning. The participatory approach allowed teachers to contribute their own classroom contexts and challenges, making the examples more relevant and applicable. Figure 2 shows some of the collaboratively developed problems that connect geometry, algebra, and real-world contexts.

**Contoh 1**

Seorang siswa diminta membuat pagar berbentuk persegi panjang di halaman sekolah dengan panjang 2 meter lebih panjang dari lebarnya. Luas halaman yang dipagar adalah 80 m<sup>2</sup>.

- Nyatakan masalah ini ke dalam model matematika.
- Tentukan ukuran panjang dan lebar halaman tersebut.
- Gambarkan grafik fungsi kuadrat yang terbentuk, lalu tunjukkan bagaimana grafik itu berkaitan dengan penyelesaian sistem persamaan yang kamu buat.
- Sebutkan dan jelaskan konsep-konsep matematika apa saja yang digunakan dalam menyelesaikan soal ini.

**Indikator Koneksi Matematis:** Mengenali dan menggunakan hubungan antar ide-ide matematika

**Berkesadaran:** Siswa sadar bahwa masalah ini tidak hanya soal hitung luas, tapi bagaimana hubungan antar konsep (geometri ↔ aljabar ↔ grafik kuadrat). siswa belajar secara reflektif, bukan hanya hitung cepat.

**Bermakna:** Konteks pagar sekolah dekat dengan kehidupan nyata siswa → membangun rasa relevansi; Hubungan antar Luas (geometri) → persamaan kuadrat (aljabar) → grafik parabola (fungsi). Siswa memahami matematika itu terpadu, bukan potongan-potongan yang terpisah.

**Menggembarakan:** Konteks sederhana dan familiar membantu siswa lebih percaya diri; Tantangan multi-langkah ini membuat soal lebih dari sekadar hitungan rutin.

Figure 2 Example of a mathematical connection problem involving geometry, algebra, and quadratic graphs

To further illustrate the practical outcomes of the training, two examples of revised teacher-developed problems are presented. These examples demonstrate how participants integrated the principles of deep learning (meaningful, mindful, joyful) with mathematical



connection indicators after the collaborative workshop. An example of a mathematical relationship and a deep learning problem (compound interest context) is shown in Figure 3.

|                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Rizki menabungkan uangnya Rp. 8.200.000,- pada sebuah bank yang memberikan bunga majemuk 12 % pertahun ; tentukan Uang tabungan rizki setelah $5\frac{1}{2}$ tahun ? |                                                                                                                                                                                                                                                                                                                                                                                                                                              | Suatu Pola yang membentuk suatu aturan bilangan dari uang setoran awal ke suatu bank Rp 8.200.000,- dan suku bunga tahunan 12 % pertahun<br>a. Buat runutan secara rasional yang dinyatakan dalam pola bilangan hingga barisan bilangan tertentu<br>b. Tentukan banyaknya tabungan andaikata selama $\frac{1}{2}$ tahun kemudian setelah $5\frac{1}{2}$ tahun<br>c. Buat rumusan barisan hingga jumlah sampai tahun yang diinginkan |                                                                                                                                                                                                                                                                                      |
| Indikator koneksi matematis :<br>Menghubungkan matematika dengan kehidupan sehari-hari<br>Menerapkam matematika dalam konteks mata pelajaran lain misalnya ekonomi   | Berkesadaran :<br>Tujuan : Siswa sadar apa / kenapa mereka lakukan tiap langkah (mempolakan bilangan → <i>menghitung / aturan perubahan</i> → <i>menafsirkan</i> → <i>menyimpulkan rumusan</i> )<br>Bukti : Dilembar kerja ada catatan singkat " Kenapa bisa " di tiap langkah ada ketetapan ; misal : pola bilangan tertentu yang mengarah ke barisan geometri , eksponen ( Aljabar ) karena pemberian tambahan bunga majemuk tiap tahunnya | Bermakna :<br>Tujuan : Peserta didik melihat kegunaan model untuk keputusan nyata (memilih/ memikirkan tafsiran perumpamaan nyata, meramalkan / memperkirakan persoalan kenyataan akan datang )<br>Bukti : Deret bilangan Geometri terhingga                                                                                                                                                                                        | Menggembirakan :<br>Konteks sederhana dan familiar membuat peserta didik bersemangat dan percaya diri serta berkeinginan baik; walaupun mempunyai tantangan multi langkah yang membuat soal lebih dari sekedar hitunga rutin tetapi campuran macam-macam operasi aljabar dan lainnya |

Figure 3 Example of a mathematical connection and a deep learning problem (compound interest context)

The first example, developed by Teacher A, focused on compound interest within the topic of geometric sequences. Initially, the task was designed as a procedural problem, asking students to calculate the final amount of savings after a certain period. After the training, the teacher redesigned the task into a structured contextual exploration. Students were guided to identify patterns in annual growth, formulate the sequence rule, determine the number of compounding periods, and derive a general formula for the total amount. The revised version explicitly emphasized mathematical connections between algebraic representation, geometric sequences, and real-life financial contexts. Moreover, the task incorporated the mindful dimension by requiring students to justify each procedural step and reflect on why compound interest forms a geometric pattern. An example of the relationship between mathematics and deep learning tasks (arithmetic series) is shown in Figure 4.

|                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                   |                                                                                                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fawwaz adalah seorang murid yang ingin membeli sepasang sepatu idaman seharga Rp1.200.000,00. Ayahnya berjanji akan membelikannya sepatu itu jika Fawwaz berhasil mengumpulkan setengah dari harganya terlebih dahulu melalui uang jajannya sendiri. Fawwaz pun bersemangat membuat rencana menabung dari uang jajannya diminggu pertama Rp20.000,00 dimana setiap minggunya selalu bertambah Rp5.000,00. |                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                   |                                                                                                                                                                              |
| a. Berapakah besar tabungan Fawwaz pada minggu ke-10?<br>b. Berapa total tabungan Fawwaz setelah 10 minggu?<br>c. Setelah 10 minggu, apakah Fawwaz berhasil mengumpulkan setengah dari harga sepatu? Tunjukkan perhitunganmu.<br>d. Pada minggu ke berapakah Fawwaz persis berhasil mencapai atau melebihi target?                                                                                        |                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                   |                                                                                                                                                                              |
| Indikator Koneksi<br>Menghubungkan matematika (barisan aritmatika) dengan kegiatan menabung dalam kehidupan sehari-hari.                                                                                                                                                                                                                                                                                  | Berkesadaran<br>Murid tidak hanya menghitung, tetapi dia harus menyadari hubungan dari setiap angka yang dihitung terhadap tujuan akhir (membeli sepatu idaman).<br><br>Murid juga menyadari perbedaan antara tabungan per minggu dan total tabungan. | Bermakna<br>Menabung untuk membeli barang idaman adalah situasi yang sangat nyata dialami oleh hampir semua murid, membuat matematika (barisan aritmatika) menjadi salah satu alat yang berpengaruh untuk mencapai tujuan mereka. | Menggembirakan<br>Permasalahan ini dirancang seperti sebuah "misi" dengan level-level pertanyaan yang semakin menantang untuk memicu keterlibatan dan rasa ingin tahu murid. |

Figure 4 Example of mathematical connection and deep learning task (arithmetic sequence)



The second example, developed by Teacher B, involved an arithmetic sequence problem contextualized through a savings plan scenario. Instead of merely asking students to compute totals, the revised task presented a narrative about a student saving weekly allowances to purchase shoes. The problem was structured into progressive levels of questions, guiding students to determine the savings at a specific week, compute cumulative totals, evaluate whether the target amount was achieved, and identify the exact week when the goal was met. This redesign strengthened meaningful learning by situating mathematics within a relatable real-life goal, while also enhancing joyful learning through a mission-based structure that increased student engagement. The task also highlighted mathematical connections by linking arithmetic sequences with financial decision-making in daily life.

These examples indicate that the training not only improved teachers' conceptual understanding, as reflected in the statistical results, but also enhanced their ability to design contextual, reflective, and cognitively engaging mathematical problems aligned with Deep Learning principles.

### 3. Participatory Evaluation and Reflection

At the end of the training, a post-test was administered to measure changes in teachers' understanding. Descriptive statistics of the pretest and posttest scores are shown in Table 3.

Table 3 Descriptive statistics of pretest and posttest scores

| Test      | Mean  | SD    |
|-----------|-------|-------|
| Pre-test  | 86.95 | 8.96  |
| Post-test | 90.85 | 10.05 |

The descriptive statistics presented in Table 3 show that the mean score increased from 86.95 (SD = 8.96) in the pretest to 90.85 (SD = 10.05) in the post-test, indicating an average gain of 3.90 points (approximately 4.48%). The slightly higher post-test standard deviation suggests a broader distribution of understanding levels after the training, possibly reflecting differential gains among participants. Although participants already demonstrated a relatively high initial understanding, the increase suggests further improvement after the training program. The results of the paired sample t-test and effect sizes are shown in Table 4.

Table 4 Paired sample t-test and effect size results

| Comparison         | t     | df | Sig. (p) | Cohen's d | Interpretation |
|--------------------|-------|----|----------|-----------|----------------|
| Posttest – Pretest | 2.806 | 68 | 0.007    | 0.41      | Moderate       |

The paired sample t-test results shown in Table 4 indicate that the improvement was statistically significant,  $t = 2.806$ ,  $p = 0.007$ . Furthermore, the calculated Cohen's d value of 0.41 reflects a moderate effect size, suggesting that the CBPR-based training produced a meaningful practical impact on teachers' understanding of deep learning and mathematical connections.

### 4. Follow-Up and Sustainability

As part of the CBPR approach, the teachers' outputs—such as contextual mathematical connection problems—were collected and shared through a digital repository for continued use and adaptation. The MGMP also expressed interest in follow-up workshops and peer mentoring sessions to sustain the momentum of deep learning implementation.

To operationalize this follow-up, a structured three-month mentoring scheme was agreed upon collaboratively. The 32-hour intensive training served as the foundational

phase, followed by a structured implementation phase designed to support teachers in applying deep learning principles in their classrooms. A three-month structured mentoring program following the 32-hour in-depth learning training is shown in Figure 5.

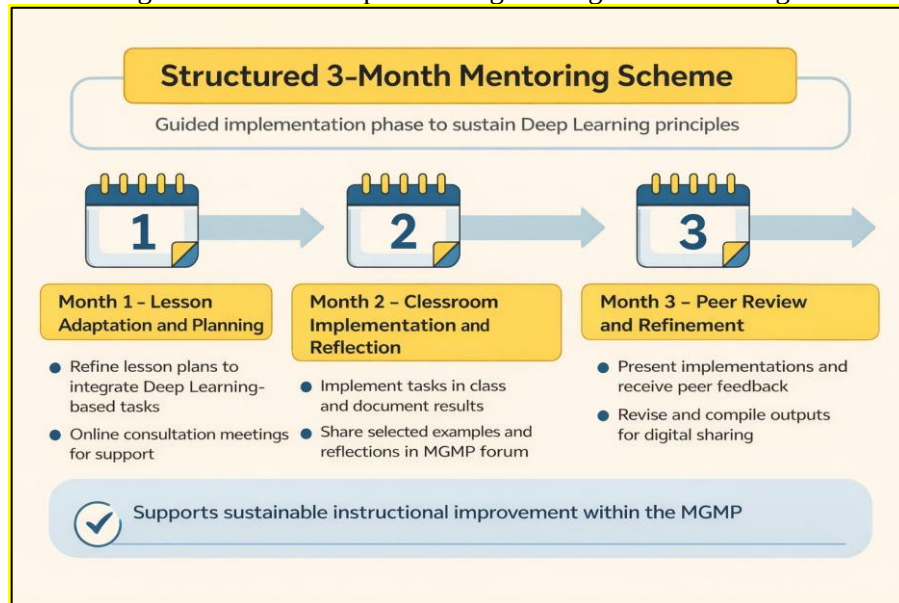


Figure 5 Structured three-month mentoring scheme following the 32-hour deep learning training

This structured follow-up ensures that the impact of the initial training extends beyond short-term knowledge gains and supports sustainable instructional improvement within the MGMP community. The participatory evaluation process also identified areas for further development, such as the need for more examples in statistics and assessment tools aligned with deep learning principles. These insights will guide future collaborative programs between the university and the MGMP.

The use of the CBPR approach in this program facilitated a deeper level of engagement and ownership among teachers. Unlike conventional training models, this approach positioned teachers as co-learners and co-designers, which not only enhanced their conceptual understanding but also built their confidence in implementing deep learning strategies.

The significant improvement in post-test scores, combined with positive qualitative feedback, demonstrates that participatory, context-sensitive professional development can effectively address teachers' needs and foster meaningful changes in practice. Moreover, the collaborative process strengthened the partnership between Universitas Lambung Mangkurat and the MGMP, creating a foundation for ongoing dialogue and joint initiatives in mathematics education innovation.

## CONCLUSION

This study demonstrates that a CBPR approach successfully enhanced the competence of senior high school mathematics teachers in Banjarmasin in implementing a framework that can serve as an effective model for strengthening teachers' capacity to implement Deep Learning through mathematical connections. The participatory process from needs identification to evaluation ensured that the program was relevant, contextual, and owned by the teacher community.

The statistically significant improvement between pretest and post-test results demonstrated a clear improvement in teachers' scores, accompanied by a moderate effect size (Cohen's  $d = 0.41$ ), indicating that the intervention produced measurable and practically meaningful gains in teachers' conceptual understanding

Importantly, the findings extend beyond quantitative outcomes. Teachers exhibited increased competence in designing contextual mathematical tasks that integrate inter-topic connections, real-world applications, and the dimensions of meaningful, mindful, and joyful learning. These outcomes suggest that structured, participatory professional development can bridge the gap between policy-driven instructional reforms and classroom-level implementation.

The inclusion of a structured three-month mentoring phase further strengthened the sustainability of the program by supporting classroom application, reflective practice, and peer-based refinement of instructional materials. This follow-up mechanism positions professional development not as a one-time training event but as a guided transition toward instructional transformation.

Overall, the results highlight the potential of CBPR-based models to promote context-sensitive, collaborative, and sustainable teacher professional development. Future initiatives may build upon this framework by incorporating longer-term classroom impact measures and student learning outcomes to further validate the effectiveness of deep learning-oriented interventions in mathematics education.

#### **CONFLICTS OF INTEREST**

The authors declare that there is no conflict of interest.

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#### **AUTHOR CONTRIBUTIONS STATEMENT**

KAR was responsible for the conceptualization of the study, overall supervision, and final manuscript review. CFP contributed to the design of the research methodology, validation, and refinement of the research framework. RNB coordinated the research activities, collected data, and prepared the results section. RHK performed data analysis, interpreted the findings, and contributed to writing the discussion section. AH assisted in the literature review, initial data processing, and writing of the introduction. ZJ contributed to the preparation of references, documentation, and final editing of the manuscript. All authors actively contributed to the research process and approved the final version of the manuscript for publication.

#### **AI DISCLOSURE STATEMENT**

The authors used QuillBot and Grammarly to correct grammatical errors. After using these tools/services, the author thoroughly reviewed and edited the work as needed and takes full responsibility for the content of the publication. The authors declare that this research was prepared, researched, written, and edited without the aid of artificial intelligence (AI) techniques.

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