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Digital Mind Mapping in Learning Journals (DMMILJ): A Pedagogical Innovation to Foster Self-Regulated Learning in Higher Education

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ABSTRACT

This study aims to develop and test the effectiveness of the Digital Mind Mapping in Learning Journal (DMMILJ) learning technique to improve students' Self-Regulated Learning (SRL) abilities in the Plant Development Structure course. This technique integrates digital concept mapping using applications such as *Canva* and *Mind Meister* with individual and group reflective journal practices. The development was carried out using the ADDIE model, which includes the stages of needs analysis, format design, product development, implementation in the experimental class, and effectiveness evaluation. The trial was conducted in one class of Biology Education students at Cenderawasih University using a one-group pretest-posttest design. The research instruments included a learning outcome test and an SRL questionnaire validated by experts. The validation results showed that the DMMILJ learning technique was highly valid with an average score above 92%. Data analysis using N-Gain showed an increase in learning outcomes of 67.86% (medium-high category). In addition, there was an increase in SRL scores from 70% to 75% (good category). These findings indicate that the DMMILJ technique encourages active engagement, strengthens reflective skills, and enhances students' ability to independently manage their learning strategies and goals. This technique can be recommended as an innovative digital-based learning strategy in higher education contexts. By merging visual mapping and narrative reflection in a digital ecosystem, this study offers a scalable and innovative learning strategy that aligns with the demands of 21st-century education. The DMMILJ technique significantly contributes to improving learning quality in schools and universities by fostering digital competence, deeper cognitive engagement, and self-directed learning, making it a valuable model for transforming science education in digital classrooms.

Keywords: Digital Mind Mapping, Innovative Learning Techniques, Learning Journal, Self-Regulated Learning

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INTRODUCTION

The development of the digital era has brought significant changes to the world of education, especially in how technology supports learning. Innovation in learning techniques is urgently needed to enhance the effectiveness of teaching and student outcomes. In the 21st century learning era, critical thinking skills, the ability to organize information, and self-regulation in learning are essential competencies that students must have (Azmi, 2016; Panadero, 2017). One crucial requirement in higher education is strengthening Self-Regulated Learning (SRL), which is the ability of students to independently organize learning strategies, monitor their progress, and evaluate their learning process (Anazifa et al., 2023; Blackmore et al., 2021; Rinjani, 2019).

SRL is the process by which students actively manage their learning through planning, monitoring, and self-assessment. This skill is vital for achieving the best learning results,

particularly in digital learning environments. The use of interactive learning media can improve student outcomes and SRL (Dewi et al., 2023; Satar et al., 2024). Additionally, research by Mulyati (2023) indicates that digital literacy and SRL positively influence student motivation to learn. Previous studies show that combining two techniques, mind mapping and learning journals, can effectively enhance SRL, as demonstrated in the development of Mind Mapping in Learning Journal (MMILJ) (Satar et al., 2025).

Mind mapping has been proven to promote active student engagement by organizing concepts in a branching visual format, using color, images, and keywords (Annisa' & Suhartini, 2022; Faizah et al., 2021; Oktavia et al., 2021; Wulandary & Purwanti, 2023). Educational integration models such as Synectics with Mind Mapping show positive results in reducing misconceptions and strengthening conceptual understanding (Sairo et al., 2021; Sani et al., 2025). Misconceptions can reduce the effectiveness of learning, hinder the achievement of competencies, and even reduce students' self-confidence because their mistakes are considered correct (Hala, Arifin, et al., 2019; Hala, Saenab, et al., 2019). It helps generate and record new ideas from learned information, allowing students to see and develop ideas holistically, clearly, and effortlessly, which can foster innovation and creativity (Faradiba P & Bahri, 2024; Novioleta et al., 2020). Astuti (2019) suggests that combining the Problem-Based Learning model with mind mapping can boost student engagement in 21st-century science classes. Digital Mind Mapping has been proven to increase creativity, organization of ideas, and the effectiveness of project-based learning (Ardiansyah et al., 2024). Additionally, mind mapping serves as an effective alternative to enhance student creativity (Hidayati et al., 2024; Wati & Purwowidodo, 2024).

With technological advancements, this technique has evolved into Digital Mind Mapping (DMM), an interactive visual tool that allows hierarchical organization of ideas through digital applications (Lin & Wu, 2016). Digital Mind Mapping is considered flexible, collaborative, accessible anytime, and capable of stimulating the brain to absorb information efficiently (Abd. Karim et al., 2023; Rahmi et al., 2023). The use of digital-based mind maps in learning has also been proven to significantly improve creative thinking skills (Syahputri & Murdiono, 2022). It utilizes technology to create visual representations of information, enabling students to organize and connect concepts interactively (Chiu, 2024). The use of digital mind maps has been shown to improve student understanding and foster creativity. Digital Mind Mapping has been shown to improve students' creative thinking and cognitive organization skills, particularly in project-based learning contexts such as PBL and writing instruction (Putra et al., 2024; Sairo et al., 2021)

Maningsih & Fitriani (2023) suggest that digital mind maps can clearly illustrate the relationships between ideas, words, and information, which can help students better understand the subject matter. This medium not only assists teachers in designing and presenting learning materials more structurally but also helps students visualize concepts. On the other hand, learning journaling is a reflective technique that encourages students to write down their understanding, questions, and reflections during the learning process. This technique supports metacognitive awareness and enhances the development of personalized learning strategies(Paris & Paris, 2001). Journaling also plays a role in exploring thoughts and feelings, allowing students to evaluate and find solutions to their learning challenges. Multiple studies have looked into the effectiveness of each technique individually, but the integration of digital mind mapping and learning journaling into a single learning strategy remains underexplored.

Combining digital mind mapping and learning journaling offers a holistic approach to learning, merging information visualization with in-depth reflection. Although specific research on integrating these two techniques is limited, related studies demonstrate their potential benefits. Therefore, integrating digital mind mapping and learning journaling holds significant promise for improving students' self-regulated learning (SRL)(Fang et al., 2023). The digital approach provides flexibility in organizing information visually and promotes in-depth reflection on the learning process, fostering independent and effective learners.

Consequently, this study aims to develop an innovative learning method that combines digital mind mapping and learning journaling and to assess its effectiveness in enhancing students' self-regulated learning. This research is highly relevant in addressing the need to strengthen SRL at the higher education level, especially in the context of independent and digital learning.

Self-Regulated Learning (SRL) skills, such as planning, monitoring, and reflection, are seen as essential skills in higher education, especially in STEM fields, which demand independent mastery of complex ideas (Machado & Carvalho, 2020; Sui et al., 2024). SRL not only boosts academic performance but also enhances students' independence in learning and their metacognitive awareness. However, many learning interventions still focus on supporting SRL components separately, overlooking instructional designs that combine visual and reflective strategies.

Previous research indicates that concept mapping, including digital mind mapping, effectively supports planning and monitoring during the learning process. For instance, an SRL-based approach utilizing concept mapping has been shown to enhance students' self-regulation in STEM learning contexts (Fang et al., 2023). Alt & Naamati-Schneider (2021) also discovered that digital concept mapping can boost SRL skills such as goal setting, task strategies, time management, and self-evaluation in healthcare management students studying online. Additionally, research by Sieben et al. (2021) demonstrates that concept mapping can promote reflection and critical thinking among medical students.

On the other hand, learning journals, or reflective journals, have long been used to enhance metacognitive awareness and deepen understanding. Zhang et al. (2022) showed that EFL students in China increased their use of SRL strategies such as planning, monitoring, and regulating emotions through regular reflective journal writing. Another study by Alt et al. (2022) also demonstrated that reflective journal writing can promote meaningful learning and lifelong learning skills. However, this approach is usually implemented separately from visual strategies like mind mapping, without structured pedagogical integration.

A significant gap in the literature lies in the lack of an approach that integrates visual concept mapping and narrative reflection into a cohesive digital framework. Most studies still separate the use of visual and reflective tools, without evaluating the potential synergy between the two in supporting SRL holistically—particularly in the context of STEM education at the tertiary level. For example, a study by Thomas et al. (2016) integrated concept mapping and goal setting into a problem-based learning (PBL) curriculum, but did not include structured reflection. Liang et al. (2016) used a digital portfolio system for reflection, but without any idea visualization elements. Meanwhile, Ateş Akdeniz (2023) found that a structured SRL intervention improved self-regulation, but did not combine visual mapping with written reflection. Recent research by Kubsch et al. (2025) used a machine learning-based digital workbook to track learning activities, but did not provide visual-reflective artifacts produced by students.

Additional implications emerge from studies of educational technology. The technological environment and self-assessment tools directly and indirectly influence SRL, but they did not develop a pedagogical approach that integrated visual mapping and reflective journals into an integrated instructional design (Adler et al., 2025; Sui et al., 2024; Xu et al., 2023). Furthermore, Nückles et al. (2020) emphasized that the effectiveness of learning journal prompts is highly dependent on students' level of learning strategy expertise and can even negatively impact motivation if not carefully designed. This highlights the importance of adaptive and multimodal instructional design.

To address this gap, this study introduces the Digital Mind Mapping in Learning Journal (DMMILJ) framework—a hybrid learning technique that combines digital mind mapping and reflective learning journaling into a single, integrated digital flow. This technique was developed and implemented over eight sessions in the Plant Development Structure course and piloted with Biology Education students at Cenderawasih University.

METHOD

This research is a research and development (R&D) study using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. The primary objective of the study is to develop a learning technique based on the integration of Digital Mind Mapping and Learning Journals (DMMILJ), which will be implemented into the Semester Learning Plan (SLP) document and applied to the Plant Developmental Structure course. The study population is all students of the Biology Education Study Program, Faculty of Teacher Training and Education, Cenderawasih University, who are taking the Plant Developmental Structure course in the even semester of the 2024/2025 academic year. The sample was taken purposively, namely 22 students who actively attended lectures during the product implementation period from February to June 2025. The instruments used in this study consisted of (1) a RPS validation sheet to assess the validity of the developed product, (2) pretest and posttest questions to measure learning outcomes, and (3) a student Self-Regulated Learning (SRL) questionnaire adapted from the Self-Regulation Formative Questionnaire by Erickson (2021), which consists of 28 items with a reliability of 0.889. The content validity of this instrument was tested by four expert validators with competencies in biology education, educational technology, and learning evaluation. The research procedure began with a needs analysis based on observations and documentation of previous non-digital learning techniques. The DMMILJ technique was then designed and developed, which was incorporated into the RPS. The product was then validated by experts, and the validated product was piloted on a sample of students during the learning process. Implementation took place over 8 sessions, during which the DMMILJ technique was applied as part of an active learning strategy focused on critical thinking and student self-management skills. Data were analyzed using several approaches. For validation, scores from the validators were calculated and analyzed using the validity percentage with the formula *Percentage value sought* = (*Score obtained*/*Maximum score*) × 100%, and the results were categorized based on the interpretation table from Purwanto (2010).

Table 1. Validation Category

Interval	Validity Criteria
≤ 54%	Very Invalid
55% - 64%	Less Valid
65% - 79%	Quite Valid
80% - 89%	Valid
90% - 100%	Very Valid

To measure the effectiveness of the learning techniques, a learning outcome improvement test was used by comparing pretest and posttest scores using the normalized gain (N-Gain) formula. Interpretation of the N-Gain value refers to Hake (1999), which divides students into three categories: high (≥0.70), moderate (0.30–0.69) and low (<0.30).

The improvement in students' Self-Regulated Learning abilities was also analyzed using the N-Gain test based on the pretest and posttest results of the SRL questionnaire. In addition, quantitative data from the student response questionnaire, which included the SRL test, regarding the implementation of the learning techniques, were analyzed using the percentage formula *Percentage* = (*Score obtained*/*Maximum score*) × 100%, and categorized based on the assessment criteria of (Nurhaliza et al., 2023)

Table 2. SRL Criteria

Rentang Presentase	Kriteria
< 40%	Very Bad
41% - 60%	Not Good
61% - 80%	Good
80% - 100%	Very Good

This study's limitations lie in the limited test population, namely only one course and one study program, so the generalizability of the results is limited. However, this innovative approach to digital-based learning techniques can be replicated or modified for other contexts and courses.

RESULT AND DISCUSSION

The development process for the Digital Mind Mapping in Learning Journal (DMMILJ) learning technique in this study was conducted using the ADDIE model approach, which consists of five systematic stages: Analysis, Design, Development, Implementation, and Evaluation. This model was chosen because it has proven effective in designing technology-based learning instructions and facilitating independent learning engagement.

During the analysis phase, researchers identified students' learning needs in the Plant Development Structure course, specifically related to low active engagement and difficulties in organizing and reflecting on the material independently. These initial findings were also reinforced by the results of a previous study, namely the conventional Mind Mapping in Learning Journal technique developed by Satar et al. (2025), which, although proven effective, did not fully accommodate the increasingly relevant digital approach. Therefore, this phase concluded the need for a new approach that is more adaptive and flexible and supports the optimal development of students' Self-Regulated Learning (SRL) skills through digital technology.

In the design phase, researchers developed the DMMILJ learning scheme in two main activity formats. First, individual activities in the form of Learning Journals were completed by students at the end of each learning session. This reflection was supported by digital applications such as *Canva*, *Google Slides*, or *Jamboard*, which provided a visual and expressive space for students to record understanding, questions, and future learning strategies. Second, group activities focused on the use of digital mind mapping using the *MindMeister* application as a means to summarize discussion results and establish connections between concepts discussed in the lesson. This design was then systematically formulated into a Semester Learning Plan (RPS) document based on Outcome-Based Education (OBE), which included course learning outcomes, assessment indicators, active learning activities, and aligned evaluation methods and strategies.

The development phase produced four main products: (1) a guide to implementing the DMMILJ technique, which explains the technical procedures for individual and group activities; (2) an individual learning journal format for daily reflection; (3) a group learning journal format for documenting discussion results in the form of a visual mind map; and (4) an OBE-based RPS document integrated with the DMMILJ learning technique. All products were validated by four experts in pedagogy, materials, and learning technology, using a quantitative-qualitative assessment instrument. The validation results showed that all four products achieved an average score of 92%, categorized as "very valid" based on Purwanto's (2010) criteria.

The DMMILJ-based learning activity implementation guide (Table 3) is designed as a practical and systematic reference for lecturers and students in implementing digital reflective learning processes. It lists activity aspects, a description of the digital mind mapping implementation, the media or applications used, and the expected outputs.

Table 3. Learning Guide using Mind Mapping in Learning Journal technique

Aspects	Description of Activities	Media/Applications Used	Expected Output
Activity Type	1. Individual Activities: Independent reflection on learning at the end of each lecture session. 2. Group Activities: Reflection on discussion results and a summary of the material conducted collaboratively.	1. Canva/Coggle, PPT, Ms. Word (individual) 2. MindMeister (group)	1. Individual Digital Learning Journal 2. Group Collaborative Mind Map

Aspects	Description of Activities	Media/Applications Used	Expected Output
Implementation Time	1. Individual activities are conducted at the end of each learning session. 2. Group activities are conducted after the weekly group discussion.	Class academic calendar and Google Classroom	Regularly scheduled according to the Lesson Plan
Individual Activity Steps	1. Create a reflective learning journal. 2. Create a digital mind map. 3. Link material, concepts, and applications. 4. Write reflective notes (understanding, confusion, learning plan). 5. Upload results to Google Classroom.	Canva, Coggle, MindMup, Google Classroom	Mind map file with learning journal reflection per student per meeting
Group Activity Steps	1. Discuss the material in groups. 2. Create a digital collaborative mind map. 3. Summarize the discussion results. 4. Presentation and group reflection.	MindMeister and Google Classroom	Group mind map file + discussion presentation
Assessment	Formative assessment based on the rubric: a. Structure and accuracy of mind map content b. Critical and in-depth reflection c. Neatness and creativity d. Group participation	Standardized digital rubric (PDF/Sheet)	Daily and weekly scores as part of the process assessment
Lecturer's Role	a. Provide examples of mind map and journal products. b. Provide technical guidance on digital applications. c. Providing feedback and facilitating discussions. d. Monitoring the development of students' reflective skills.	Google Classroom, lecture media, class WhatsApp group	Improving students' reflective skills and conceptual mastery

An individual learning journal format designed to encourage students to reflect independently after each class meeting. This format has an organized structure and supports students' self-monitoring and self-reflection activities on their learning process. The format's components include a sample mind map with several map branches to explain learning reflection materials, such as "What did I learn today?", "What is still confusing?", and "My plan for further understanding." In addition, a map branch is provided for open reflection as a space for students to freely express their emotions, challenges faced, and personal learning strategies. This format is in the form of images in .jpg format embedded in the assignments for each meeting in Google Classroom. Assignments are submitted in the form of digital documents (Word, JPG, PNG, etc.) through the digital learning platform, namely Google Classroom.

A group reflection journal format is used to document the results of group discussions in collaborative learning. This activity is designed to encourage students to not only learn individually but also to construct shared meaning collectively through discussion. This format includes the group identity, member names, discussion title, a summary of the discussion (containing key points and conclusions), and a link to the collaborative mind map created using the MindMeister application—a dedicated platform for creating mind maps collaboratively in real-time. Students are also asked to write down any responses or criticisms raised during the group presentation session and to complete a group reflection section on the discussion dynamics, each member's contribution, challenges encountered, and strategies for resolving them. Furthermore, there is a dedicated space for formulating topic development plans or follow-up questions based on the discussion. This format fosters communication, collaboration, and team problem-solving skills, while also facilitating students' social self-regulation.

The developed lesson plan (Table 4) incorporates individual and group reflection activities through learning journals, combined with concept visualizations in the form of digital mind maps. Weekly activities are designed with a combination of lectures, group discussions, presentations, and reflections using mind mapping. Assessment methods include cognitive, affective, and psychomotor assessments, with specific assessment rubrics for reflection journals and mind map results. The RPS also lists the applications used (*Canva, MindMeister*), primary learning resources, and a plan for periodic learning evaluations. This RPS serves as the primary reference document, ensuring that learning activities align with expected outcomes and are responsive to students' needs in the digital age.

Table 4. Example of Activities in SLP using Digital Mind Mapping technique in Learning Journal in Plant Development Structure course

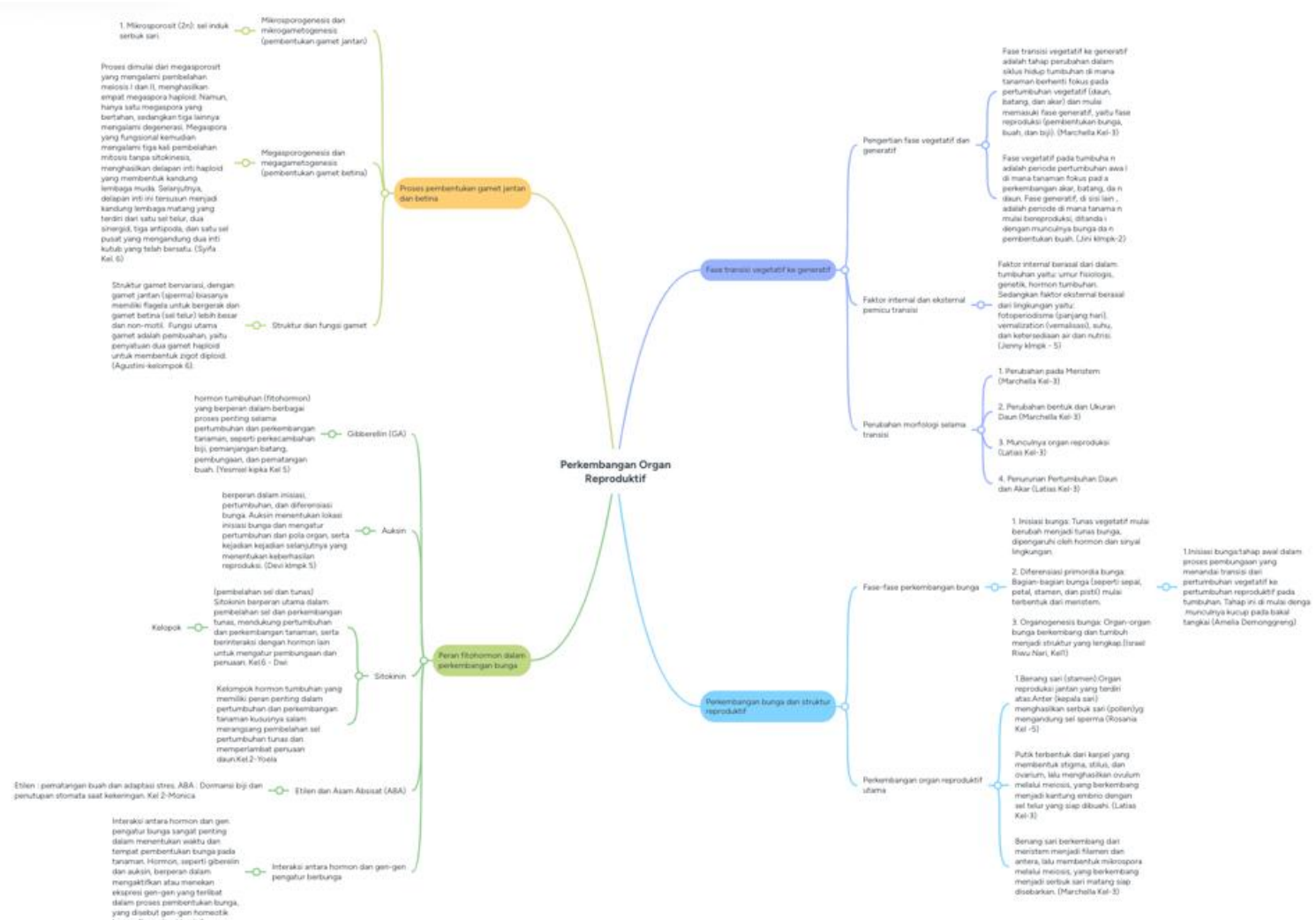
Course learning outcomes	**Assessment (Indicators, Criteria, Forms)**	**Learning Forms & Methods and Student Assignments**	**Learning materials**	**Time Allocation**
Students are able to differentiate the characteristics of meristem tissue and permanent tissue, and present the results of observations and reflections on learning through digital media individually and in groups.	**Indicators:** - Students are able to explain the characteristics of meristematic and permanent tissues. - Students are able to create individual digital mind maps. - Students are able to create group mind maps based on discussion results. **Criteria:** - Accuracy of content and relationships between concepts. - Neatness and visual creativity. - Active participation in group discussions.	**Learning Format:** - Face-to-face: interactive lectures and group discussions - Independent: individual reflection in a digital journal **Methods:** - Group discussions - Image/preparation observation - Application of digital mind mapping techniques (Canva, Coggle, MindMeister) **Assignments:** - Group assignment: creating a collaborative digital mind map -	- Structure of meristem and permanent tissue - Characteristics and functions of tissue - Examples of plant tissue (images/preparations) - Integration of material into digital visual form	2 x 50 minutes face to face + 60 minutes independent assignments

Assessment Forms: - Individual and group mind map assessment rubric. - Digital daily learning journal.	Individual assignment: creating a reflective learning journal using a digital mind map

During the implementation phase, the DMMILJ technique was used with one experimental class over eight sessions in the even semester of the 2024/2025 academic year. Students actively participated in creating daily reflections and group mind maps according to the lesson plan instructions. Researchers employed a one-group pretest-posttest design to evaluate the technique's effect on learning outcomes and SRL skills. Throughout the implementation, observations, documentation, and assistance with digital application use were also provided to ensure the process proceeded as planned.

Figure 1. Example of individual learning journal results using the MMILJ technique

Figure 2. Example of group learning journal results using the MMILJ technique



(DMMILJ). The effectiveness test results showed significant improvements in students' cognitive aspects. The N-Gain values obtained ranged from 0.40 to 0.86, with an average of 0.6786 or 67.86%, falling within the moderate to high category.

Table 5. N-Gain Value

	Minimum	Maximum	Mean
N-Gain Value	.40	.86	.6786
Percentage of N-Gain (%)	40.00	86.00	67.8561

This indicates that the use of DMMILJ was quite effective in improving students' conceptual understanding. In addition to improving learning outcomes, students' self-regulation skills also improved. The SRL questionnaire score increased from 70% to 75%, remaining in the "good" category. Aspects such as learning planning, strategy monitoring, and self-evaluation showed improvement through the implementation of this learning technique.

These findings are also supported by previous literature. Fang et al. (2023) stated that self-regulated concept mapping can significantly improve students' conceptual mastery and self-control in STEM learning. Another study by Alsuraihi (2022) also emphasized that digital mind mapping can enhance student engagement and self-regulation in online learning. This finding aligns with the concept of technology-enhanced scaffolding described by Blau et al. (2020), where digital learning technology can serve as a reflective buffer that strengthens students' digital literacy and critical thinking skills. Digital Mind Mapping makes it easier for students to organize and visualize information systematically, which contributes to improving creative thinking skills and conceptual understanding. Furthermore, the use of digital modules based on a self-regulated learning (SRL) approach has been shown to strengthen students' critical thinking skills (Hadi et al., 2022; Hidayati et al., 2023; Kusmaharti & Yustitia, 2022; Putra et al., 2024)

Digital mind mapping and reflective journaling, conducted individually or in groups, provide students with a platform to develop metacognitive skills systematically and continuously. This aligns with the findings of Joshi et al. (2022), who found that concept mapping was proven to be an effective metacognitive strategy that facilitates students' independent monitoring, organization, and control of their learning processes. Further research by Tuononen et al. (2023) and Mathew et al. (2021)in Metacognition and Learning showed that metacognitive awareness, including cognitive knowledge and regulation, significantly correlated with the deep learning approach, namely planning, monitoring, and self-evaluation. Learning Journals provide a reflective space that can strengthen the SRL process through recording learning planning, monitoring, and reflection (She et al., 2023; Suraworachet et al., 2023). These findings support the DMMILJ technique's motivation to employ more reflective and meaningful learning strategies.

Furthermore, research by Zeitlhofer et al. (2023) providing cognitive and metacognitive prompts in a digital environment significantly improved students' learning performance and self-regulation. This confirms that the use of digital mind mapping combined with structured reflection acts as a metacognitive prompt that strengthens students' self-control and self-monitoring. This process reinforces the principles of SRL, where students become more aware of their learning process, can evaluate learning outcomes, and design follow-up strategies.

When compared to the conventional Mind Mapping in Learning Journal technique previously developed by Satar et al. (2025), the digital version offers several advantages, particularly in terms of flexibility of use, real-time collaboration, more aesthetically pleasing visualizations, and ease of access across devices. While conventional techniques can foster personal engagement, the digital version offers greater efficiency in the revision process and collaborative work. This is supported by research by Alt & Naamati-Schneider (2021), which states that digital concept mapping provides greater support for self-regulation processes compared to traditional methods. Digital concept mapping significantly enhances various

aspects of Self-Regulated Learning (SRL), including goal-setting, task strategies, environmental structure, and time management.

The implications of this research indicate that digital technology-based learning, such as DMMILJ, can not only improve cognitive understanding but also strengthen students' independent learning skills, which are essential components of lifelong learning in the digital age. This technique can be replicated and adapted for use in other courses with similar characteristics. However, this study has several limitations. The lack of a control group makes the results impossible to directly compare with different learning approaches. Furthermore, the eight-meeting implementation period may not have been sufficient to capture the dynamics of SRL development over the long term. Further in-depth evaluation of cognitive load and user experience in using digital platforms has also not been conducted. Further research is strongly recommended to explore these dimensions more comprehensively.

In the context of technology-based educational transformation, digital competence (digital compensation) is a crucial foundation for supporting the success of self-regulated learning (SRL)-based learning strategies. This research demonstrates that the integration of Digital Mind Mapping and Learning Journals within a single learning framework will not be optimal without students' core digital competencies. Students are required not only to be able to access and use digital devices but also to systematically organize information, analyze conceptual relationships, and independently reflect on their learning process using digital platforms.

Digital competence encompasses digital literacy skills, information management, and critical thinking skills in using digital tools for academic purposes (Listiani et al., 2024; Nurbaya et al., 2025; Tanta, 2024). In this study, students with strong digital competence were better able to utilize digital mind mapping features to structure complex biological concepts and write reflective and structured learning journals. This supports the argument of (Nurbaya, 2024, 2023; Tanta et al., 2023) that digital competence directly contributes to the effectiveness of self-regulation in both online and blended learning contexts.

The main findings of this study indicate that the integration of Digital Mind Mapping in Learning Journals (DMMILJ) significantly improved students' Self-Regulated Learning (SRL) skills, particularly in the Plant Development Structure course. N-Gain analysis revealed improvements in all three dimensions of SRL, planning, monitoring, and reflection, suggesting that combining a visual strategy (mind mapping) with a reflective strategy (learning journal) within a single digital framework can foster a more independent and structured learning process. Product validity was also very high, with an average score of 92%, strengthening the reliability of this approach in concept-based learning.

These findings are consistent with previous studies demonstrating the role of mind mapping in supporting SRL. Fang et al. (2023) found that an SRL-based concept mapping approach significantly improved STEM students' self-efficacy. Sieben et al. (2021) also emphasized that concept maps can strengthen medical students' reflection and enhance metacognitive awareness. A systematic review by Chen et al. (2024) and Kefalis et al. (2025) confirmed that digital mind maps in STEM education enhance conceptual understanding and critical thinking. However, most of these studies have not explicitly integrated elements of reflective journaling.

Unlike Alt & Naamati-Schneider (2021) and Stevenson et al. (2017), who only examined the influence of digital mind mapping on goal-setting and task strategies without integrating reflection, the DMMILJ approach offers a comprehensive framework. Zhang et al. (2022) and Udvardi-Lakos et al. (2023) highlight the importance of reflective journaling in building self-awareness and learning motivation, but without the visualization element. DMMILJ combines the two strategies, providing a deeper metacognitive dimension.

In the context of digital education, Chatti et al. (2021) emphasize the importance of developing learning environments that explicitly and implicitly support SRL. A similar finding is confirmed in the TrackThinkDashboard study by Watanabe et al. (2025), which demonstrated that visualization of learning activities supports students in recognizing patterns, errors, and independent reflection. Integrating metacognitive data into digital platforms can accurately

predict learning outcomes and provide a scaffold to support SRL development (Anthonysamy et al., 2021; Broadbent & Poon, 2015; Kubsch et al., 2025).

The implications of this research are broad for designing digital learning in higher education. DMMILJ can be adopted as an effective student-centered learning model to improve SRL, especially in complex concept-based courses in STEM fields. This also aligns with the Independent Curriculum policy and digital transformation efforts in higher education. Furthermore, this approach can build lifelong learning skills by strengthening metacognitive and reflective strategies.

However, this study has several limitations. First, the research design used a one-group pretest-posttest without a control group, which limits causal validity. Second, the population was limited to one institution and one course, so the results cannot be broadly generalized. Third, the SRL measurement instrument was self-reported, which is susceptible to subjective perception bias. Qualitative analysis, such as interviews and journal content, has not been thoroughly included.

For future research, it is recommended to use an experimental design with a control group and a mixed-methods approach to explore qualitative data from digital journals and reflective interviews. A 6–12-month longitudinal study would help test the retention of conceptual understanding and the stability of SRL improvements. Furthermore, the development of a mobile-based and gamified DMMILJ platform can increase student engagement and enable real-time SRL data collection. Integration of learning analytics to visualize the learning process is also recommended to provide in-depth feedback on students' metacognitive skills, as suggested by Chatti et al. (2021) and Kubsch et al. (2025).

CONCLUSION

This study concludes that the development and implementation of the Digital Mind Mapping in Learning Journal (DMMILJ) learning technique significantly improved students' Self-Regulated Learning (SRL) abilities and learning outcomes in the Plant Development Structure course. The average N-Gain value of 0.6786 indicated a moderate to high cognitive improvement, while the SRL score increased from 70% to 75%. These findings suggest that the integration of digital-based reflective and visual strategies can strengthen students' active engagement, conceptual understanding, and metacognitive awareness in learning. The DMMILJ technique offers an adaptive approach to the demands of learning in the digital era, while complementing previous studies that emphasize the importance of self-directed learning strategies and conceptual visualization. The implications of this study are relevant for the development of OBE-based curricula and the transformation of learning in higher education, and open up space for the replication and adaptation of this technique in various learning contexts and other educational levels.

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AUTHOR CONTRIBUTION STATEMENT

SS designed and developed the research design, developed the instruments, and performed data analysis. NN assisted in data collection, instrument validation, and documentation of implementation results. HL contributed to the literature review, questionnaire data processing, and editing of the final manuscript. All authors (SS, NN, HL) actively participated in the discussion of the results and in revising the article for publication.

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