

A Design Framework for Mathematics Learning in Junior High School to Improve Students' Mathematical Connection Ability

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Abstract

This research aims to develop an innovative mathematics learning design for Junior High School students, which explicitly integrates mathematical connection skills. These connections make learning more meaningful and relevant, thus enhancing students' ability to meet the challenges of the 21st century. This design is presented as a solution to the problem of low mathematical connection skills among students and the limitations of teachers in designing effective learning experiences. This design encourages students to actively construct their own understanding of mathematical concepts and their interrelationships. This research produces a comprehensive learning design, encompassing the formulation of measurable learning outcomes, the mapping and organization of coherent learning materials, and the design of learning activities and assessment strategies that align with the goal of developing mathematical connection skills. After undergoing a validation process by two expert reviewers, achieving an average score of 3.40 and categorized as valid, and incorporating minor revisions based on their feedback, this mathematics learning design is deemed ready to be piloted in learning setting. However, the scope of this article is limited to the development and validation stages of the learning design. This research is expected to make a significant contribution to improving the quality of mathematics learning at the Junior High School level, as well as equipping students with the critical thinking, creative, and problem-solving skills essential for their future success. By equipping students with strong mathematical connection skills, they will possess the essential thinking skills for success in the future, both in academic and non-academic fields.

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Keywords: Mathematics Learning Design; Mathematical Connections; Junior High School.

INTRODUCTION

In this era of rapid globalization and digitalization, education is challenged to transcend the mere transmission of knowledge and equip students with the essential skills needed to navigate the complexities of the 21st century (Živković, 2016). Critical thinking, problem-solving, creativity, collaboration, and communication are among the skills that can be fostered through mathematical connections. By connecting mathematical concepts across topics, with other disciplines, and with real-world situations, students are encouraged to analyze, solve problems creatively, communicate ideas effectively, and collaborate to find solutions. These connections make learning more meaningful and relevant, thus enhancing students' ability to meet the challenges of the 21st century (Ke-Du, 2018; Soulé & Warrick, 2015). Previous research has indicated a positive correlation between students' mathematical connection ability and their conceptual understanding and problem-solving skills (Mumu & Bada, 2022; Yilmaz & Argun, 2020). Students who can establish mathematical connections are able to understand mathematics holistically. This allows them to apply mathematical concepts flexibly in various contexts. However, in reality, many students still struggle to build these mathematical connections (Palmér & Burman, 2021). This difficulty stems from various factors, including less effective instructional design. Therefore, a more student-centered approach is needed, one that encourages their active participation in the learning process (Ali, 2019).

In the increasingly complex era of modern education, the learning of mathematics must evolve from mere knowledge transfer to a process that fosters deep understanding and critical thinking skills. This evolution underscores the importance of integrating mathematical connection skills into the conceptual framework of mathematics education (Son & Loka, 2022). Mathematical connection ability refers to students' capacity to recognize relationships between mathematical concepts, both internally within mathematics and externally with other disciplines and everyday life (Badillo et al., 2024). This ability is an essential competency for students, as it equips them to solve problems relevant to their daily experiences (Baiduri et al., 2020; Putri Ramadisae et al., 2020; Siregar & Surya, 2017; Siregar & Siagian, 2019).

Effective mathematics learning emphasizes not only the mastery of procedures and algorithms but also the development of a deep conceptual understanding. Skills in mathematical connections enable students to construct a robust network of understanding in which mathematical concepts are interrelated and mutually supportive (Husband, 2021; Nurhudha et



al., 2022; Zengin, 2019). Consequently, students not only memorize formulas but also comprehend their meanings and the ways in which these concepts can be applied across various contexts. Furthermore, the ability to make mathematical connections facilitates the transfer of mathematical knowledge and skills to other fields and everyday life (NCTM, 2000; Siregar & Siagian, 2019). Mathematics is not an isolated subject; rather, it serves as a powerful tool for solving problems and understanding phenomena across diverse fields, including science, technology, economics, and art. By cultivating mathematical connection skills, students can recognize the relevance of mathematics in their lives and apply their mathematical knowledge to confront real-world challenges.

Although the ability to make mathematical connections is recognized as a crucial aspect of learning mathematics, it has yet to be fully mastered by students. Various studies support this assertion, indicating that students' mathematical connection skills remain relatively low (Kenedi et al., 2019; Pratiwi & Sudihartinih, 2021; Rafiepour & Faramarzpour, 2023; Samo, 2021; Siregar & Surya., 2017). The teacher-centered learning approach contributes to students' low mathematical connection abilities, as it often results in a lack of active student participation and insufficient variety in assignments. Consequently, students struggle to apply mathematical concepts to solve contextual problem (Kurniati et al., 2015; Yudha et al., 2019). Students who can effectively make mathematical connections tend to be more engaged in their learning, exhibit greater curiosity, and demonstrate increased confidence when facing mathematical challenges. Therefore, educators must design a conceptual framework for mathematics instruction that explicitly integrates the development of mathematical connection skills.

This conceptual design should encompass clear objectives, effective learning strategies, and comprehensive assessments. Learning objectives should emphasize the development of students' abilities to connect mathematical concepts with other fields and apply mathematics to everyday life. Learning strategies should promote critical thinking, collaboration, and the application of mathematical knowledge in meaningful contexts. Assessments should incorporate various formats, such as project-based assignments, presentations, and group discussions, to evaluate students' proficiency in making mathematical connections.

By integrating mathematical connection skills into the conceptual design of mathematics education, we can equip students to tackle the increasingly complex challenges of the 21st century. Students who possess strong mathematical connection skills will become independent, critical, and creative learners capable of applying their mathematical knowledge to solve problems, make informed decisions, and contribute meaningfully to society (A Dudung, 2020;



Ayunani et al., 2020).

RESEARCH METHODS

Constructing a conceptual design for mathematics learning that integrates mathematical connection skills is achieved through a logical, rational, and theory-based approach (Mirriahi et al., 2015). This framework is developed through a comprehensive literature review, an analysis of relevant research findings, and the careful implementation of preliminary research. According to Plomp's model, preliminary research serves as the initial stage in understanding teachers' needs when designing lessons. This understanding forms a crucial foundation for creating effective learning designs that explicitly incorporate mathematical connection skills within the context of mathematics education in junior high school (Akker et al., 2010; van den Akker, 2013)

This research focuses on developing a conceptual design for learning design that integrates mathematical connection skills. This framework is intended to serve as a practical guide for teachers in implementing meaningful learning experiences in the classroom. To achieve this objective, data were collected through direct observations of classroom learning practices and in-depth interviews with teachers. These methods aimed to explore teachers' understanding of learning and to identify gaps in their knowledge and skills related to designing effective learning experiences.

The data analysis technique employed is Level 1 Needs Analysis (Gupta et al., 2007). This method entails a thorough assessment of teachers' knowledge and skills. Through this analysis, the ideal conditions specifically, the competencies expected of teachers in designing learning experiences that integrate students' mathematical connection skills can be compared with the actual conditions observed in the field. These ideal conditions encompass teachers' abilities to formulate clear learning objectives, systematically map and organize learning materials, design engaging learning activities that foster mathematical connection skills, and create valid and reliable assessments to evaluate student progress.

RESULT AND DISCUSSION

Needs Analysis

Observations and interviews with mathematics teachers revealed a significant disparity between the ideal conditions anticipated for mathematics learning and the actual circumstances in the field. These findings underscore the challenges and obstacles that teachers face in delivering high-quality and meaningful learning experiences. This result shown in the Table 1.



Table 1. The Disparity Between the Ideal and the Reality of Mathematics Learning Design

Ideal Condition	Facts	Needs
having guidelines as instructions for implementing learning that is integrated with mathematical connection skills.	teachers still require comprehensive guidance in integrating learning with mathematical connection skills.	developing guidelines as instructions in implementing learning integrated with mathematical connection skills
possess knowledge and skills in instructional design.	teachers' competence in designing effective learning experiences still requires enhancement.	operational boundaries in designing learning
able to develop clear and measurable learning objectives that integrate relevant knowledge and skills, ensuring that these objectives meet established standards.	teachers must have a comprehensive understanding and seek assistance in formulating learning outcomes that align with established quality standards.	Criteria for Developing Learning Objectives Aligned with Established Standards through the Integration of Relevant Competencies.
understand, structure, and organize learning materials in a systematic manner that aligns with the learning objectives.	teachers have not yet fully compiled and organized learning materials in a structured and systematic manner, resulting in suboptimal alignment with the expected learning outcomes.	Criteria for compiling teaching materials should be structured and systematic to align with the expected learning outcomes, accompanied by guidelines and examples.
understand how to design practical and relevant learning activities.	teachers' competence in designing learning activities that are meaningful and appropriate for the learning context still requires improvement.	Criteria for Designing Effective and Relevant Learning Activities To create learning activities that are both effective and relevant, it is essential to structure them

		systematically in alignment with the expected learning outcomes. This involves adhering to specific guidelines and incorporating practical examples.
Understand how to design valid and reliable assessment instruments that accurately measure the achievement of learning objectives.	Teachers must be fully equipped to develop valid and reliable assessment instruments that accurately measure the achievement of predetermined learning objectives.	Practical guidelines, criteria, and examples for developing assessments that are both adequate and relevant to learning objectives.

The analysis presented in Table 1 highlights the urgent need for a mathematics learning design that integrates mathematical connection skills. This design will serve as a crucial reference for teachers implementing meaningful learning at the junior high school level, specifically tailored to the sub-topic of the material being taught. The identified needs include: (1) the development of clear guidelines and criteria for formulating learning outcomes, (2) the creation of guidelines and criteria for mapping and organizing materials, (3) the design of guidelines and criteria for integrating mathematical connection skills into the learning process, and (4) the establishment of guidelines and criteria for designing assessments that align with learning objectives. By addressing these needs, the quality of mathematics education in junior high schools is expected to improve significantly. Students will not only master mathematical concepts in isolation but also be able to establish connections between these concepts and apply their knowledge in various contexts, both within and beyond mathematics. This approach will equip students with critical thinking, creativity, and problem-solving skills that are essential for their future success.

Developing a framework for mathematics learning design

The development of the conceptual design has resulted in a comprehensive learning design that serves as a practical guide for teachers in implementing mathematics instruction. This approach not only emphasizes the mastery of concepts but also fosters students' ability to establish connections between mathematical concepts and their real-world applications. The



design process begins with the formulation of measurable and specific learning outcomes, a crucial stage that ensures clear objectives guide the subsequent learning process. Next, the mapping and organization of learning materials are conducted meticulously to ensure alignment between the presented material and the expected learning outcomes, thereby facilitating the formation of meaningful mathematical connections. The selection of learning activities is the subsequent important step; these activities should be strategically designed to encourage students to actively engage in learning, think critically, collaborate, and independently discover mathematical connections. Furthermore, the integration of skills related to mathematical connections is explicitly planned into every activity, enabling students to consciously build and reinforce their understanding.

Furthermore, the assessment strategy must offer an accurate and comprehensive representation of the development of students' mathematical connection skills. To achieve this goal, authentic assessment, which involves applying mathematical concepts in real-world situations, is recommended. The resulting instructional design component contained in the guidebook is 1) Formulating Learning Outcomes, 2) Mapping and Organizing Learning Materials, 3) Designing Learning Activities, 4) Designing Assessment Strategy.

Formulating Learning Outcomes

The first step in designing an integrated learning framework for mathematical connection skills is to formulate learning outcomes, which are defined as the competencies or abilities that students are expected to master after completing the learning process in a subject or educational program. These learning outcomes stem from a systematically designed educational process aimed at achieving national education goals. Learning outcomes can be categorized into three main domains: (1) cognitive learning outcomes, which focus on students' abilities to understand, remember, and apply acquired knowledge and concepts; (2) affective learning outcomes, which emphasize the development of students' positive attitudes, values, and emotions in addressing various situations and challenges; and (3) psychomotor learning outcomes, which pertain to the development of students' skills and physical abilities in executing tasks and activities.

Mapping and Organizing Learning Materials

The second step involves mapping and organizing learning materials. This process includes identifying, grouping, and categorizing materials according to subject matter, sub-topics, and alignment with the previously established learning sub-achievements and indicators. This step is



essential for ensuring coherence and alignment between the learning materials and the learning objectives.

Designing Learning Activities

The third stage involves formulating steps and activities for the integrated learning of comprehensive mathematical connection skills. This learning design addresses two primary issues: the low achievement of students in mathematical connection skills and teachers' limitations in creating quality learning experiences that facilitate the development of these skills. The design presented is a pedagogical innovation grounded in an in-depth analysis, elaboration, synthesis, and abstraction of various learning theories, including constructivism, behaviorism, cognitivism, and humanistic learning theories, as well as recent studies on mathematical connection skills. The constructivist approach has been adopted as the primary philosophical foundation for this learning design. Its goal is to empower students to construct their understanding of mathematical concepts and their interrelationships, thereby significantly enhancing their learning outcomes in mathematical connection skills. Each phase of this mathematics learning is expected to improve students' mathematical connection skills through five stages: 1) focus on prior knowledge, 2) connection, 3) construction, 4) application, 5) evaluation and reflection (table 2). These five phases of mathematics learning design are called In action learning, which is an acronym for the five phases of mathematics learning.

Table 2. Phases of Math Learning (In Action Learning)

Activities	Learning Activities
Phase 1: Initial Abilities Focus Exploring Prior Knowledge	- The teacher provides motivation or stimulation to capture students' attention on the subject matter. - The teacher presents images, photographs, and videos related to the material to be learned. - Conduct a question-and-answer session to assess students' prior knowledge and experiences before introducing the new topic.
Phase 2: Connection Connect your existing knowledge to receive information related to the	- The teacher organizes the students into several diverse groups. - The teacher presents the material using digital media, which includes information relevant to the topic being



discussed topic.	studied. This approach allows students to connect their existing knowledge with the new concepts they are learning. - Guiding students to connect prior knowledge with new information related to the topic being studied through the use of media. - Provide opportunities for students to request clarification on information that is unclear.
Phase 3: Construction Analyzing Information and Constructing Problem-Solving Strategies	- The teacher instructs students to gather information, study, and analyze the problem presented in the Learner Worksheet. - The teacher instructs students to analyze information and develop problem-solving strategies. - They are guiding students in solving problems independently.
Phase 4: Application Discuss and share information.	- The teacher guides students in discussing the steps to solve the problem with their classmates. - Encourage students to share information about their individual work. - The teacher continued to offer limited guidance and scaffolding to groups that required assistance in mathematizing, developing strategies, implementing those strategies, drawing conclusions, and making systematic reports. - The teacher assists students in summarizing the results of the discussion, which are prepared for presentation in class.
Phase 5: Reflection and Evaluation Presentation and making Conclusions	- The teacher permits group representatives to communicate orally or present the outcomes of their group discussions. - The teacher provides each group with the opportunity to express their opinions, respond, or ask questions.

	- At the conclusion of the reflection stage, students draw their final conclusions. - The teacher provides reinforcement and assigns homework.
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Designing Assessment Strategy

The next step is to design effective assessment strategies. Educators must possess a clear understanding of their own learning and teaching philosophies to select materials, activities, and assessments coherently. Assessment activities and processes should reflect the values upheld by educators (Lile & Bran, 2014). Assessment is a crucial component of the learning process, as it is used to evaluate the achievement of learner competencies (Pantiwati & Husamah, 2017; Putra et al., 2019). The primary objectives of assessment are to determine the level of mastery of competencies, evaluate the completeness of that mastery, identify areas for improvement or enrichment programs based on competency mastery, and enhance the overall learning process. Assessment serves as a method to evaluate an object using measurement data from various dimensions (Leeuwenkamp et al., 2019; Lile & Bran, 2014), including knowledge, attitudes, skills, and more.

Learning outcomes can be categorized into three domains: cognitive, psychomotor, and affective. Each of these domains is distinct, yet all subjects encompass these three aspects, albeit with varying emphasis. The cognitive domain focuses on theoretical understanding, the psychomotor domain emphasizes practical skills, and both domains contribute to overall effectiveness. Assessment of cognitive, affective, and psychomotor skills is essential in the evaluation process of teaching and learning activities. Together, they provide a comprehensive overview of an individual's capabilities. Validity

The validation process began by submitting the initial draft of the mathematics learning design to experts for critical feedback on the developed concepts and framework. The validators provided several suggestions for improving the mathematics learning design guidebook: (1) Highlight the unique features that differentiate this mathematics learning design from others, (2) pay attention to the time allocation in the assessment section, (3) use a flexible rubric in the assessment strategies section, (4) ensure the cover design aligns with the title.

The validation process conducted on the Mathematics Learning Design has significantly contributed to improving the quality of learning. Based on the suggestions provided by the validators, several revisions were implemented to accommodate this feedback. A summary of the



validity analysis results for the learning design guidebook is shown in the following table 3.

Tabel 3. Validator Team Assessment Analysis Results

Indicator	Mean Score	Categori
Supporting Theories	3,50	Highly valid
Design Procedure	3,63	Highly valid
Formulating Learning Outcomes	3,25	Valid
Mapping and Organizing Learning Materials	3,50	Highly valid
Designing Learning Activities	3,17	Valid
Designing Assessment Strategy	3,25	Valid
Design Format	3,50	Highly valid
Average score	3,40	Valid

The analysis results show that overall, this mathematics learning design is considered valid. The average assessment score reached 3.40, indicating that this design has met the established validity criteria. This means that the design has been built on a strong framework, has clear learning objectives, and uses relevant learning strategies. The validation results indicate that the learning design has met the established validity criteria and is feasible for implementation in the learning process. These validity criteria include alignment with relevant learning theories, clarity of learning objectives formulation, completeness and accuracy of content, and the effectiveness of the designed learning strategies. The implementation of this learning design is expected to facilitate the development of students' mathematical connection abilities. Mathematical connection ability is an essential skill that enables students to see relationships between mathematical concepts, apply mathematics in real-world contexts, and use mathematics as a problem-solving tool.

A valid learning design is expected to create a conducive learning environment for the development of students' mathematical connection abilities through structured and meaningful learning activities. Furthermore, empirical research needs to be conducted to examine the effectiveness of the learning design in improving students' mathematical connection abilities. This research can provide more in-depth information regarding the impact of the learning design on the development of students' mathematical connection skills and the factors that influence the success of its implementation.

This research has developed an innovative mathematics learning design for junior high school



students, emphasizing the integration of mathematical connection skills. This design aims to address the challenges posed by low student learning outcomes in mathematical connections and the limitations teachers face in creating effective learning experiences. The core of this learning design is rooted in the philosophical foundation of constructivism, which encourages students to actively construct their understanding of mathematical concepts and their interrelationships (Bhattacharjee, 2015; Lee et al., 2021). By adopting this approach, it is anticipated that students' learning outcomes regarding mathematical connection skills will improve significantly.

The proposed learning design outlines a structured and systematic pedagogical framework (Gravemeijer & Cobb, 2006) comprising four interdependent and integrated stages :1) formulation of learning outcomes, 2) mapping and organizing learning materials, 3) designing learning activities, 4) designing an assessment strategy. This learning design is grounded in relevant learning theories, particularly those emphasizing the importance of mathematical connection skills in building strong and meaningful conceptual understanding. These theories include Piaget's constructivism, Ausubel's meaningful learning theory, and problem-based learning. The integration of mathematical connection skills in this learning design is realized through various strategies, such as: presenting contextual problems that connect mathematical concepts with everyday life, utilizing multiple representations to facilitate understanding concepts from various perspectives, and emphasizing student discussion and collaboration to develop mathematical argumentation and justification skills.

Prior to implementation in the learning process, this learning design underwent a validation process by two expert reviewers in the field of mathematics education. This validation aimed to assess the feasibility of the learning design from various aspects, including: alignment with learning theories, appropriateness of learning strategy selection, potential effectiveness in improving students' mathematical connection skills, and the ease and practicality of implementation in the field. Feedback and suggestions from the expert reviewers were used as considerations in revising and refining the learning design before piloting it with students.

After undergoing a rigorous validation process by two expert reviewers in mathematics education, the learning design integrating mathematical connection skills is deemed feasible and ready for implementation in field trials. This validation included an assessment of the content's relevance, the effectiveness of the strategies, and the potential impact on students' mathematical connection skills. The experts assessed that this learning design has the potential to facilitate students in constructing a comprehensive and meaningful understanding of mathematical concepts, as well as connecting these concepts with various contexts both within and outside of



mathematics.

Based on input from the reviewers, several minor revisions were made to optimize the learning design. These revisions included simplifying the language, adding contextual examples, and clarifying instructions for certain learning activities. Although minor, these improvements are expected to enhance the effectiveness and ease of implementation of the learning design during field trials. Thus, after this revision stage, the mathematics learning design is ready to be piloted with teachers and students in schools to obtain empirical data regarding its effectiveness in improving mathematical connection skills.

The primary purpose of learning design is to offer a structured and comprehensive framework that guides educators in creating high-quality, effective, and meaningful learning experiences for students (Putrawangsa, 2019). This approach to learning design enhances students' mathematical connection skills and yields broader benefits. By emphasizing meaningful learning and fostering active student engagement, this design significantly boosts student motivation to learn (Simon et al., 2018). As students perceive their active role in the learning process and recognize the relevance of mathematics in everyday life, they become more enthusiastic and interested in studying the subject (Ayunani et al., 2020).

In addition, this learning design encourages the development of students' social and emotional skills. Through collaborative activities and group discussions, students learn to communicate effectively, respect diverse opinions, and work together to achieve common goals (Chiu & Douglas, 2013; Ismiyati et al., 2023). These skills are essential for their future success in both academic and professional fields. Furthermore, Herbert Simon defines design as a problem-solving process (Dick et al., 2004).

The resulting learning design serves as a valuable reference for educators aiming to create effective and meaningful learning experiences that emphasize conceptual mastery and the development of students' mathematical connection skills. By developing strong connection skills, students will be better prepared to face the challenges and opportunities of the 21st century, which aligns with curriculum changes and innovations, with the main goal of improving student learning outcomes (Ke-Du, 2018; Rafiepour & Faramarzpour, 2023). Implementing this design, the quality of mathematics education can be enhanced, enabling students to reach their full potential and prepare for future challenges. Carl and Rosalind proposed that learning design can be understood from multiple perspectives, including as a discipline, a science, and a process. In the realm of scientific disciplines, learning design explores various research findings and theories related to strategies for developing and implementing effective learning experiences.



However, it is essential to recognize that the successful implementation of this learning design necessitates support and commitment from multiple parties, including teachers, schools, and other stakeholders. Ongoing training and professional development for educators are crucial to ensure they fully understand and effectively apply this learning design. Furthermore, schools must provide sufficient resources and infrastructure to facilitate the successful execution of effective learning practices. With collaboration and commitment from all stakeholders, this learning design is anticipated to have a sustainable impact on mathematics education in Indonesia. Students will gain improved opportunities to develop their mathematical connection skills, enabling them to become competent, creative individuals prepared to face challenges in the global era.

CONCLUSION

This research presents a comprehensive learning design aimed at addressing the gap between ideal conditions and actual practices in the field, particularly concerning teachers' abilities to design and implement effective learning experiences that foster the development of students' mathematical connection skills. This design emphasizes the mastery of mathematical concepts in isolation while also focusing on enhancing students' abilities to establish connections between these concepts and relate them to real-world situations. Consequently, the quality of mathematics education at the junior high school level is expected to improve significantly, equipping students with critical thinking, creativity, and problem-solving skills that are essential for their future success.

The process of designing this learning design begins with formulating clear and measurable learning outcomes, followed by mapping and organizing learning materials that align with these outcomes. Next, learning activities are crafted to promote active student engagement, collaboration, and independent exploration of mathematical connections. The integration of skills related to mathematical connections is explicitly incorporated into each activity, culminating in the development of a precise and comprehensive assessment strategy to evaluate students' progress. Following a thorough validation analysis, it was concluded that the developed mathematics learning design meets the validity criteria and is suitable for implementation. Therefore, the next stage of this research will involve conducting a field trial to examine the effectiveness of the learning design within the context of actual classroom practice. By adopting this conceptual framework, it is anticipated that educators can create more meaningful, relevant, and engaging learning experiences, enabling students not only to master mathematical concepts



but also to apply them in various real-life contexts.

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