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# ENHANCING HIGH SCHOOL STUDENTS' NUMERACY SKILLS IN 3D POSITIONING THROUGH AUGMENTED REALITY

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***ABSTRACT***

This study explores a learning trajectory to teach three-dimensional positioning using augmented reality (AR) and assesses students' numeracy literacy skills after using AR-based learning. The research follows a three-stage design research approach: preparation, the design experiment (split into pilot and teaching phases), and retrospective analysis. The study incorporates three AR-based activities in a student worksheet. In the first activity, students observe the AR simulation of a futsal field to identify spatial elements. In the second, they interact with the AR to determine positions in three-dimensional space. In the third, students solve related spatial problems, applying their numeracy skills. The AR-based design aims to enhance students' understanding of three-dimensional positioning for Grade XII high school students and assess improvements in their numeracy literacy through these interactive, structured activities.

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## INTRODUCTION

Based on the results of the PISA study in 2022, Indonesia scored lower on average than in the 2018 survey across mathematics, reading, and science. Indonesia achieved an average score of 356 in reading and 366 in mathematics (OECD, 2023). The overall results in 2022 were among the lowest ever recorded by PISA in all three subjects—reading, mathematics, and science—indicating that Indonesian students' abilities in geometry and numeracy literacy remain very low. Students struggle with using numbers and symbols to solve everyday problems and have difficulty understanding geometric concepts, leading to errors in interpreting the information provided in problems (Lestary & Hamdu, 2022; Rezky et al., 2022).

Several factors contribute to the low student performance in geometry, particularly regarding the topic of position in three-dimensional space. These factors include conventional and monotonous teaching methods, limited learning tools or inadequate facilities, difficulties in translating problems into mathematical models, and students' challenges in visually illustrating three-dimensional concepts (Kusumawardani et al.,2018; Rezky et al.,2022). Additionally, using outdated or inappropriate teaching approaches, models, and strategies further hampers students' understanding and numeracy literacy (Kusumawardani et al., 2018; Kosasih & Jaelani, 2020).

One effort to improve mathematics learning in Indonesia is encouraging educators to design learning activities that help students better understand mathematical concepts (Warsito et al., 2019). In line with this, according to Nursyahidah et al. (2020) support this, stating that well-designed learning activities and adjusted teaching methods can enhance student understanding of three-dimensional geometry.

A learning design, or learning trajectory, is a structured method for designing, developing, and evaluating interventions such as programs, strategies, and materials for learning activities (Prahmana, 2017). It involves a series of student activities aimed at solving learning challenges, improving the quality of education, and achieving the desired learning outcomes (Nurhusain & Hadi, 2021). Therefore, a well-crafted learning design and appropriate teaching approach are essential for teaching geometry in a three-dimensional space.

One effective approach for this study is the Indonesian Realistic Mathematics Approach (PMRI), which is well-suited for using the context of a futsal field to teach the position of points, lines, and planes in three-dimensional space. PMRI links mathematical concepts to real-life situations, helping students discover solutions through familiar contexts, ultimately improving their understanding (Rahmayani et al.,2021). Nova, Retta, and Nopriyanti (2022) further support this, noting that using real-life contexts in learning can make education more objective and accessible for students. In this study, the futsal field is used as a real-world context, leveraging objects in the field to support the achievement of learning objectives.

This research adopts the PMRI approach to guide the design of a learning trajectory for teaching the position of points, lines, and planes in three-dimensional space. In learning three-dimensional geometry, students need the ability to visualize and reason spatially, which helps them grasp the material (Ng et al., 2020). Given the rapid development of information and communication technologies, which are rooted in mathematical advancements (Artmann et al., 2023). This study aims to update traditional learning processes by incorporating digital teaching materials based on augmented reality.

Augmented reality (AR) is a technology that integrates 3D graphical data with both the real and virtual worlds (Herman et al., 2023). It is defined as a technology that merges two-dimensional or three-dimensional virtual elements and projects them into the real world (Hanan et al., 2018). The interactive nature of AR and its mobile-based application makes it effective for enhancing the understanding of 3D concepts, promoting quality learning, and improving efficiency (Auliya, 2018). Learning designs that incorporate AR are expected to aid students in grasping three-dimensional concepts and visualizing geometry in three-dimensional space through smartphones (Listiawan, Hayuningrat, & Anwar, 2017). As technology advances, students are increasingly vulnerable to receiving overwhelming information (Artmann et al., 2023). Thus, the use of AR in learning is intended to enhance students' comprehension of position material in three-dimensional space and improve their numeracy literacy, specifically in interpreting symbols and translating problem statements into mathematical models.

Numeracy literacy refers to the knowledge and skills required to use various numbers and symbols related to basic mathematics to solve practical problems in daily life (Han et al., 2017). It is also defined as the ability to analyze information and solve problems related to the position in three-dimensional space (Rachmawati, 2022). According to Nursyamsudin and Jaelani (2021) numeracy literacy involves logical, systematic reasoning using learned concepts and knowledge, along with the skills to organize and process information. Several factors contribute to the low numeracy literacy of students, including inadequate learning designs, limited mastery of three-dimensional geometry, and students' struggles to use numbers, symbols, and terms in geometry (e.g., graphs, diagrams, and tables). Additionally, students have difficulty interpreting problems into mathematical models due to the continued use of conventional learning methods (Lestary & Hamdu, 2022). Numeracy literacy is crucial for improving students' cognitive abilities, and it is essential that students develop this skill to effectively gather and process information (Haerudin, 2018). To address this, the researchers have revamped the conventional learning process, introducing a structured learning trajectory design with augmented reality to improve numeracy literacy.

Numeracy literacy indicators used in this study include: the ability to use various numbers and symbols to solve problems in different everyday contexts; the ability to analyze information presented in various formats, such as graphs, tables, and charts; the ability to interpret analytical results for making predictions and drawing conclusions (Akmalia, 2023; Lamada et al., 2019; Salvia et al., 2022)

These indicators align with the study's objective: to assess students' numeracy literacy skills after implementing AR-based learning to visually illustrate the position of points, lines, and planes in three-dimensional space. According to studies by Safuwan et al., (2022) and Nisa and Ramlah (2023), numeracy literacy skills can be categorized into high, medium, and low levels. High numeracy literacy skills means that students meet all the indicators. Medium numeracy literacy skills means that students meet two out of three indicators. Low numeracy literacy skills means that students meet only one of the three indicators.

Several prior studies are relevant to the present research, including “Learning Design of Lines and Angles Using the Context of Reed Fences in Class VII," which aimed to create a learning trajectory that helps students understand line and angle concepts using real-world contexts (Widiawati & Dodi, 2018). "Learning Design of Fraction Material Using PMRI Approach in Class VII," which produced a learning trajectory using the PMRI approach to assist students in understanding the concept of consecutive fractions (Zabeta, Hartono, & Putri, 2015). "The Effect of Augmented Reality on Digital Numeracy Literacy Skills in Mathematics Learning for Grade V Students," which examined the impact of AR media on students' digital numeracy literacy in mathematics (Jannah & Oktaviani, 2022).

Building on previous research that explores augmented reality technology in mathematics learning design, this study aims to design a student learning trajectory using AR technology based on numeracy literacy for position material in three-dimensional space in class XII. The goal is to develop a learning trajectory for position material in three-dimensional space using AR and to assess students' numeracy literacy skills after applying AR-based learning.

## METHOD

This research employs a design research validation study. According to Gravemeijer & Van Eerde, design research is a method that addresses complex problem-solving in educational applications or validates theories related to the learning process, learning environment, and similar aspects (Prahmana, 2017). This aligns with Plomp, who states that design research is a systematically designed method aimed at formulating solutions to problems in educational practice. It involves designing, developing, and evaluating various educational components, such as learning programs, learning processes, learning environments, teaching materials, learning products, and learning systems (Putrawangsa, 2018).

This study specifically uses the validation study type of design research. According to Putrawangsa (2018), a validation study involves developing, validating, designing, and evaluating educational interventions based on a theory related to the learning process and the learning tools designed to support it. The research subjects were XII-grade students from high schools (SMA/MAN) in Palembang City.

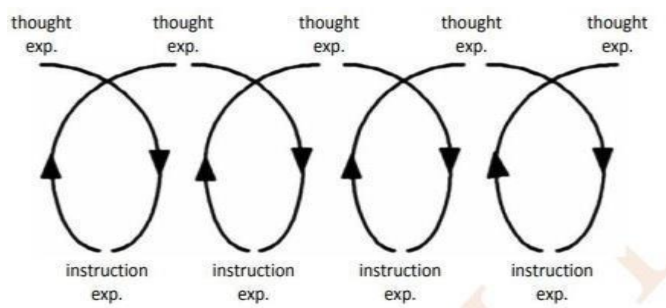



Figure 1. Design Research Procedure

There are three stages in the implementation of this research design research according to Gravemeijer & Cobb in (Putrawangsa, 2018) there are three stages in the implementation of this design research: preparation, design experiment, and retrospective analysis.

### *Preparing for the Experiment*

This stage involves designing an initial Hypothetical Learning Trajectory (HLT), creating Learner Worksheets (LKPD), preparing augmented reality materials, and conducting expert reviews. The initial HLT includes hypotheses or conjectures related to students' cognitive processes, comprising three components: student learning objectives, student learning activities, and hypotheses about the students' learning processes (Fauzan et al., 2020). The outcome of this stage is a set of learning activity designs intended to achieve the learning objectives at each stage, along with conjectures regarding the learning trajectory towards achieving Design Experiment.

***Design Experiment***

In the second stage, researchers test the learning activities designed in the previous stage. This stage consists of two cycles: the pilot experiment and the teaching experiment.

a. Pilot Experiment: This involves testing the designed HLT with a small group of six students of varying abilities. The goal is to gather data to adjust the initial HLT before moving on to the teaching experiment. At this stage, researchers carefully observe the process for revising the HLT to ensure it is well-targeted and capable of achieving the learning objectives.
b. Teaching Experiment: This stage tests the revised HLT design under real classroom conditions to determine whether the anticipated conjectures occur. The teaching experiment collects data about students' responses to the HLT design during each activity, which is then used to develop Local Instructional Theory (LIT). LIT is the final product of the HLT, which has been revised and evaluated based on the learning activities to ensure the achievement of the learning objectives. During this process, conjectures can be modified to revise the HLT for future activities. This is because conjectures can be modified during the learning process as revisions to the HLT for subsequent activities, provided the learning objectives have not yet been achieved.

***Retrospective Analysis***

The third stage aims to develop Local Instructional Theory (LIT) and evaluate the learning outcomes from the implemented activities. At this stage, the initial HLT is analyzed compared to the Actual Learning Trajectory (ALT). The ALT reflects the actual learning path taken by the students, and this analysis serves as a basis for revising the HLT for future activities. After conducting the design experiment, the data obtained from the learning activities is analyzed retrospectively to make revisions if the learning objectives have not been met. (Prahmana, 2017; Sukirwan et al., 2022).

The data analysis technique in this research involves comparing the observations made during the learning process with the HLT. Four data analysis techniques are used:

a. Observation Data Analysis: Data collected during the "preparing for the experiment" stage is analyzed to inform revisions to the designed HLT.
b. Interview Data Analysis: Data obtained during the pilot experiment, including student interviews and teacher responses, is analyzed. This helps determine whether the designed HLT is appropriate. Based on the analysis, the initial HLT is revised to create a more practical version for the teaching experiment stage.
c. Test Data Analysis: Data from the initial ability test (conducted before the pilot experiment) is analyzed to help plan the initial HLT. Additionally, test data from the ability test conducted after the teaching experiment is analyzed to evaluate the student's learning outcomes after using the HLT for a position in three-dimensional space. During the retrospective analysis, the HLT is compared with the learning actions in the teaching experiment (ALT). This comparison investigates how students developed an understanding of position in three-dimensional space.
d. Documentation Data Analysis: Documentation data is analyzed to assess whether the conjectures in the HLT design were anticipated in the field. This data is used as a basis for revising the HLT.

## RESULT AND DISCUSSION

This research focuses on the position of a point relative to another point, a point to a line, a point to a plane, and a line to a plane in three-dimensional space. The research aims to describe the Hypothetical Learning Trajectory (HLT) learning design, leading to developing a Local Instructional Trajectory (LIT) based on numeracy literacy. Data collection was conducted during the second semester of the 2023/2024 academic year.

### *Preparing for the Experiment*

The initial HLT design was developed at this stage before being tested in the pilot experiment. The process began with researchers conducting a literature review to deepen their understanding of position concepts in three-dimensional space. Learning objectives were selected by reviewing the latest syllabus for compulsory mathematics for grade XII in senior high school (SMA/MAN). This review helped formulate the planned problem, ensuring that a series of learning trajectories could be achieved. The learning objectives, indicators, and basic competencies were established as part of the initial HLT design (see Table 1).

Table 1. Basic Competencies and Indicators

| Basic Competencies | Indicator | Learning Objectives |
|---|---|---|
| 3.1. Describe distances in space (between points, points to lines, and points to planes).<br>3.2. Determine distances in space (between points, points to lines, and points to planes). | a. Understand the concept of three-dimensional geometry.<br>b. Identify the elements of three-dimensional space (positions of points, lines, and planes).<br>c. Determine the positions of points, lines, and planes in three-dimensional geometric objects.<br>d. Solve problems involving the positions of points, lines, and planes in three-dimensional space based on numeracy literacy. | 1. Students can understand and identify the concept of the positions of points, lines, and planes in three-dimensional space.<br>2. Students can describe and determine the positions of points, lines, and planes in three-dimensional geometric objects.<br>3. Based on numeracy literacy, Students can solve problems involving the positions of points, lines, and planes in three-dimensional space. |

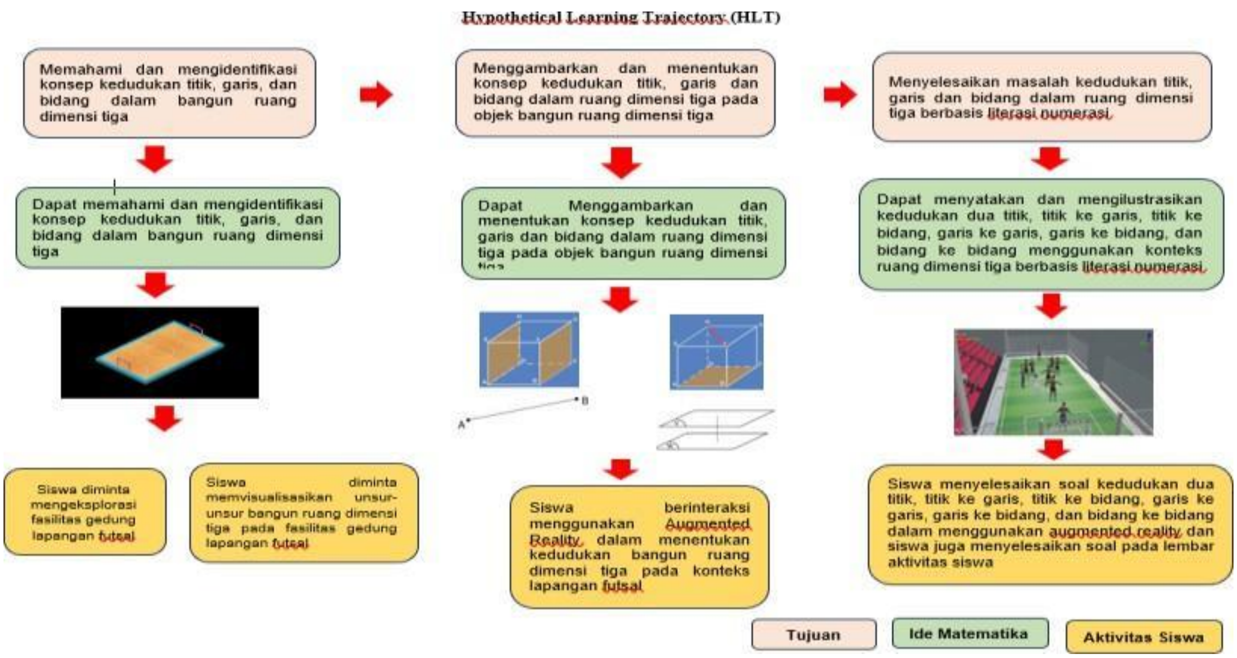



Figure 2. Initial HLT Design

Then, an HLT design and an iceberg model were developed, consisting of three activities using the context of a futsal field as shown in Figure 2 and 3. The use of the futsal field, which is familiar to students, can enhance their understanding, as incorporating contexts that are close to students' experiences provides a concrete, real-world application in learning. The futsal field serves as a context for objects that support the successful achievement of learning objectives (Nova, Retta, & Nopriyanti, 2022). Therefore, this research uses the context of the futsal field to design learning activities on the topic of positions in three-dimensional space for Grade XII students of SMA/MAN.

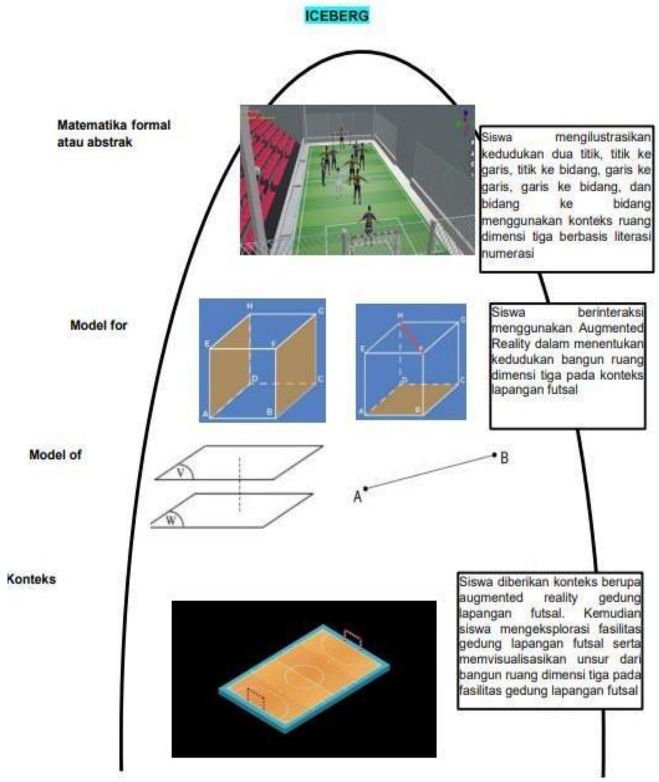



Figure 3. Early iceberg

Subsequently, the researcher developed the Learner Worksheet (LKPD), which contained a series of activities aligned with the designed HLT, including several numeracy literacy-based questions. During the "preparing for the experiment" stage, an expert review was also conducted with specialists, resulting in suggestions to further improve the HLT. One such improvement involved Activity 1, where the original conjecture used a 3D design in the form of a picture. After the expert review, it was revised to use a real-world context—specifically, a futsal field. Taking into account the validators' suggestions, the researchers made revisions to both the HLT and the iceberg model that had been previously validated. Below are the HLT and iceberg designs after the expert review with the validators.

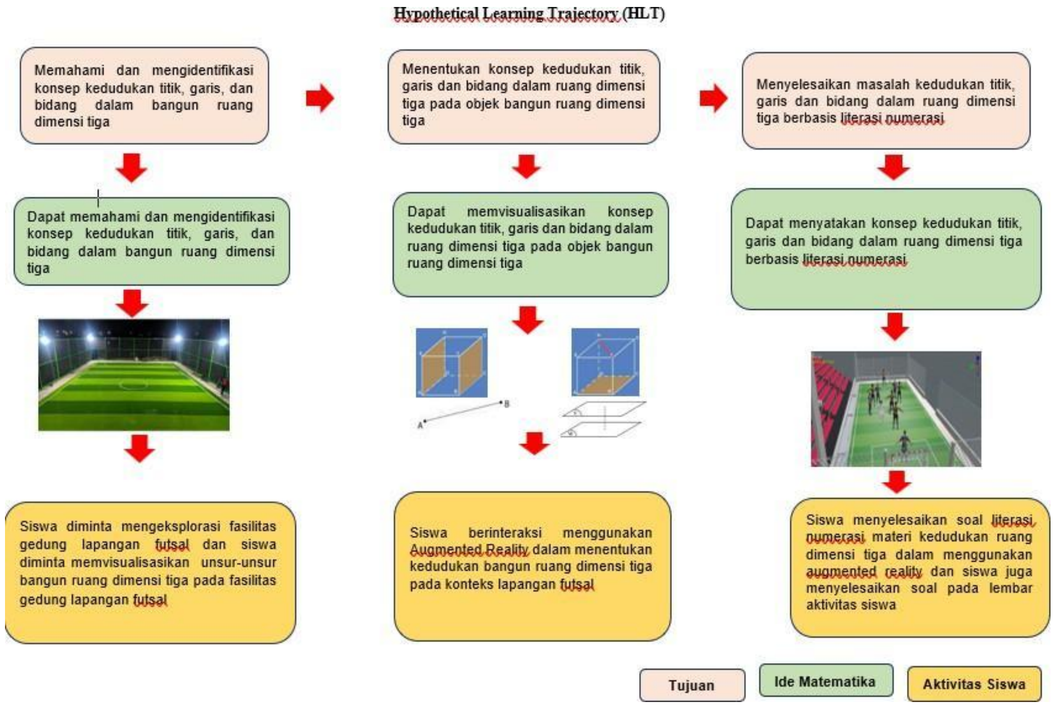



Figure 4. Improved HLT

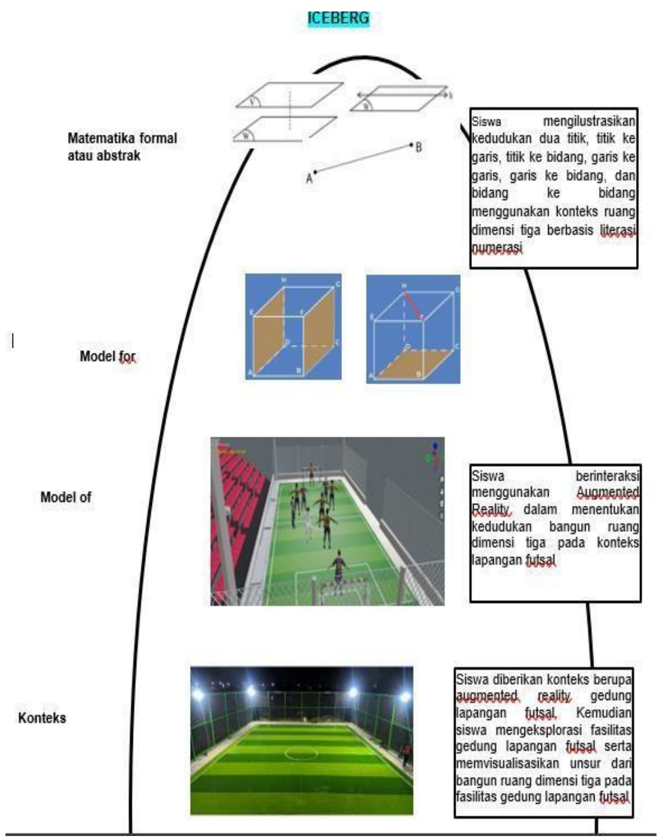



Figure 5. Iceberg After Expert Review

***Design Experiment***

This stage was started by conducting pilot experiment. The piloting was conducted with a small group of six students with varying abilities. The purpose was to collect data and adjust the initial HLT before proceeding to the teaching experiment stage. Researchers paid close attention to the process, using it as a basis for revising the HLT to ensure it effectively achieved the learning objectives.

Before conducting the pilot experiment with the Learner Worksheet (LKPD), the researcher first carried out an Initial Ability Test (TKA) to assess student's prior knowledge on the topic of positions in three-dimensional space. The TKA included one introductory description question on prerequisite material that students were expected to have already mastered, which was related to three-dimensional geometry, as well as two description questions on the topic of positions in three-dimensional space. The results of the TKA showed that most students understood the prerequisite material, but many had difficulty grasping the concept of position in three-dimensional space. In addition, students struggled to distinguish between the elements of a three-dimensional figure and those of a two-dimensional shape.

Following this, the LKPD was tested in the pilot experiment, marking the first stage of the design experiment before moving to the next stage, the teaching experiment. In the pilot experiment, the HLT and LKPD on positions in three-dimensional space were tested with a small group of six grade XII students. The researcher distributed the LKPD to each student and provided brief instructions on how to complete it using augmented reality. The LKPD contained activities designed to help students understand the concept of position in three-dimensional space through the context of a futsal field.

The researcher also interacted directly with the students by asking them questions about the activities, observing their understanding, and identifying any difficulties they encountered while working on the LKPD.

Based on the results of the pilot experiment on the second LKPD activity, students were asked to determine positions in three-dimensional space during a scenario where a player kicks the ball towards the goalpost. Through this activity, students learned the concepts of point position on a plane and on a line. Below are the results of students' answers for the second activity:

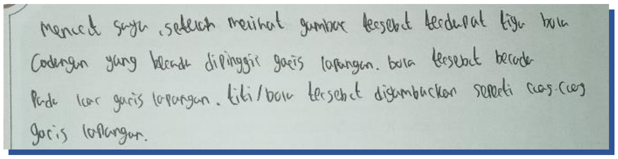
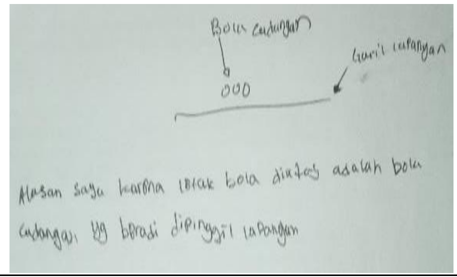
| AP’s Answer | MMD’s Answer |
|---|---|
|   |   |

Figure 6. Comparison of Student Answer Results Activity 2

Based on Figure 6, comparing the answers from two students, AP and MMD, it can be seen that AP's responses align with the conjecture of the learning trajectory that the researcher previously established, indicating that the position of the spare ball is outside the line. In contrast, MMD's answer did not align with the researcher’s conjecture; he misunderstood the provided information, leading him to incorrectly illustrate the ball's position relative to the goal line. This feedback highlights areas for improvement and revision for the researcher as they proceed to the teaching experiment stage.

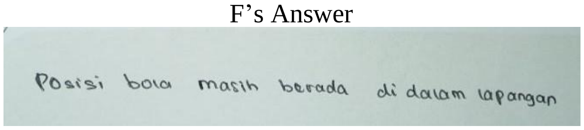
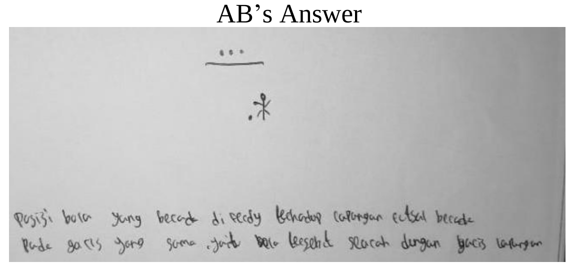
| F’s Answer | AB’s Answer |
|---|---|
|   |  |

Figure 7. Student Answer Results Activity 3

Based on Figure 7, the comparison of the answers from students F and AB reveals that a similar situation occurred in the third activity. Student F's responses align with the learning trajectory previously established by the researchers, as he accurately stated the ball's position about the futsal field based on the augmented reality visualization of the futsal game and the provided information. In contrast, student AB's answers did not align with the thinking conjecture or learning trajectory the researchers had designed earlier. This feedback provides the researchers an opportunity to improve as they proceed to the teaching experiment stage.

***Retrospective* Analysis Pilot Experiment**

After completing the pilot experiment stage, the next step is the retrospective analysis, which compares the student learning trajectory (HLT) previously designed with the actual learning trajectory (ALT) condition. This comparison helps determine whether the learning objectives of the initial HLT were achieved. The retrospective analysis for the pilot experiment stage was conducted in collaboration with our supervisor. Below are the results of the HLT and ALT data comparison analysis:

Table 2. Student Thinking Conjecture

| Number | Activity | HLT | ALT |
|---|---|---|---|
| Activity 1 | In this activity, students explore the elements of spatial design related to the facilities in the futsal field building. | 1. Students can explore some facilities in the futsal court building.<br>2. Students cannot explore some facilities in the futsal court building.<br>3. Students can identify the elements of three-dimensional space in the futsal court building.<br>4. Students cannot identify the elements of a three-dimensional building in the futsal court.<br>5. Students can write a conclusion for the activity that has been completed.<br>6. Students cannot write a conclusion for the activity that has been completed. | 1. Students identify the elements of building space.<br>2. Students identify types of spatial figures, including flat and curved figures.<br>3. Students provide conclusions on the activities that have been carried out. |
| Activity 2 | Students determine the statement that matches the picture on the LKPD based on the ball movement during the game in the futsal field building. | 1. Students can write down the ball's displacement during the game to determine its position in three-dimensional space.<br>2. Students cannot write down the ball's displacement during the game, making determining the position in three-dimensional space difficult.<br>3. Students can conclude from the results of the activities that have been carried out.<br>4. Students cannot conclude from the results that have been obtained. | 1. Students determine the position of the reserve ball on the sidelines.<br>2. Students determine the position of the reserve ball relative to the sideline by illustrating it as a picture.<br>3. Students do not understand the meaning of several statements in Activity 2 regarding the position of facilities related to the futsal field, such as the ABCD field, the ball as point X, the lamppost as line PQ, and the goalpost as line BC.<br>4. Students write conclusions about several activities that have been carried out. |
| Activity 3 | Students complete the questions on the LKPD based on numeracy literacy. | 1. Students can state their position in the futsal field according to the information provided.<br>2. Students make mistakes in analyzing the questions, preventing them from stating their position on the futsal field. | 1. Students provide a few reasons to support the previous statement, and then they conclude the prior activity.<br>2. Students observe the AR of the futsal field building and, using picture illustrations, determine the position of the spare ball relative to Ferdy.<br>3. Some students cannot conclude from the results of the activities they have completed. |

The next stage is teaching experiment. The testing stage of the teaching experiment aims to determine whether the anticipated conjecture will occur in the field. After revising the results of the retrospective analysis, the teaching experiment stage was conducted to test the revised HLT in actual classes. Before carrying out the LKPD trial at the teaching experiment stage, an Initial Ability Test (TKA) was administered to 26 class XII students. From the three questions given in the TKA, it was found that most students understood the prerequisite material. However, some students still struggled with the concepts related to three-dimensional shapes and their positions. Therefore, a trial of the LKPD at the teaching experiment stage was conducted with the 26 class XII students, who were divided into four groups, each consisting of 5 to 6 students.

Based on the results of the teaching experiment in the third activity, students were asked to write conclusions based on the first activity, where they determined the position of the ball against the futsal field through augmented reality. In the second activity, students were asked to position the ball that bounced against the futsal field. The conjectures or student learning trajectories in the third activity, which the researchers had previously established, occurred during the teaching experiments in each group. Students were able to provide conclusions related to the differences between the position of the ball against the futsal field in the first and second activities. The following are the results of an interview conducted by the researchers with one of the students from Group 2 during the third activity:

Activity 3 determines the position in three-dimensional space

Researcher : *Why does group 2 state that the position of the ball in Activity 1 and Activity 2 is different?*

Student : *Yes! If position number 1 is the ball is in the field. Well, number 2 would be outside the field.*

Based on the results of student conversations, he can determine the difference between the ball's position in the first and second activities and draw conclusions based on their activities. Therefore, it can be concluded that the learning objectives for the teaching experiment phase have been achieved.

***Retrospective Analysis Teaching Experiment***

Based on the implementation of teaching experiments shows that students can carry out the learning activities that the researchers had previously designed. In the teaching experiment, students in Groups 1 and 2 both understood the material regarding positions in three-dimensional space well. The results from Groups 3 and 4 also indicate that they could grasp the material related to determining the position of three-dimensional shapes. However, there were several errors in solving the questions on the LKPD, particularly in Activities 2 and 3. Despite this, the conjecture regarding students' thinking processes, which had been designed previously, could be achieved, and the learning activities proceeded well according to the revised HLT. Therefore, it can be concluded that, based on these results, the HLT design has been implemented effectively in all four groups in Class XII, meeting the researchers' expectations, and is thus worthy of being used as a Local Instruction Theory (LIT). Below is the HLT that has been achieved in the teaching experiment phase, making it suitable to serve as a Local Instruction Theory (LIT):

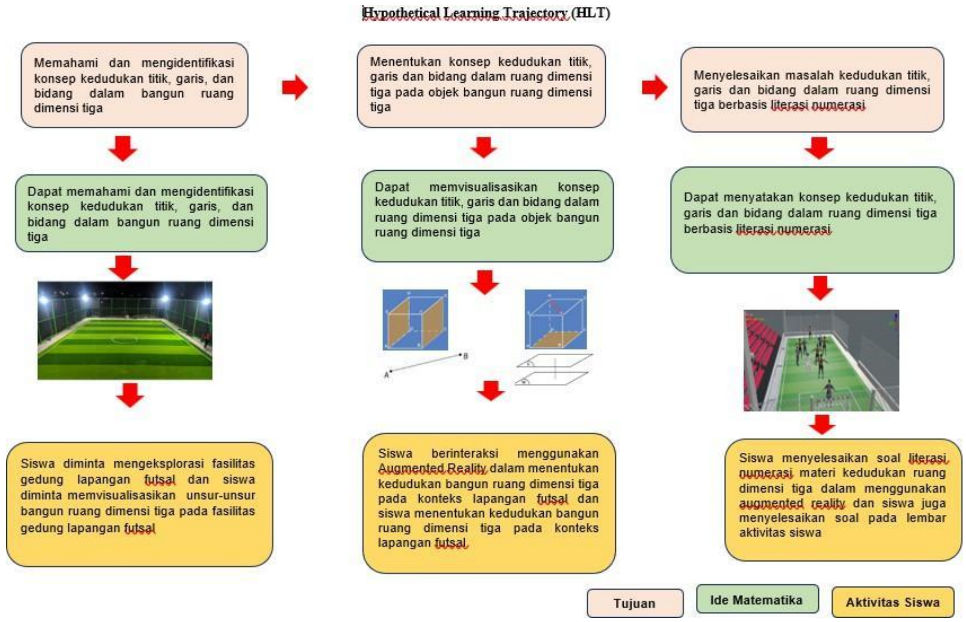



Figure 9. HLT After Teaching Experiment

Based on the results of the research that has been carried out it is in line with the study by Widiawati and Dodi Marzal (2018), which states that engaging students in a variety of learning activities and encouraging direct interaction or visual aids will help them better understand the learning material. Thus, this aligns with the findings of previous research by Widiawati and Dodi Marzal (2018). The difference between this research and the previous relevant studies lies in the sub-material used and the context applied to build students' understanding. In this research, the material focuses on spatial geometry, specifically the sub-material of position in three-dimensional spatial shapes. At the same time, the context employed involves futsal field building and augmented reality technology to enhance students' understanding and numeracy literacy skills.

***Achieving Numeracy Literacy***

Based on interviews and observations conducted by researchers with mathematics teachers at the school, the level of numeracy literacy skills among students is still relatively low. The school also organized literacy activities before learning commenced, which helped to engage students during the research as they showed interest in working on activities that contained questions based on numeracy literacy. The following are the results of the interviews conducted by researchers with the mathematics teachers at the school:

Interview conversation with mathematics teacher:
Researcher : *What about the numeracy literacy skills of students at this school, ma'am?*

Teacher : *Students' numeracy literacy skills are currently still relatively low, and schools are even making efforts to improve them by holding joint literacy activities every morning before learning begins.*

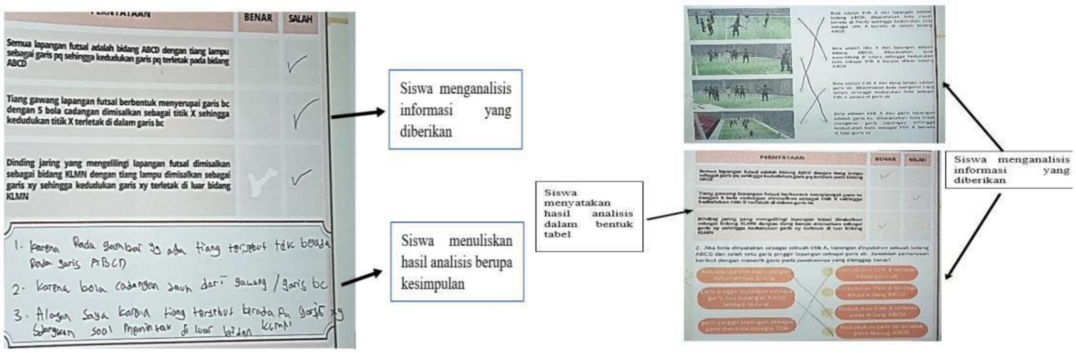



Figure 11. Literacy Numeracy Results of Student Answers

Based on the results of the trial stages that have been conducted, it can be seen in Figure 11 that the activities the students have carried out indicate that many of their numeracy literacy skills have been fulfilled, particularly in indicators 2 and 3. This aligns with research conducted by Sudirman (2017), which found that students classified as low performers often struggle with each indicator. At the teaching experiment stage, students' numeracy literacy abilities were still relatively moderate; however, several learning activities were completed well, resulting in a significant number of numeracy literacy indicators being met, specifically indicators 2 and 3. Thus, it can be concluded that numeracy literacy abilities improved from the pilot experiment stage to the teaching experiment stage, although students' numeracy literacy skills remained moderate at both stages.

According to Kurniawaty, Makmuri, and Meiliasari (2023), learning by connecting everyday life to formal mathematics can help form conjectures about students' thinking, which is then implemented as a problem-solving process. This interaction occurs not only between educators and students but also among students through discussion activities. Therefore, implementing the learning design encourages students to engage actively in discussions with group members, fostering a strong interaction between researchers and students. The success of the learning process is by how educators provide guidance for learning (Wibawa, 2022).

## CONCLUSION

Based on the research stages that have been carried out, the results obtained from the learning design of position material in three-dimensional space, based on numeracy literacy with augmented reality, using the context of a futsal field building, show that it can support students' understanding of position material in three-dimensional space for class XII SMA/MAN through various activities in the augmented reality application and the Learner Worksheet (LKPD).

From the implementation of the research, it is evident that there was development in the comparison between the pilot and teaching experiments. Initially, three students answered outside the conjecture that the researchers had previously designed. However, during the teaching experiment stage, although there were several errors in solving the questions on the LKPD—especially in activities 2 and 3—the conjecture regarding students' ways of thinking that had been designed earlier was achieved, allowing the learning activities to proceed well under the HLT.

Therefore, it can be concluded that among the four groups in class XII, the HLT design has been implemented effectively according to the researchers' expectations, making it suitable for use as a Local Instruction Theory (LIT).

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