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From Oral Assessment Findings to Digital Intervention: AI-Assisted Development of an Interactive Cartesian Coordinate Learning Application

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Abstract
Many university students continue to experience difficulties in understanding the Cartesian coordinate system, particularly in identifying coordinate points, distinguishing axes, determining quadrants, and interpreting coordinate movement. These difficulties emerged from an oral assessment conducted within a vector-related mathematics examination, in which students' responses indicated weaknesses in prerequisite Cartesian coordinate concepts. Therefore, this study aims to develop an interactive Cartesian coordinate learning application through an AI-assisted development process as a digital intervention to address these conceptual difficulties. The study also seeks to demonstrate how diagnostic findings from oral assessment can be translated into a targeted instructional solution that supports visualization and active learning. This study employed an initial cycle of Design-Based Research consisting of four stages: problem identification, formulation of instructional design requirements, application development, and initial evaluation. The application was developed as an HTML-based interactive learning environment, with generative AI used to support the design and coding process. Following development, the same 50 students independently used the application, and their responses were collected through a questionnaire. The initial evaluation suggests that the application provided a structured and engaging learning experience that supported students in visualizing coordinate movement and understanding relationships among axes, points, and quadrants. These findings indicate that AI-assisted application development can support the creation of targeted digital interventions in mathematics learning. The study further highlights the importance of grounding instructional design in students' actual learning difficulties.

Keywords: AI-Assisted Development, Cartesian Coordinate System, Digital Intervention, Interactive Learning Application, Oral Assessment

Introduction

Sustainable Mathematics plays an essential role in developing logical reasoning, analytical thinking, and problem-solving abilities. One foundational topic is the Cartesian coordinate system, which supports the understanding of geometry, functions, graph interpretation, and vector representation. Learning Cartesian coordinates requires students to connect symbolic information, such as ordered pairs, with spatial positions on a plane. From a cognitive perspective, this connection involves conversion between semiotic representations, a process that is central to mathematical understanding but can also become a source of learning difficulty (Duval, 2006).

Difficulties in coordinate representation may appear when students identify ordered pairs, distinguish horizontal and vertical axes, determine quadrants, or interpret movement on the Cartesian plane. These weaknesses are important because they can interfere with students' engagement in more advanced visual and spatial topics, including graphical vector representation. Prior research has also shown that mathematical misconceptions often persist when foundational concepts are not fully understood (Jamaludin & Maat, 2020).

Identifying such difficulties requires assessment approaches that reveal how students reason, not merely, whether their final answers are correct. Oral assessment allows instructors to probe students' explanations, observe hesitation and representational confusion, and obtain richer evidence of conceptual understanding than static written responses alone (Theobold, 2021; Hankeln et al., 2025). In this study, difficulties related to Cartesian coordinates emerged during an oral examination on vector-related tasks, where students were required to represent mathematical ideas graphically. These findings were treated as diagnostic evidence for designing a targeted instructional intervention.

Digital learning environments offer opportunities to support mathematics learning through visualization, interaction, and structured practice. Meta-analytic evidence suggests that digital tools can contribute positively to mathematics learning when their design is aligned with the learning task and pedagogical purpose (Hillmayr et al., 2020). Interactive digital learning activities can also encourage students to engage actively with mathematical processes and revise their responses through structured interaction (Barana et al., 2021). At the same time, the growing use of artificial intelligence in education creates opportunities to support the development of digital learning interventions, if its use remains pedagogically grounded and connected to actual learning needs (Zawacki-Richter et al., 2019; Govender, 2025). However, the value of such digital interventions depends on whether they are designed in response to specific learning difficulties rather than developed as general-purpose technological tools.

Therefore, this study aims to develop an interactive Cartesian coordinate learning application through an AI-assisted development process based on findings from oral assessment. Specifically, it seeks to identify students' conceptual difficulties in Cartesian coordinate understanding, translate these findings into instructional design requirements, develop a targeted digital intervention, and conduct an initial evaluation of students' responses to the application.

Review of Related Literature

A growing body of research highlights the importance of addressing students' conceptual difficulties in mathematics through targeted digital interventions. Duval (2006) emphasizes that comprehension challenges often stem from the need to convert between semiotic representations, a process central to understanding Cartesian coordinates. Misconceptions in foundational topics, such as ordered pairs and quadrants, can persist and hinder advanced learning (Jamaludin & Maat, 2020). Oral assessment has been shown to provide richer diagnostic evidence of students' reasoning, capturing hesitation and representational confusion more effectively than written responses (Theobold, 2021; Hankeln et al., 2025).

Digital learning environments offer promising avenues to support these needs. Meta-analytic findings confirm that well-designed digital tools can enhance mathematics learning when aligned with pedagogical goals (Hillmayr et al., 2020). Interactive feedback mechanisms foster active engagement and iterative improvement in mathematical reasoning (Barana et al., 2021; Smit et al., 2023), while outdoor and contextualized digital feedback further enrich learning experiences (Jablonski, 2024). The integration of artificial intelligence into education has been widely explored, with systematic reviews noting its potential but stressing the importance of pedagogical grounding (Zawacki-Richter et al., 2019). Govender (2025) underscores that contextual factors and resource availability must be considered when implementing AI-based tools in mathematics education.

Recent design-based research studies (Reilly & Reeves, 2023; Richardson et al., 2025; Sathya & Alamelu, 2026) demonstrate how digital competence and transdisciplinary approaches can strengthen instructional design and teacher practice. Collectively, these studies suggest that AI-assisted, interactive applications tailored to diagnostic findings—such as those from oral assessments—can effectively address specific learning difficulties in Cartesian coordinates and contribute to deeper mathematical understanding.

Objectives

The objectives of the article are to identify students' difficulties in Cartesian coordinate representation through oral assessment and to analyze misconceptions related to ordered pairs, axes, quadrants, and movement on the plane. It seeks to connect semiotic representations between symbolic information and spatial positions, while using oral examination as diagnostic evidence of conceptual understanding. The study aims to translate assessment findings into instructional design requirements and develop a targeted digital intervention addressing specific learning difficulties. It emphasizes the integration of visualization and interaction into the learning application and the application of AI-assisted development in creating the interactive Cartesian coordinate tool. Finally, the study intends to evaluate students' responses to the application during initial implementation and to contribute to mathematics learning by aligning digital tools with pedagogical purpose.

Methodology

Research Design and Participants

This study employed an initial cycle of Design-Based Research (DBR) to develop an interactive Cartesian coordinate learning application through an AI-assisted development process. DBR was selected because the study aimed to address an educational problem identified in an authentic learning context and translate it into a targeted instructional intervention. The research process consisted of four interconnected stages: (1) problem identification through oral assessment, (2) formulation of instructional design requirements, (3) AI-assisted application development, and (4) initial evaluation of the developed application (Reilly & Reeves, 2023; Richardson et al., 2025; Sathya & Alamelu, 2026). The overall research process is presented in Figure 1.

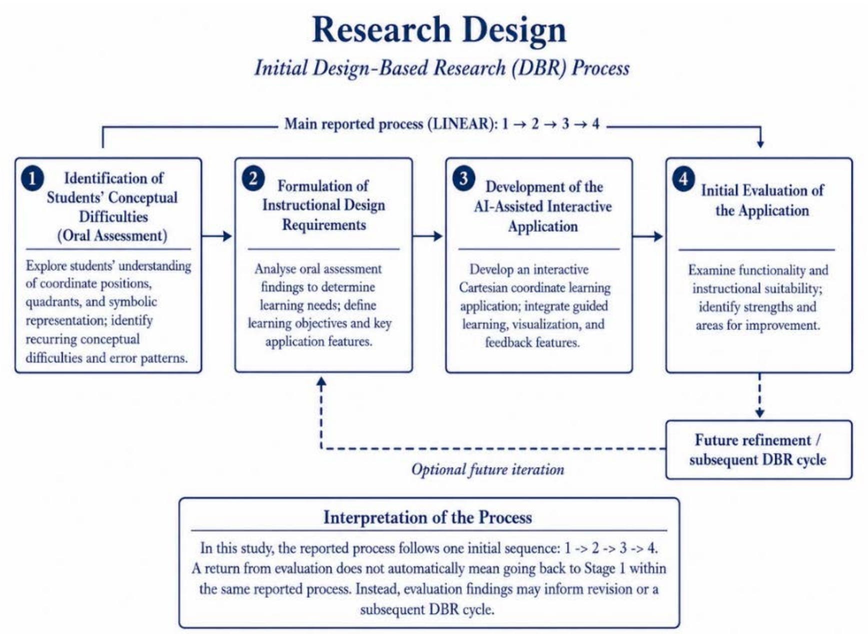

Figure 1. Initial Design-Based Research Process of the Study

A total of 50 university students from an engineering programme participated in this study. These students had previously encountered Cartesian coordinate concepts in earlier mathematics learning, making them relevant participants for examining persistent difficulties in coordinate understanding. The same group was involved in both the initial problem-identification stage and the initial evaluation of the developed application.

Analysis

Oral Assessment-Based Problem Identification

The initial learning problem was identified from an individual oral examination conducted as part of a mathematics course assessment. The examination focused primarily on vector-related concepts. During the assessment, each student was questioned directly by the lecturer and asked to explain mathematical ideas, perform calculations, and represent selected tasks graphically. One task required students to determine the result of vector addition and illustrate the vectors on a Cartesian plane.

Although the oral examination was originally administered for classroom assessment purposes, students' responses provided diagnostic information relevant to this study. Because the vector representation task required prerequisite understanding of Cartesian coordinates, the oral responses were subsequently reviewed to identify recurring conceptual difficulties related to coordinate representation. The review focused not only on the final correctness of students' answers, but also on the patterns of hesitation, confusion, and representational errors that appeared during their explanations and graphical work. The recurring patterns identified through this review were then used to formulate the instructional design requirements of the application.

AI-Assisted Application Development

The identified conceptual difficulties were translated into instructional design requirements focusing on students' understanding of: (1) the Cartesian plane and the orientation of the axes, (2) ordered pairs and point location, (3) quadrant positions, and (4) coordinate movement as a basis for interpreting displacement on the plane. These requirements served as the pedagogical foundation for determining the scope, learning flow, and interaction logic of the digital intervention.

Based on these requirements, an HTML-based interactive Cartesian coordinate learning application was developed. Generative AI was used to support the development process, particularly in structuring the interface, generating and refining code, and implementing the planned interaction logic. The use of AI enabled the instructional ideas derived from the oral assessment findings to be translated more efficiently into a functional prototype. In this study, the term AI-assisted refers to the use of AI as a development support tool rather than as an AI tutoring system embedded in the application.

Initial Evaluation and Data Analysis

After development, the same 50 students were asked to use the application independently. Following the activity, students completed a response questionnaire that explored their perceptions of the application in relation to conceptual understanding, engagement, confidence during learning, and usability.

The data were analysed descriptively. Oral assessment responses were reviewed to identify recurring patterns of conceptual difficulty that informed the application design. Supporting oral assessment records, including students' vector-task scores, were used to contextualise the identified learning problems. Students' questionnaire responses were summarised descriptively to examine their perceptions of the application, while open-ended responses were grouped into recurring categories to identify difficulties that remained after using the digital intervention.

Findings and Discussion

Oral Assessment Findings as the Basis for Digital Intervention

The oral assessment conducted in the vector-related mathematics examination revealed that students' difficulties in graphical vector representation were closely connected to weaknesses in prerequisite Cartesian coordinate concepts. During the examination, several students showed uncertainty when locating ordered pairs, distinguishing the horizontal and vertical axes, identifying quadrants, and interpreting coordinate movement on the plane. These difficulties emerged when students were required to explain and draw vectors graphically, indicating that the problem was not limited to vector operations, but also involved foundational spatial and representational understanding.

The distribution of students' scores in the vector oral assessment is presented in Table 1. Among the 50 students, scores ranged from 0 to 100, with a mean score of 59 and a median score of 50. The most frequent score was 50, obtained by 15 students, while 14 students achieved a score of 100. Although these scores were not interpreted as a direct measure of Cartesian coordinate mastery, the variation in performance provided contextual evidence that students differed substantially in their ability to complete graphically oriented vector tasks.

Table 1. Distribution of Students' Scores in the Vector Oral Assessment

Score	Number of Students
0	5
25	8

50	15
75	8
100	14
Total	50

Source: Authors' analysis of oral assessment records

The oral assessment played an important diagnostic role in making students' underlying conceptual difficulties visible. Rather than relying only on numerical scores or final written answers, the oral format allowed the lecturer to observe students' explanations, hesitation, and representational confusion during the vector task. This aligns with previous studies showing that oral responses can provide richer insight into students' conceptual understanding and reasoning processes (Theobold, 2021; Hankeln et al., 2025).

In this study, the oral assessment functioned not only as an evaluation of vector-related performance, but also as a source for identifying prerequisite learning problems in Cartesian coordinate understanding. Students' difficulties in graphical vector representation indicated challenges in coordinating symbolic and spatial representations, consistent with Duval's (2006) view that conversion between representation forms is central to mathematical comprehension. Accordingly, the findings were treated as diagnostic evidence for determining the focus of the digital intervention rather than as a direct measure of overall coordinate competence.

Based on recurring patterns in the oral responses, four central learning difficulties were identified: understanding the orientation of the axes, locating ordered pairs accurately, identifying quadrant positions, and interpreting movement or displacement on the Cartesian plane. These difficulties became the conceptual basis for the application, ensuring that the digital intervention was developed in response to a specific instructional need rather than from a general intention to introduce technology into mathematics learning.

Developed Interactive Cartesian Coordinate Learning Application

Based on the oral assessment findings, an HTML-based interactive Cartesian coordinate learning application was developed through an AI-assisted development process. The application was designed to help students connect coordinate notation with spatial movement by navigating a character toward target points on a Cartesian plane. A visual overview of the application interface and its coordinate-navigation environment is presented in Figure 2.

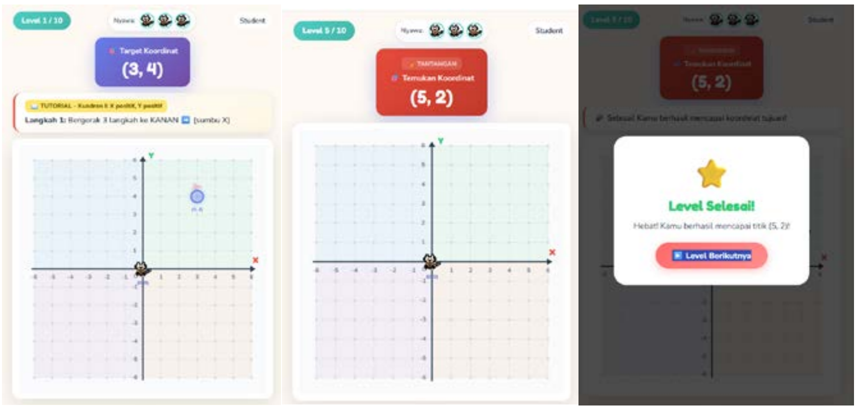

Figure 2. Interface of the Interactive Cartesian Coordinate Learning Application

The application includes guided and challenge-oriented coordinate tasks. In the guided stage, students receive systematic support for moving along the x- and y-directions, while in the challenge stage they determine the required movement independently. Students are presented with target coordinates and must navigate the character across the Cartesian plane until the intended position is reached. An error-sensitive mechanism is also embedded: incorrect movement or movement beyond the intended coordinate reduces students' available lives, encouraging closer attention to coordinate direction, magnitude, and positional accuracy.

The application design directly reflects the diagnostic findings from the oral assessment. Difficulties in distinguishing x- and y-coordinates informed the use of horizontal and vertical movement tasks; difficulties in locating points informed target-coordinate navigation; and difficulties in interpreting movement informed stepwise displacement activities. Through this structure, students do not merely read coordinate information, but actively translate symbolic coordinates into visible movement on the plane. Thus, the application was developed not as a generic mathematics game, but as a targeted intervention, responding to specific conceptual difficulties identified in an authentic assessment context.

This design is consistent with evidence that digital tools are more educationally meaningful when their features are aligned with clear pedagogical purposes and specific learning tasks (Hillmayr et al., 2020). The application's interactive structure allows students to act on coordinate information, observe the consequences of their decisions, and revise their movement when errors occur. Such interaction is aligned with digital mathematics learning approaches that support active engagement and iterative improvement through feedback-informed activity (Barana et al., 2021; Jablonski, 2024).

Generative AI in translating instructional ideas into functional interface elements and interaction logic supported the development process. However, the pedagogical direction remained grounded in the researcher's interpretation of students' oral assessment findings. In this sense, AI functioned as a development support tool rather than as an autonomous instructional agent, consistent with calls for AI use in education to remain context-sensitive and pedagogically grounded (Zawacki-Richter et al., 2019; Govender, 2025).

Students' Initial Responses to the Application

After independently using the application, students completed a response questionnaire. The descriptive results are summarised in Table 2. Overall, students reported positive perceptions across four aspects: conceptual understanding, confidence and persistence, engagement, and usability. As presented in Table 2, the highest mean score was found in usability and clarity ($M = 3.61$), followed by confidence and persistence ($M = 3.53$), conceptual understanding ($M = 3.48$), and engagement ($M = 3.42$).

Table 2. Summary of Students' Responses after Using the Application

Aspect	Mean Score
Conceptual understanding	3.48
Confidence and persistence	3.53
Engagement	3.42
Usability and clarity	3.61

The strongest response appeared in the aspect of usability and clarity. This suggests that students generally perceived the application as understandable and manageable to use. This result is important because the intervention was intended to address concepts that students had previously found confusing in an oral assessment context. If the application interface or task structure had been difficult to follow, the digital medium could have added a new layer of cognitive burden. Instead, the high perception of usability indicates that the application was able to present Cartesian coordinate tasks in a form that students considered accessible. This supports the importance of designing digital mathematics tools whose technical operation does not distract from the conceptual learning objective. Hillmayr et al. (2020) similarly emphasise that the effectiveness of digital tools depends on how appropriately they are integrated with the learning purpose and task structure, not simply on the presence of technology itself.

The second-highest mean score was found in confidence and persistence. This is a meaningful result because students had previously displayed hesitation and confusion during the oral assessment when working with coordinate-related aspects of vector representation. The application has guided movement tasks, repeated attempts, and visible task progression may have helped create a lower-risk space for students to try, make errors, and continue. In digital mathematics learning, persistence can be supported when students receive immediate indications of their actions and have opportunities to revise their responses rather than being positioned only as right or wrong. Barana et al. (2021) argue that interactive feedback can encourage learners to actively close the gap between their current and desired performance. The present finding is also compatible with Jablonski's (2024) observation that feedback indicating an error can stimulate verification and further reasoning rather than merely signalling failure.

The mean score for conceptual understanding was also positive. Students' responses suggest that the application helped them perceive coordinate-related ideas more clearly, particularly through the visualisation of movement on the Cartesian plane. This is consistent with the initial purpose of the intervention: to strengthen the connection between numerical coordinate notation and spatial representation. The finding is conceptually aligned with Duval’s (2006) perspective that mathematical understanding depends on the coordination of different representation systems. By requiring students to translate target coordinates into movement decisions, the application creates opportunities for them to connect symbolic information, spatial position, and directional action. Although this study did not yet measure learning gains through a pre-test–post-test design, the positive perception in conceptual understanding indicates that students experienced the application as supportive of the conceptual difficulties it was intended to address.

The engagement aspect received the lowest mean score among the four aspects, although it remained positive overall. This result should not be interpreted as a weakness of the application, but rather as a useful direction for refinement. The application appears to have been perceived as clear, confidence supporting, and conceptually helpful; however, engagement may be further strengthened through richer task variation, more progressive levels of challenge, expanded feedback, or additional forms of interactive reward. Research on mathematics learning environments suggests that interaction alone does not automatically guarantee sustained engagement; rather, engagement is strengthened when tasks are meaningfully challenging, feedback is informative, and students can actively participate in improving their reasoning (Barana et al., 2021; Smit et al., 2023). Smit et al. (2023), for example, highlight the importance of feedback-rich interaction in supporting mathematical reasoning, suggesting that future iterations of the application may benefit from more elaborated prompts or feedback messages that guide students to reflect on why a movement is correct or incorrect.

The open-ended questionnaire responses further contextualised the quantitative findings. A total of 28 students stated that they no longer experienced major difficulties after using the application. This response is encouraging because it suggests that, for many students, the intervention was perceived as sufficient to reduce the coordinate-related confusion they had encountered earlier. However, several students still reported remaining challenges, including determining points according to instructions, reading points from coordinate images, distinguishing x- and y-values, and identifying quadrants. These remaining difficulties are important because they show that the intervention addressed some aspects of students’ needs while also revealing areas that require further scaffolding.

From a design-based research perspective, these remaining challenges are not merely limitations; they are also valuable inputs for the next cycle of refinement. The initial application was developed in response to diagnosed learning needs and was positively received, but the open-ended responses indicate that some concepts may require representation that is more explicit, additional guided examples, or repeated transitions between symbolic and visual forms. For example, difficulty distinguishing x- and y-values may be addressed through enhanced visual cues and comparison tasks, while difficulty-identifying quadrants may benefit from focused activities that repeatedly connect the signs of coordinates with quadrant positions. Such refinements would strengthen the alignment between the application’s instructional features and the specific misconceptions or uncertainties that persist among students.

The overall findings therefore suggest that the application functioned as a promising initial intervention. It was perceived positively across all measured aspects and appeared to respond meaningfully to the coordinate-related difficulties that informed its development. At the same time, the findings should be interpreted within the scope of an early DBR cycle and a perception-based initial evaluation. The results support the feasibility and instructional relevance of translating oral assessment findings into a targeted digital learning application, but they do not yet establish causal effectiveness in improving students' mathematical achievement. Future empirical testing is needed to determine whether the application leads to measurable improvements in coordinate understanding and transfer to vector representation tasks.

Limitations and Future Research

Despite these promising initial findings, this study has several limitations. First, the study focused on a single group of 50 students from one university learning context, which limits the generalisability of the findings. Second, the evaluation was based primarily on students' perceptual responses after using the application and did not yet include a pre-test–post-test comparison or an experimental design to examine learning gains more rigorously. Third, the application was developed to address coordinate-related difficulties identified during a vector-related oral assessment, so its effectiveness for broader Cartesian coordinate learning contexts still requires further investigation.

Future research may extend this study by involving larger and more diverse student groups, conducting experimental or quasi-experimental evaluations, and examining the application's effects on students' conceptual understanding and transfer to vector representation tasks. Further development may also explore iterative refinement of the application based on students' remaining difficulties, as well as more advanced AI-supported design processes for creating targeted mathematics learning interventions.

Conclusion

This study developed an interactive Cartesian coordinate learning application through an AI-assisted development process based on conceptual difficulties identified from oral assessment findings. The oral assessment, originally conducted within a vector-related mathematics examination, revealed that students experienced difficulties in prerequisite coordinate concepts, including locating ordered pairs, distinguishing axes, determining quadrants, and interpreting coordinate movement. These findings were then translated into instructional design requirements that guided the development of the digital intervention.

The resulting application provided a visual and interactive learning environment designed to support students' understanding of coordinate positions and movement on the Cartesian plane. Students' initial responses indicated positive perceptions of the application across conceptual understanding, confidence and persistence, engagement, and usability. These findings suggest that transforming assessment-based diagnostic insights into targeted digital interventions can offer a meaningful approach to supporting foundational mathematics learning.

This study also demonstrates the potential of generative AI as a support tool in the development of educational applications, particularly for translating instructional ideas into functional digital prototypes. However, the findings should be interpreted as initial evidence from an early DBR cycle rather than as conclusive proof of learning effectiveness. Further research is needed to examine the application through broader implementation, experimental or quasi-experimental evaluation, and refinement based on students' remaining learning difficulties.

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