Intervention Case Study: Developing Vector Resolution Skills via Technology-Enhanced Learning

By Shafiq R

Vectors Resolution

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Developing Vector Resolution Skills via Technology-Enhanced Learning

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Executive Summary

This report outlines a short-term teaching intervention aimed at improving students' conceptual understanding of vector decomposition into x and y components, a fundamental skill in pre-university physics. The intervention was carried out with four Semester 1 Malaysian matriculation students who had demonstrated difficulty with this concept during early kinematics lessons. The intervention incorporated online vector simulations, a scaffolded worksheet, and Think-Pair-Share problem-solving strategies over two face-to-face sessions (1 hour each). Students engaged with interactive tools such as PhET, oPhysics, and The Physics Classroom, allowing them to visualize and manipulate vectors in real time. Structured worksheets helped break the concept into manageable steps, while peer discussion supported active reasoning and correction of misconceptions. Student performance was assessed through pre- and post-tests. Results showed significant learning gains, with normalized gains ranging from 0.45 to 0.83, and two students scoring above 0.70, indicating high conceptual improvement. Informal feedback also revealed increased confidence and clarity in approaching vector problems. The intervention demonstrated that even a short, well-structured, and technology-integrated approach can lead to meaningful learning improvements. Recommendations include using simulations earlier in instruction, integrating peer collaboration regularly, and expanding the method to more students or topics involving vector concepts.

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1 Introduction

Context and Background

During early lessons on kinematics and vector analysis, it became evident that some students struggled with the fundamental concept of vector decomposition into x and y components. Despite classroom instruction, students were unable to confidently resolve two-dimensional vectors into horizontal and vertical parts—an essential skill for solving problems in motion and force.

This intervention was designed to address this conceptual gap using a combination of interactive simulations, scaffolded problem-solving, and collaborative learning techniques. The approach aligns with 21st-century teaching principles, particularly visual learning, technology integration, and peer-supported learning.

Target Group of Students

The intervention focused on four Semester 1 pre-university physics students from the Malaysian Matriculation Programme. These students demonstrated difficulty in understanding vector resolution concepts, as revealed through classroom discussions and low scores in early kinematics exercises. They were selected for a short, intensive intervention aimed at building both conceptual understanding and confidence.

Learning Objectives

By the end of this intervention, students will be able to:

- Resolve vectors into horizontal (x) and vertical (y) components using trigonometric relationships.
- Use vector simulation tools to visualize vector breakdowns and verify answers.
- Collaborate effectively in small group settings to solve physics problems involving vector decomposition.
- Apply vector decomposition skills to solve basic problems in motion and forces.

2 Intervention Design

Instructional Strategies

This intervention used a combination of technology-enhanced instruction, scaffolded problem-solving, and the Think-Pair-Share cooperative learning technique. The instructional strategy was centered around constructivist learning, where students actively built understanding through visual, interactive experiences and peer collaboration.

Interactive simulations were used to help students visualize vector components dynamically, while scaffolded worksheets gradually guided them from basic to more complex vector decomposition problems. The Think-Pair-Share method encouraged individual thinking, peer explanation, and group problem-solving, reinforcing both conceptual clarity and communication skills.

Planned Activities

The key activities were structured as follows across the two sessions:

- **Simulation Demonstration**
  Instructor introduced key concepts using online vector simulation tools (e.g., PhET, oPhysics, Physics Classroom).
- **Guided Worksheet Practice**
  Students worked through a worksheet with scaffolded problems, beginning with identifying vector angles and magnitudes, and progressing to decomposing vectors using sine and cosine.
- **Think-Pair-Share**
  Students first attempted problems individually, then discussed answers in pairs using simulation tools to verify their reasoning, before sharing their responses with the group.
- **Concept Application**
  Final set of problems required applying vector decomposition in simple kinematics or force problems (e.g., inclined planes, projectile motion contexts).

Materials and Resources Used

- Online Vector Simulations
    - https://phet.colorado.edu/sims/html/vector-addition/latest/vector-addition_all.html
    - https://ophysics.com/k2.html
    - https://ophysics.com/k3.html
    - https://www.physicsclassroom.com/physics-interactives/vectors-and-projectiles/vector-addition/vector-addition-interactive

- Scaffolded Worksheets
  Custom-designed worksheets with step-by-step vector decomposition problems using diagrams and trigonometric guidance.

- Basic Tools
  Scientific calculators, rulers, and protractors for manual problem-solving and vector sketching.

- Whiteboard and Markers

- Used during group discussions and summary presentations.

Planned Adaptations

To support learners with varying abilities:

- Scaffolding was applied within the worksheet, starting with visual aids and hints (e.g., labeling triangle sides and angles).
- Simulations served as visual references to validate answers and reduce abstraction.
- Flexible pacing allowed students to replay simulations or re-attempt problems during Think-Pair-Share.
- The teacher facilitated each phase, checking for misconceptions and prompting clarification when necessary.

3 Implementation

Delivery Method

The intervention was conducted through face-to-face instruction over two sessions, each lasting 1 hour, within a traditional classroom setting equipped with internet-connected devices. The in-person format allowed for direct guidance, live simulation demonstrations, and active group interaction.

Students used their own laptops or shared institutional devices to access the online simulations during the sessions.

Session Schedule

Session 1 (1 hour)	○ Introduction to 2D vectors and common misconceptions ○ Instructor-led demonstration using PhET and oPhysics simulations ○ Guided practice using the first half of the scaffolded worksheet ○ Think-Pair-Share on simple decomposition examples
Session 2 (1 hour)	○ Quick review of vector decomposition ○ Student-led exploration using Physics Classroom and oPhysics simulations ○ Completion of remaining scaffolded problems ○ Think-Pair-Share on applied problems (e.g., force components on an incline) ○ Group reflection and Q&A

People Involved

The intervention was facilitated by the physics instructor (author of this report). The four selected Semester 1 Malaysian matriculation students participated together as a single cooperative learning group. All activities, including simulation use and Think-Pair-Share discussions, were monitored and guided by the instructor in real time.

Fidelity Notes

The intervention was implemented as planned. All simulations functioned properly, and students engaged well with the hands-on, visual learning elements. Students were particularly responsive during the Think-Pair-Share activities, using simulations to justify and correct their answers collaboratively. No major deviations or technical disruptions occurred.

4 Evaluation & Results

Assessment Methods

To evaluate student understanding of vector decomposition, a pre-test and post-test were administered. Both tests consisted of multiple-choice and structured problems requiring students to resolve vectors into x and y components using diagrams and trigonometric relationships. The pre-test was given prior to the intervention to assess baseline understanding, while the post-test was conducted immediately after the final session to measure learning gains.

Data Collection Tools

- **Pre-Test and Post-Test**
  Instructor-designed assessment items aligned with worksheet content and simulation activities.
- **Normalized Gain Calculation**
  Each student's learning gain was calculated using Hake's normalized gain formula:

$$g = \frac{\%_{\text{post}-test} - \%_{pre-test}}{100 - \%_{\text{pre}-test}}$$

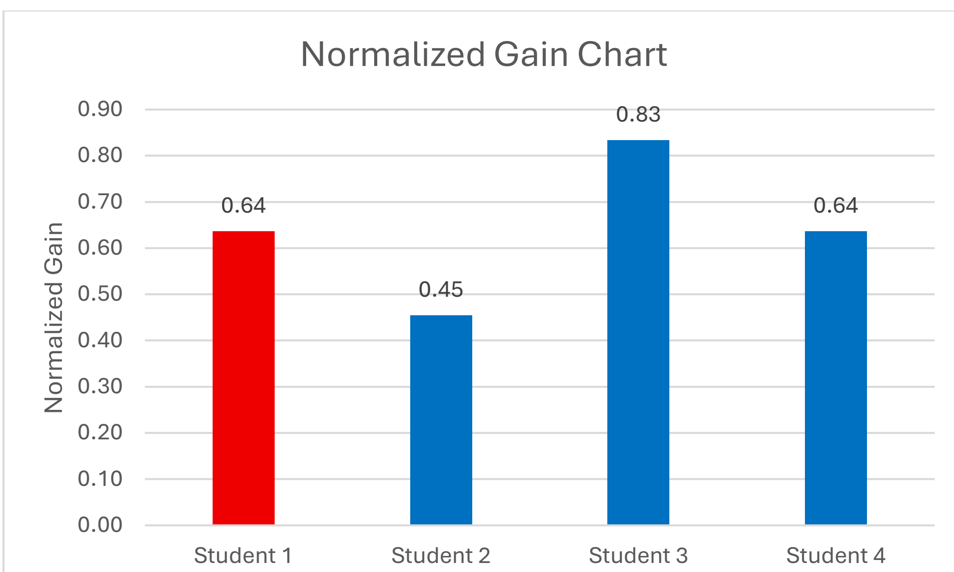
Summary of Findings

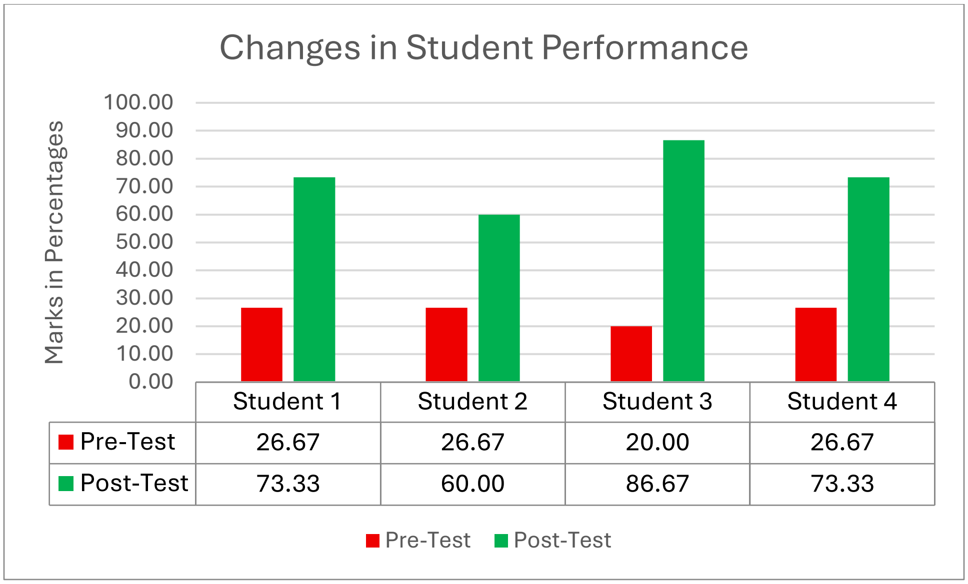
All four students showed substantial improvement in their ability to decompose vectors after the intervention.

Student	Test Scores in Percentage (%)		Normalized Gain
	Pre-Test	Post-Test	
Student 1	26.67	73.33	0.64
Student 2	26.67	60.00	0.45
Student 3	20.00	86.67	0.83
Student 4	26.67	73.33	0.64

All four students showed an increase in their scores from the pre-test to the post-test, indicating a positive learning outcome for each. The normalized gain values are all positive, reinforcing the idea that each student made progress. Student 2 showed good improvement at a normalized gain of 0.45, indicating a moderate learning gain. In this data, all normalized gains are positive and range from 0.45 to 0.83, suggesting that the intervention or learning experience was effective for all students, with Student 3 showing the most effective learning relative to their initial understanding.

These results suggest the intervention was successful in addressing the conceptual gap related to vector decomposition.





Student Feedback

Although no formal survey was conducted, informal observations and verbal feedback during the lessons indicated that:

- Students found the simulations helpful in "seeing" how vectors break into components.
- Peer discussions during Think-Pair-Share allowed students to identify and fix their own mistakes.
- The scaffolded worksheet helped structure thinking and prevented students from feeling overwhelmed.

Students comments at the end of the intervention:

- *"I always thought components were just numbers. Now I see them clearly as parts of the vector."* – Student 3
- *"When I moved the arrows in the simulation, it finally clicked."* – Student 2
- *"The steps in the worksheet helped me focus one piece at a time."* – Student 1

5 Reflection & Recommendations

Effectiveness of the Intervention

The intervention successfully addressed the core learning issue: students' difficulty in decomposing vectors into horizontal and vertical components. Pre- and post-test data show that all four students improved, with two achieving high normalized gains (≥ 0.7). The interactive simulations helped make vector direction and magnitude more concrete, while scaffolded worksheets provided the necessary structure to support problem-solving. The Think-Pair-Share technique proved especially valuable in encouraging active dialogue and peer clarification.

Overall, the blend of technology, guided practice, and collaboration aligned well with 21st-century teaching principles, resulting in meaningful learning gains in a short time frame.

Lessons Learned

- **Visualization is key**

  Students grasped vector concepts better when they could manipulate and observe them dynamically through simulations.

- **Structure reduces confusion**

  Scaffolding helped students who were overwhelmed by multi-step problems.

- **Peer interaction supports confidence**

  Students were more willing to take risks and revise their thinking when supported by peers.

- **Short interventions can still be impactful**

  Even two well-structured sessions can significantly improve conceptual understanding.

Recommendations for Future Implementation

1. **Integrate simulations earlier in instruction**

   Introducing simulations at the start of a topic may prevent misconceptions from forming.

2. **Use Think-Pair-Share more widely**

   This approach works well with conceptual and procedural content, especially when paired with visual tools.

3. **Collect formal student feedback**

   Written reflections or short surveys could give deeper insights into the student experience.

4. **Include follow-up practice**

   A brief revisit of vector decomposition in later lessons (e.g., projectile motion) can reinforce retention.

5. **Expand to more students**

   Consider implementing this strategy across the full class to support all learners, not just those who struggle.

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Pre and Post-test: Vector Resolving

Subject: Physics
Topic: Vector Resolving
Total Marks: 20
Duration: 40 minutes

Question 1 [8 marks]

A force of 100 N is applied at an angle of 40° above the horizontal.

(a) Resolve the force into its horizontal and vertical components. [4 marks]
(b) If the force is applied to a 20 kg box on a smooth surface, calculate the horizontal acceleration of the box. [2 marks]
(c) Briefly explain how the vertical component affects the normal reaction force. [2 marks]

Question 2 [6 marks]

A force of 150 N is pulling a sled up a slope inclined at 25° to the horizontal.

(a) Determine the component of the force parallel to the incline. [2 marks]
(b) Determine the component of the force perpendicular to the incline. [2 marks]
(c) Explain the significance of each component in terms of motion and support. [2 marks]

Question 3 [6 marks]

Two forces act concurrently on a particle: 50 N due east and 80 N at 60° north of east.

(a) Resolve the 80 N force into its east and north components. [3 marks]
(b) Calculate the magnitude and direction of the resultant vector. [3 marks]

Marking Scheme

Question 1 [8 marks] - (a) Horizontal component: $F_x = 100\cos(40^\circ) \approx 76.6\ \mathrm{N}$ [2 marks]
Vertical component: $F_y = 100\sin(40^\circ) \approx 64.3\ \mathrm{N}$ [2 marks]
- (b) $a = F_x/m = 76.6/20 = 3.83\ \mathrm{m/s^2}$ [2 marks]
- (c) Vertical component reduces the normal force by F_y ; good conceptual explanation [2 marks]

Question 2 [6 marks] - (a) Parallel component: $F\cos(25^\circ) = 150\cos(25^\circ) \approx 135.9\ \mathrm{N}$ [2 marks]
- (b) Perpendicular component: $F\sin(25^\circ) = 150\sin(25^\circ) \approx 63.4\ \mathrm{N}$ [2 marks]
- (c) Explanation of motion along the incline and normal force influence [2 marks]

Question 3 [6 marks] - (a) $F_E = 80\cos(60^\circ) = 40\ \mathrm{N},\ F_N = 80\sin(60^\circ) \approx 69.3\ \mathrm{N}$ [3 marks]
- (b) Resultant east component: $R_E = 50 + 40 = 90\ \mathrm{N}$; north: $R_N = 69.3\ \mathrm{N}$
Magnitude: $R = \sqrt{90^2 + 69.3^2} \approx 113.4\ \mathrm{N}$, direction: $\tan^{-1}(69.3/90) \approx 37.5^\circ$ north of east [3 marks]