Vectors in the Time of Scalars

Daryl McPadden
Colorado School of Mines
dmcpadde@mymail.mines.edu

Eleanor C. Sayre
Kansas State University
esayre@ksu.edu

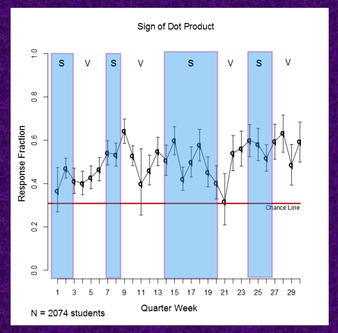
Setup - Preliminary data suggested an interference effect between students' abilities to answer vector/scalar related questions and the type of instruction that they were receiving at the time. Data were collected weekly throughout the introductory, calculus-based physics sequence at Rochester Institute of Technology (RIT). This project was designed to further investigate if students view problems involving vector concepts and problems involving scalar concepts differently depending on whether the current topic of instruction is vectors or scalars.

Tasks Investigated:
Electrostatics - 4 Questions
Magnetism - 4 Questions
Field and Potential - 10 Questions
Gravitational Potential - 4 Questions
Vectors - 13 Questions

ANOVA Statistics:
Electrostatics – 4/4 significant
Magnetism – 3/4 significant
Field and Potential – 7/10 significant
Gravitation Potential – 2/4 significant
Vectors – 11/13 significant

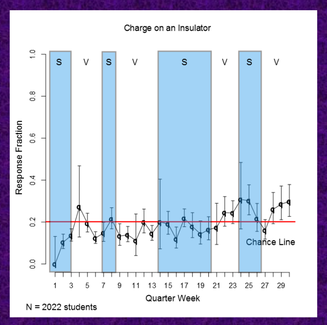
ANOVA Tests: ANOVA tests were performed on the number of correct answers as a function of the week within the semester that the task was taken.

Question: For the pair of vectors below, is their dot product positive, negative, or zero?



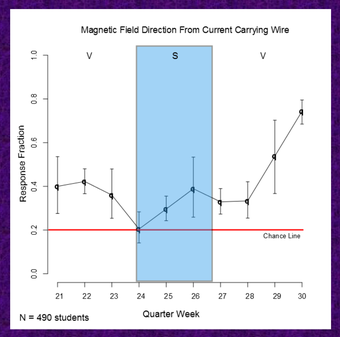
Features: Above the chance line, some variance within the graph but no pattern related to type of instruction.

Question: A hollow insulating sphere is electrically neutral. A small amount of negative charge is placed at one point on the outside of the sphere. If we check on this charge sometime later, where will it be?



Features: Hovering around the chance line, little improvement. This type of graph was not meaningful, along with those graphs that hovered around the ceiling.

Question: There is a large current in a wire coming out of the page. What direction does the magnetic field point directly above and directly to the left of the wire?



Features: This graph shows the typical learning curve – before the students did not know something, then they learned something. While good, this does not support the hypothesis.

Conclusion: There was a great diversity in the shapes of response plots. Some showed a well-defined learning curve, whereas others were completely static. Even though these questions were statistically significant, there was no clear correlation between vector/scalar instruction and students' abilities to answer related questions.

Further Investigation: The data were also split by gender, final grade in the course, and current co-registration in a math course to see if an interference effect occurred within the groups. However, after dividing by these effects and by quarter week, the sample size was too small to draw any meaningful conclusions.

Task Design: Given the results from the previous set of data, the tasks were rewritten to make them more comprehensive and longer. The new tasks were designed to be completed in 5 – 10 min, rather than 2 – 3 min.

Design: Questions were designed with the following possible research questions in mind.

- Field Interference – between gravitational fields and electric fields
- Math vs. Physics Context Study
- Equation vs. Concept Approach
- Concept Tracking across the Course of the Semester

The tasks were designed to be broad enough to investigate other research problems.

Sample Questions:

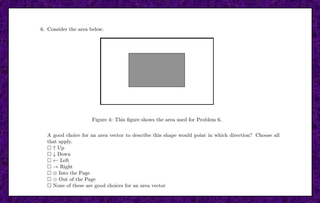

6. Consider the area below.

Figure 4: This figure shows the area used for Problem 6.

A good choice for an area vector to describe this shape would point in which direction? Choose all that apply.
□ ↑ Up
□ ↓ Down
□ ← Left
□ → Right
□ ⊙ Into the Page
□ ⊗ Out of the Page
□ None of these are good choices for an area vector

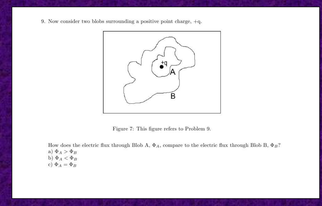

9. Now consider two blobs surrounding a positive point charge, +q.

Figure 7: This figure refers to Problem 9.

How does the electric flux through Blob A, Φ_A, compare to the electric flux through Blob B, Φ_B?
a) $\Phi_A > \Phi_B$
b) $\Phi_A < \Phi_B$
c) $\Phi_A = \Phi_B$

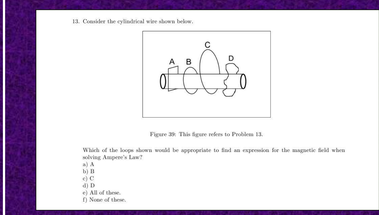

13. Consider the cylindrical wire shown below.

Figure 39: This figure refers to Problem 13.

Which of the loops shown would be appropriate to find an expression for the magnetic field when solving Ampere's Law?
a) A
b) B
c) C
d) D
e) All of these.
f) None of these.

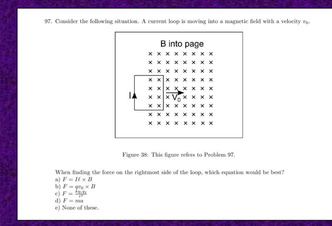

97. Consider the following situation. A current loop is moving into a magnetic field with a velocity v_0.

Figure 38: This figure refers to Problem 97.

When finding the force on the rightmost side of the loop, which equation would be best?
a) $F = IL \times B$
b) $F = qv_0 \times B$
c) $F = \frac{kqq_0}{r^2}$
d) $F = ma$
e) None of these.

Test Validation: The questions were tested for clarity and content by 11 people, ranging from undergraduate REU students, to graduate students, to faculty members.

Future Plans: These questions will be put into tasks and distributed to students at RIT throughout the Fall semester. Interviews will be conducted in October to further evaluate the questions.

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