Development of a Rubric to Assess the Effects of the Types of Vector Operations and Alignments on Student Errors

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Introduction

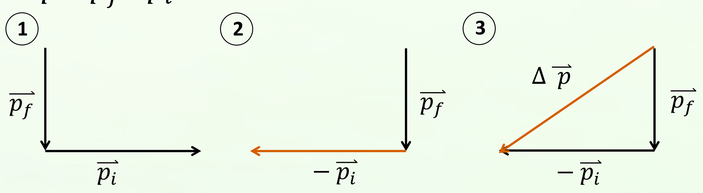
- Previous research has shown that students have **difficulties** performing vector addition and subtraction
- After a full semester of instruction, **more than half** of the students in introductory algebra-based physics were unable to execute **2D vector addition** [1]
- Students are **consistent** with the errors they make based on **problem type** [2]
- We elaborate on previous research by analyzing **free-response** student work from a large population of students

Research question

- Do the types of vector arithmetic problems given to students influence the errors they make?

Solving for change in momentum

$\Delta \vec{p} = \vec{p_f} - \vec{p_i}$



Methods

- We developed a rubric to **categorize** the errors students make when executing vector arithmetic
- The rubric consists of 27 categories
- We categorized student responses in sets of 20
- Population included **N = 122** students enrolled in **Physics 212** during the Spring 2019 semester
- We have analyzed **N = 40** students using the rubric
- Students were given an 8 question, **free-response** worksheet in class at the end of the semester
- Upon completion, students were given extra credit for participation
- The worksheet consisted of **4 vector addition** and **4 vector subtraction** problems
- For both operations, **4 various alignments** were presented: aligned, x-opposed, y-opposed, and opposed

Results

- 5 out of 40 students (13%) changed their chosen vector arrangement method at least once

Provided Resultant vector (not ambiguous)	Provided Resultant line (ambiguous)	Did not provide any Resultant
86%	5.6%	8.4%

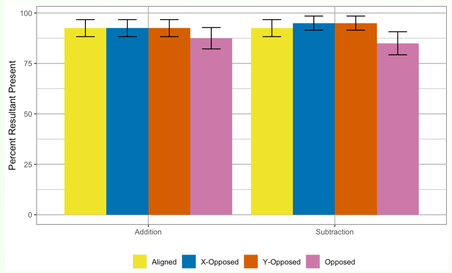


Fig. 1 : Percent of students that presented at least a single resultant "line", organized by vector operation and alignment.

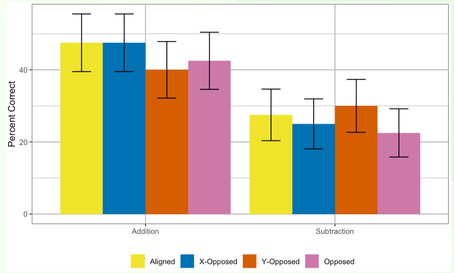


Fig. 2 : Percent of students that presented the correct resultant vector, organized by vector operation and alignment.

- Almost all students provided at least a resultant "line".

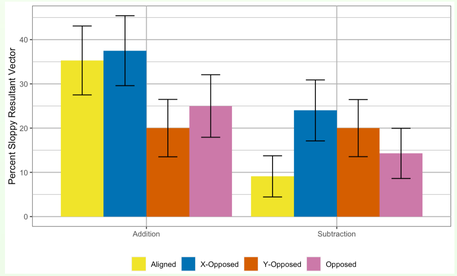


Fig. 3 : Percent of students that were not precise with the magnitude and direction of the resultant vector but were generally correct..

- More students were able to be generally correct for the addition set of problems

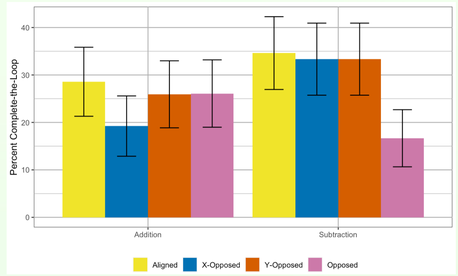


Fig. 4 : Percent of students that "completed-the-loop", organized by vector operation and alignment.

- Students were more successful performing vector addition than subtraction
- Overall, subtraction had higher rates of students that "Completed-the-Loop".

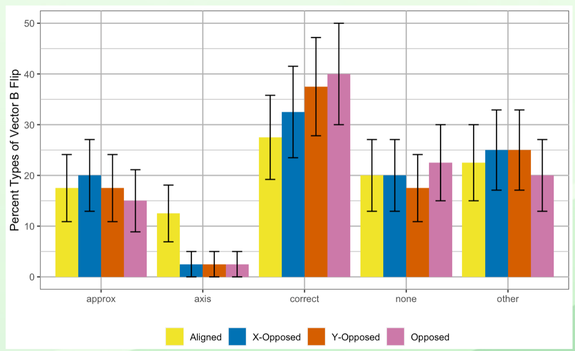
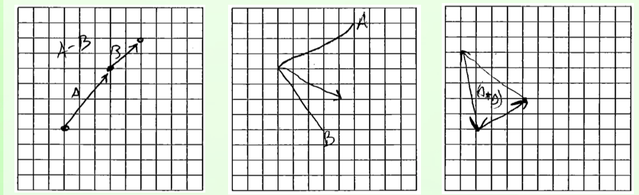


Fig. 5 : Various methods students used to flip vector B for subtraction problems and the percent of students that performed each.

- Of the students that attempted to flip vector B, most were correct

Student Samples



No resultant present | "Split-the-Difference" | "Complete-the-Loop"

Conclusions

- Students tended to be **consistent** with their chosen method, which **supports** previous research claims
- As expected, **subtraction is more difficult** for students than addition
- "Completing-the-loop" is a **prevalent** and **consistent** error
- We suspect that there were significantly fewer students that "completed-the-loop" for the **Opposed-Subtraction** problem because fewer students drew a resultant vector for this specific question
- Students reflect vector B about an **axis** more when it is **presented** in the direction of the **first quadrant**
- The rubric **successfully extracts** the information we are seeking to assess

Future Work

- Finish coding the rest of the data sets, N = 40 completed out of total N = 122
- Validate **interrater reliability** of the rubric
- **Compare results** with the multiple-choice analysis
- Check if free-response analysis **corroborates** conclusions from multiple-choice analysis

[1] Nguyen and Meltzer, *Initial understanding of vector concepts among students in introductory physics courses*
[2] Johnson and Buncher, *Examining consistency of student errors in vector operations using module analysis*

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