# Using Networks to Examine Consistency in Student Errors in Vector Operations 

## NEW MEXICO TECH

## Introduction

- Vectors are hard!
- After a semester of instruction with vectors, more than 1 in 4 students were unable to add 2 dimensional vectors [1]
Vectors are quantities with magnitude (length) and direction, like a force or a velocity
Students tend to have one method to solve vector problems that they stick with, regardless of if it's the "best" method for a given problem [2] Mistakes are extremely prevalent


## Research Question

Is there consistency in the types of errors that students make doing vector addition and subtraction problems?

## Method

- Module Analysis for Multiple Choice Responses
- Developed by Brewe et al. [3]
- Looks at each choice on its own, rather than the question as a whole
How do we do this? There are 4 steps:


First, we create a network of the students and their test responses, so each student is connected to the answers they gave

Then we project the students out of the network, allowing us to look only at how the responses are connected


This results in a dense network, so we extract the backbone network by using the LANS algorithm ( $\alpha=0.04$ ), allowing us to see the most important connections


Finally we run InfoMap, which identifies groups of nodes that are more likely to be connected to each other. We try to classify these groups based on the nodes within them

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$\sum$ 4. 1-Dimension

- Data from classes of algebra ${ }^{1.0}$ based physics 1 and 2 (PHYS211 and PHYS212)
12 questions, 6 addition and ${ }^{0.4}$ 6 subtraction
One subtraction (2s) was thrown out due to an error - Taken as an online quiz at end of course
Below is question 5:


We cannot make claims about what the students did, we can only make informed guesses

Sp15 211, N = 63



- Note that the same 3 nodes are the largest across all three networks: 1sApB, 5 sApB , and 6sApB
In 1sApB, the students may not have seen the change in operation. Future data will be collected with the order changed to look into this

Sp15 212, N = 52


Percent Correct-1D

- $\mathrm{Fan7} 211$ Sp15 211
Sp15 212


Class performance comparison. Each error bar is $\pm 1$ standard error.

- Answers were coded with 4 pieces of information:
- The question number (1-6)
- The operation (p or s)
- The directions of $A$ and $B$ that would have to be combined to get the answer ( A or $\mathrm{nA}, \mathrm{pB}$ or mB )

| $A$ | sApB |
| :---: | :---: |
|  | snApB |
|  | pAmB |
|  | pnAmB |

These shapes are the classifications of the kinds of mistakes students made

- In the all three 1D networks, we see two major trends
- The purple group contains plenty of stars, which represent doing addition instead of subtraction
- The diamonds show a pattern of doing subtraction by flipping the direction of the wrong vector

- In 5 and 6, the vectors point in opposite directions, whereas in 1 , 3 , and 4 they point in the same direction, suggesting students struggle more when B is opposite A


## 2-Dimensions

- Data came from one class of algebra based physics 1, in Fall 2017
- Taken as an online quiz at end of course - Separated by operation for easier
visualization
- Question 4 below:



ppSD/smSD Not inconsistent with ppSD/smSD pnXpYp/snXmYm pnXmYm/snXpYp pXmYm/sXpYp


2D Addition, $\mathrm{N}=175$

here are also answers matching a split the difference method (SD)

- In the both 2D networks, we see a few groups
- Group 1 (in purple) shows lots of the answers that use the "split difference" method, as well as answers that are not inconsistent with this method, that is, they point in a similar direction
- Group 2 (in orange) shows answers the complete the loop
- Group 3 (in blue) shows the answers that connect the two vectors from B to A
- Group 4 (green in both, also pink in addition) is comprised of answers that connect the vectors from $A$ to $B$


Our results indicate that module analysis is a useful method to analyze these responses!

## References/Acknowledgements

Nguyen and Meltzer, Initial understanding of vector concepts among students in introductory physics courses
[2] Hawkins et al., Students' Consistency of Graphical Vector Addition Method on 2-D Vector Addition Tasks

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