Computation as a Tool for Physics Learning

UNIVERSITY OF GUELPH

Introduction

Computation is an integral tool used in the field of physics, making it crucial to teach to our undergraduates. Additionally, many benefits of including computational physics in the curriculum have been identified: [1]

- Computational thinking skills
- Making connections
- Sensemaking
- Visualizing diverse problems
- Transferable skills

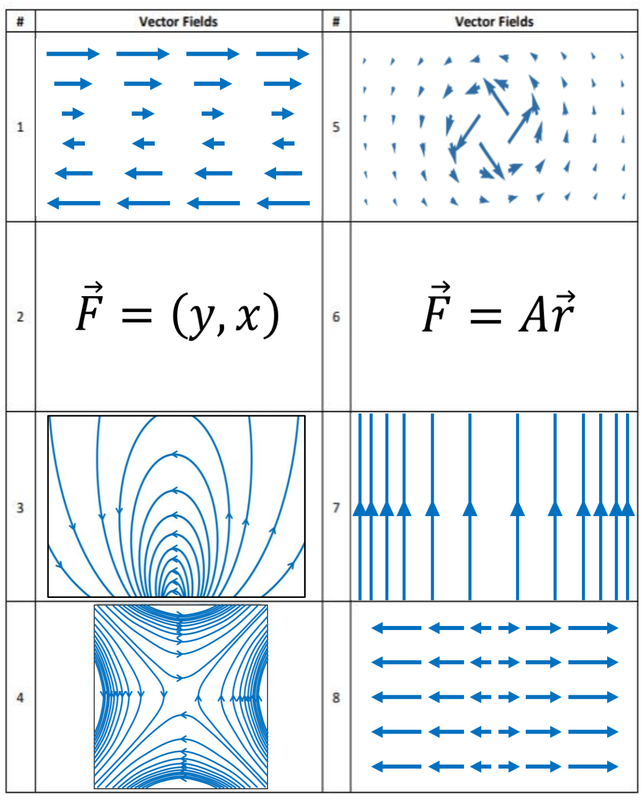
It is no surprise that introducing computation into the physics curriculum benefits students, but the question that still remains is:

How do computational exercises impact physics learning?

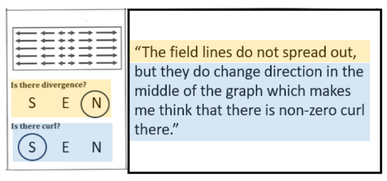
Methods

In a second-year electricity and magnetism course at the University of Guelph, students engaged in an activity to develop their understanding of curl and divergence by numerically computing vector derivatives of 2D vector fields. From the student perspective, the series of events resembled:

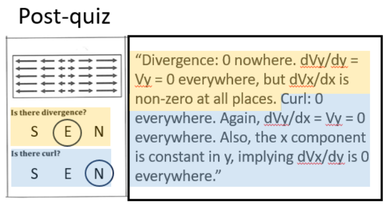
Pre-Quiz → Guided Tutorial → Comp. Activity → Post-Quiz



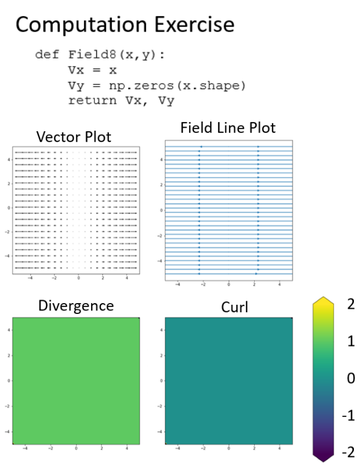
Pre-quiz



Post-quiz

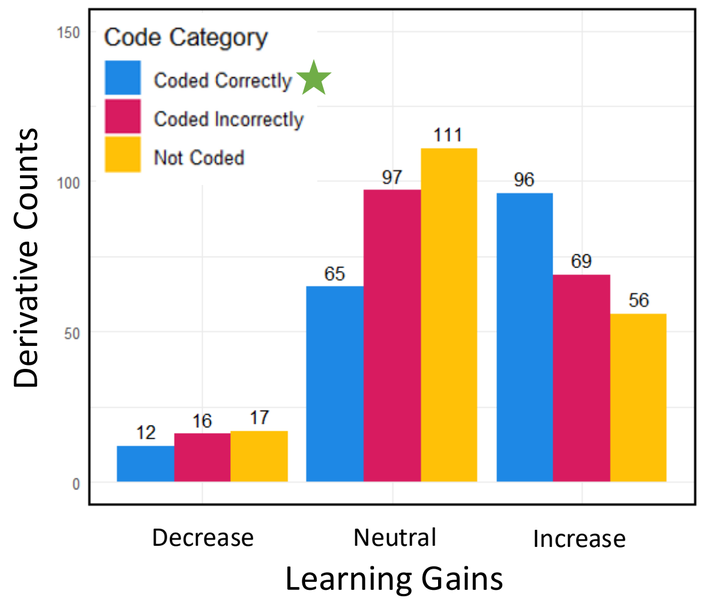


Computation Exercise



After data was collected, the method for analysis was to compare the pre- and post-quizzes for each student and quantify any Learning Gains (or losses) made for each vector derivative. Then, Learning Gains were categorized based on how the student coded the vector derivative (i.e., Correctly, Incorrectly, Not at All). The pre- and post-quizzes were further analysed for changes in approach to the vector derivative problems.

Analysis



Learning Gains of the students from the pre- to post-quizzes organized by how they coded the derivative.

Base Model (Ordinal Logistic Regression)			
N	539		
Parameter	Coeff.	Std. E	Signif.
Code Category: Incorrect	-0.67	0.21	** 0.0014
Code Category: Not Coded	-0.93	0.21	*** 8.9×10^{-6}

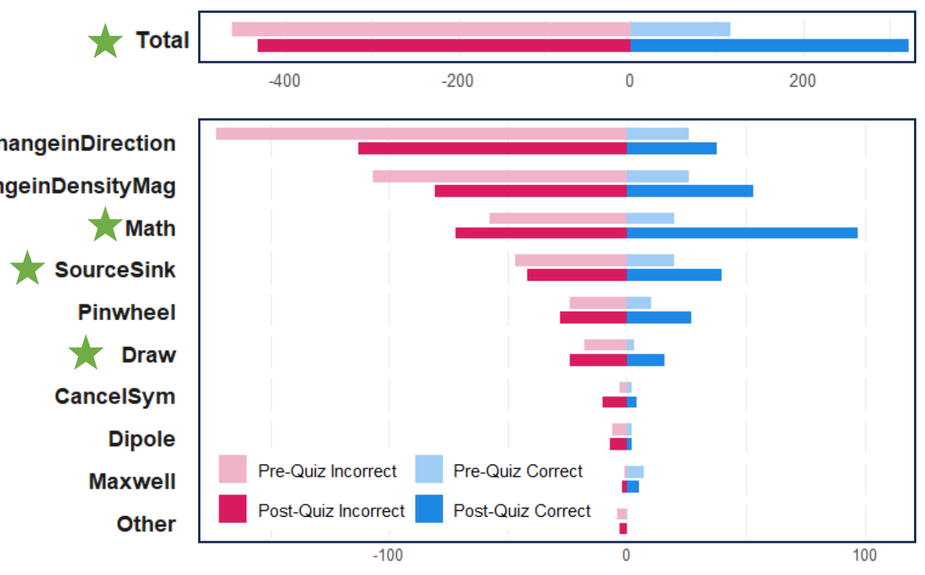
Engaging with the Computation Exercise corresponded to neutral/positive Learning Gains. They were most positive when Coded Correctly.

Coding Incorrectly did not negatively impact learning.

Tools used more frequently and correctly.

Increase in representational fluency and competency.

Shift from mostly qualitative to more quantitative.



Distributions of correctness in tool use on the pre- and post-quizzes organized by tool used in student reasoning. A star signifies a statistically significant change in the distribution using Fisher's Exact Test.

Conclusions

- Coding activity → Increased Learning Gains
- Coded Correctly → Higher chance of positive Learning Gains
- Coded Incorrectly ≠ Negative Learning Gains
- Switch from qualitative to more quantitative
- All tools were used more correctly, especially when Coded Correctly
- Increased representational competency and fluency

References:
[1] Sand, O.P., et. al. "How computation can facilitate sensemaking about physics: A case study" 2018 PERC Proceedings; https://doi.org/10.1119/perc.2018.pr.Sand

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