Algebra-Based Physics Students & Vectors : Can *ijk* Coaching Help Arrow Subtraction?

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Introduction

- Students in a calc-based intro mechanics course have been found to perform better on vector operations in the *ijk* format than in the arrow format, and evidence was found that working knowledge of the *ijk* format may be necessary to correctly perform vector operations in the arrow format [1]
- Repeated mastery-style practice significantly improved scores on a Vector Skills Assessment for students in an introductory calc-based sequence [2]
- Working knowledge of graphical vector operation is important for mastery of serveral physics concepts
- *ijk* representation is often not included in algebra-based books
- Broader Question - Can using *ijk* methods in the algebra-based sequence improve performance and understanding on graphical vector tasks?

Methods

- Students enrolled in algebra-based introductory mechanics
- Administered in last week of class, extra credit for completion
- Students randomly given arrow or *ijk* representation
- No explicit *ijk* instruction given during the semester

Intervention Attempt - Arrow vs. *ijk*

- Students were each given the same vector subtraction question (2D, multiple choice, arrows-on-a-grid)
- Students received an "arrow" or "*ijk*" intervention ("*ijk* Transfer Task", ITT)

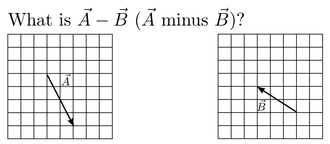

Fig. 1: Pre- (and post-) question on the ITT.

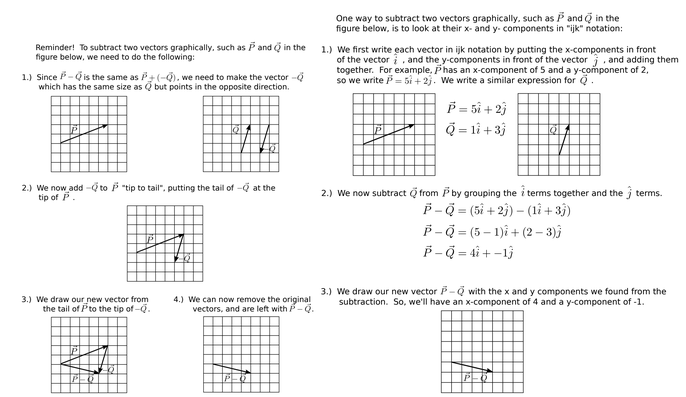

Fig. 2: Instructional portion of the interventions given in the arrow (left) and *ijk* (right) representations.

Intervention Attempt - Arrow vs. *ijk*

- Students were given 4 "Practice" questions on either identifying the negative of a vector (arrow) or translating a vector into *ijk* (ijk)
- Feedback was given after all 4 questions were completed (correctness and explanation if incorrect)
- The remaining 2 (arrow) or 4 (ijk) question "Synthesis" sequence asked students to perform the practice portion as well as subtraction for the same set of vectors (feedback given after all questions are answered)
- Posttest question (identical to pretest) is given

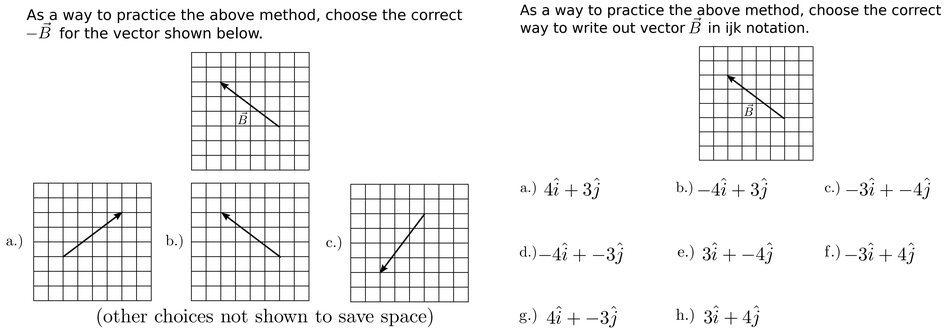

Fig. 3: Practice questions given in the arrow (left) and *ijk* (right) representations.

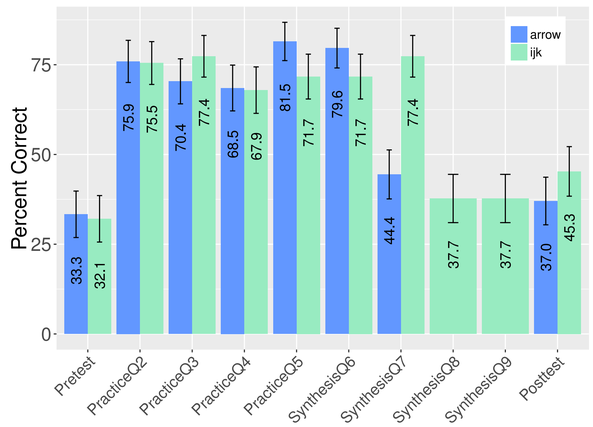

Fig. 4: Percent scores for each question on the intervention. The *ijk* intervention required two more "Synthesis" steps than the arrow, so the arrow intervention does not have an 8th or 9th question before the pretest. Error bars represent ± 1 SE.

	Pre	Post	p
ijk ($N = 52$)	17 (32.1%)	24 (45.3%)	0.13
Arrow ($N = 54$)	18 (33.3%)	20 (37.0%)	0.62

- Pretest scores were not different across groups (Wilcoxon rank sum, $W = 1413, p = 0.89$)
- Final course grades were not different across groups ($t(105) = -1.28, p = 0.20$)
- *ijk* treatment did not show significant gains (Wilcoxon-Pratt signed rank test, $Z = -1.5, p = 0.13$)
- Arrow treatment did not show significant gains (Wilcoxon-Pratt signed rank test, $Z = -0.5, p = 0.62$)
- In both treatments, the most common distractor chosen on the posttest question is consistent wtih the students performing vector addition, rather than vector subtraction

Does the Intervention Matter?

- Although the pre/post scores were not different, we can see if performance on the intervetion was a predictor of success on the posttest question
- Intervention questions were categorized into those that did not involve subtraction ("Component") and those that did ("Subtraction")
- The results of a logistic regression of posttest score against the intervention type, pretest score, "Component" score, and "Intervention" score are shown

Ind. Variable	β	β SE	z	p	OR	OR CI
Intervention (ijk)	0.619	0.469	1.32	0.187	1.85	[0.75, 4.79]
Pretest score	0.819	0.491	1.67	0.096	2.27	[0.86, 6.03]
Component score	1.820	0.817	2.23	0.024*	6.16	[1.39, 36.13]
Subtraction score	1.510	0.493	3.06	0.002*	4.52	[1.75, 12.26]

Table 1: Regression coefficients (β), standard error, z-statistic, p-value, odds ratio (OR), and 95% confidence interval (CI). The * indicates significance at the $p = 0.05$ level.

- Both "Component" score and "Subtraction" score remain significant predictors of success after controlling for pretest score
- Students who correctly answered all "Component" questions correctly were 6 times more likely to correctly answer the posttest question
- Students who correctly answered all "Subtraction" practice questions correctly were 4.5 times more likely to correctly answer the posttest question

Conclusions & Future Work

- A one-time intervention did not successfully improve arrow subtraction skills
- Although the intervention was not successful, the higher scores on the intervention questions suggest that students are not just "clicking through"
- The logistic regression suggests that further practice on "essential skills" may be key to improving students' vector subtraction skills [2]
- Additional questions or interviews would help determine why students frequently choose the "addition" distractor

References

[1] A.F. Heckler and T.M. Scaife, Phys. Rev. ST Phys. Educ. Res. **11**, 010101 (2015)
[2] B.D. Mikula and A.F. Heckler, Phys. Rev. Phys. Educ. Res. **13**, 010122 (2017)
[3] J.B. Buncher, 2015 PERC Proceedings, College Park, MD, pp. 75-78, doi:10.1119/perc.2015.pr.014

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