Using Factor Analysis to Explore the Structure of a Vector Assessment

Mateo Cacheiro[1], John B. Buncher[2], Nekeisha Johnson[2], Aliza Jacobs[3]

[1]Tennessee Technological University, [2]North Dakota State University, [3]University of Maryland

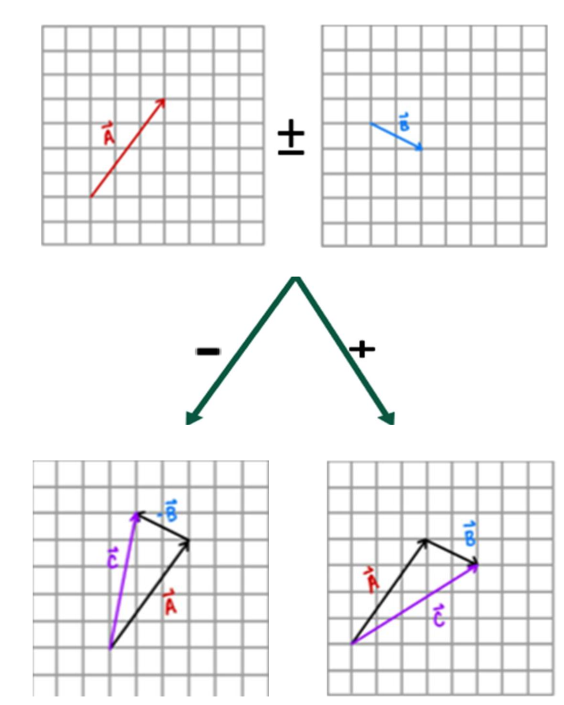
Why Examine Vector Assessment

- Insufficient vector algebra skills are often linked to difficulties in introductory physics.
- Vector addition is well studied; yet there is little research on student abilities in vector subtraction.
- We are developing a tool to assess both vector addition and subtraction.

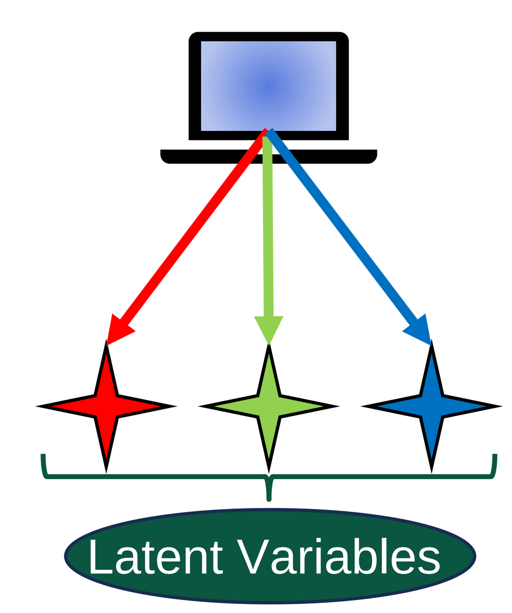
Research Question:

Can exploratory and confirmatory factor analysis (EFA and CFA) identify the factor structure and generate a model of what concepts our vector assessment is capturing?

Addition / Subtraction



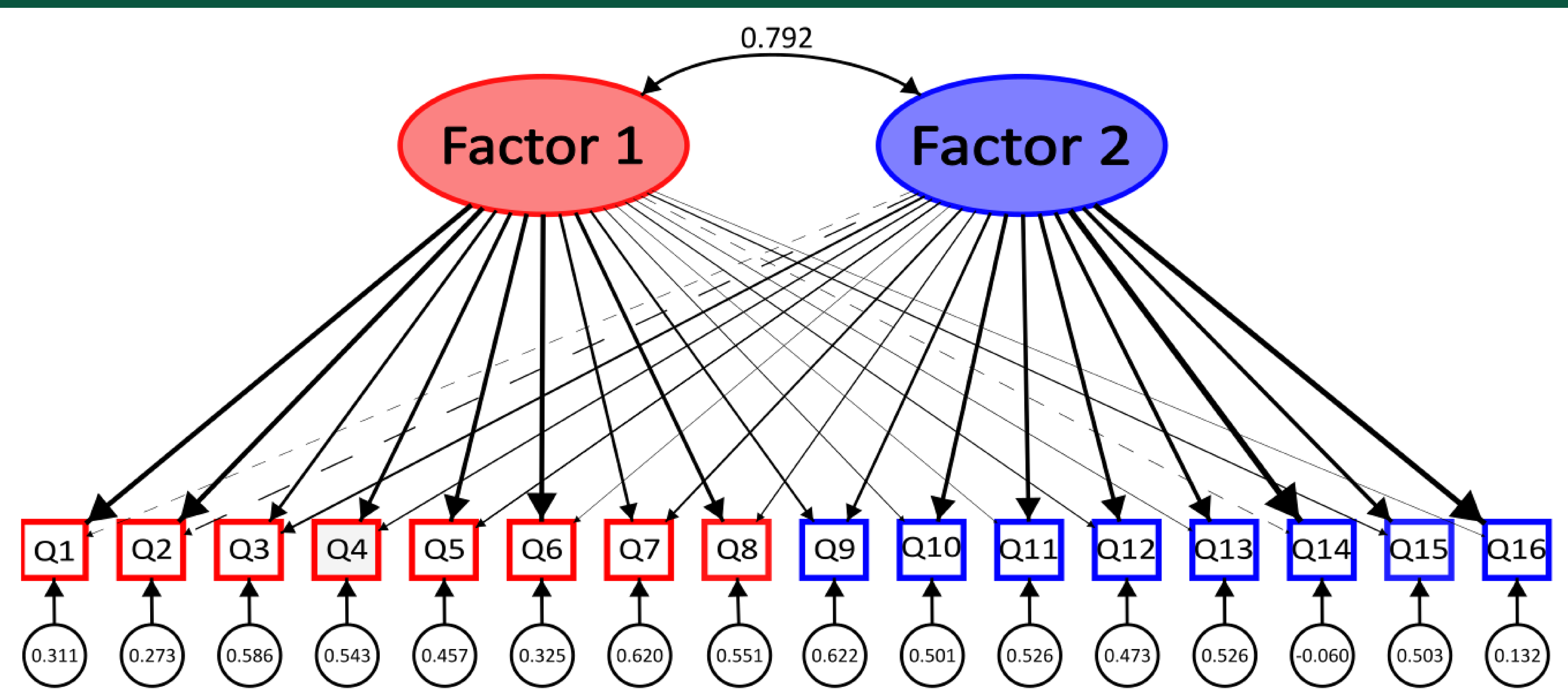
What is Factor Analysis



Methods

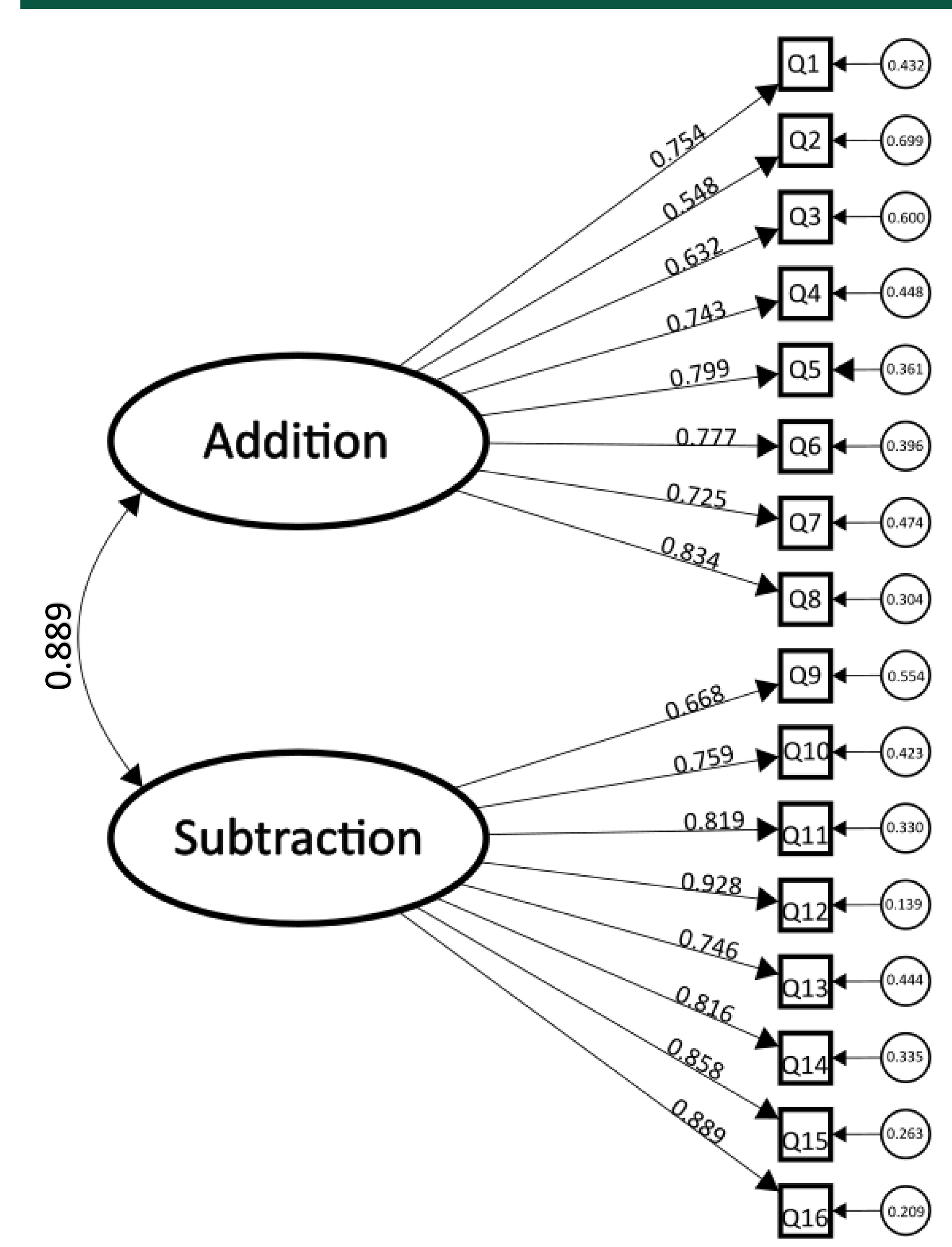
- Multiple choice assessment was given online to algebra-based introductory physics courses at NDSU.
- Data was collected over the span of 3 years.
- Assessment includes 16 multiple choice questions on vector addition and subtraction (8 each).
- A total of N = 511 Students, N_EFA = 248 N_CFA = 256.
- Student responses were treated at dichotomous data. 1 = correct, 0 = incorrect.
- We used WLS estimation for the EFA, DWLS during the CFA, and used the Tetrachoric correlation matrix because the data is categorical. Finally parallel analysis (PA) was used to determine number of factors = 2.

EFA

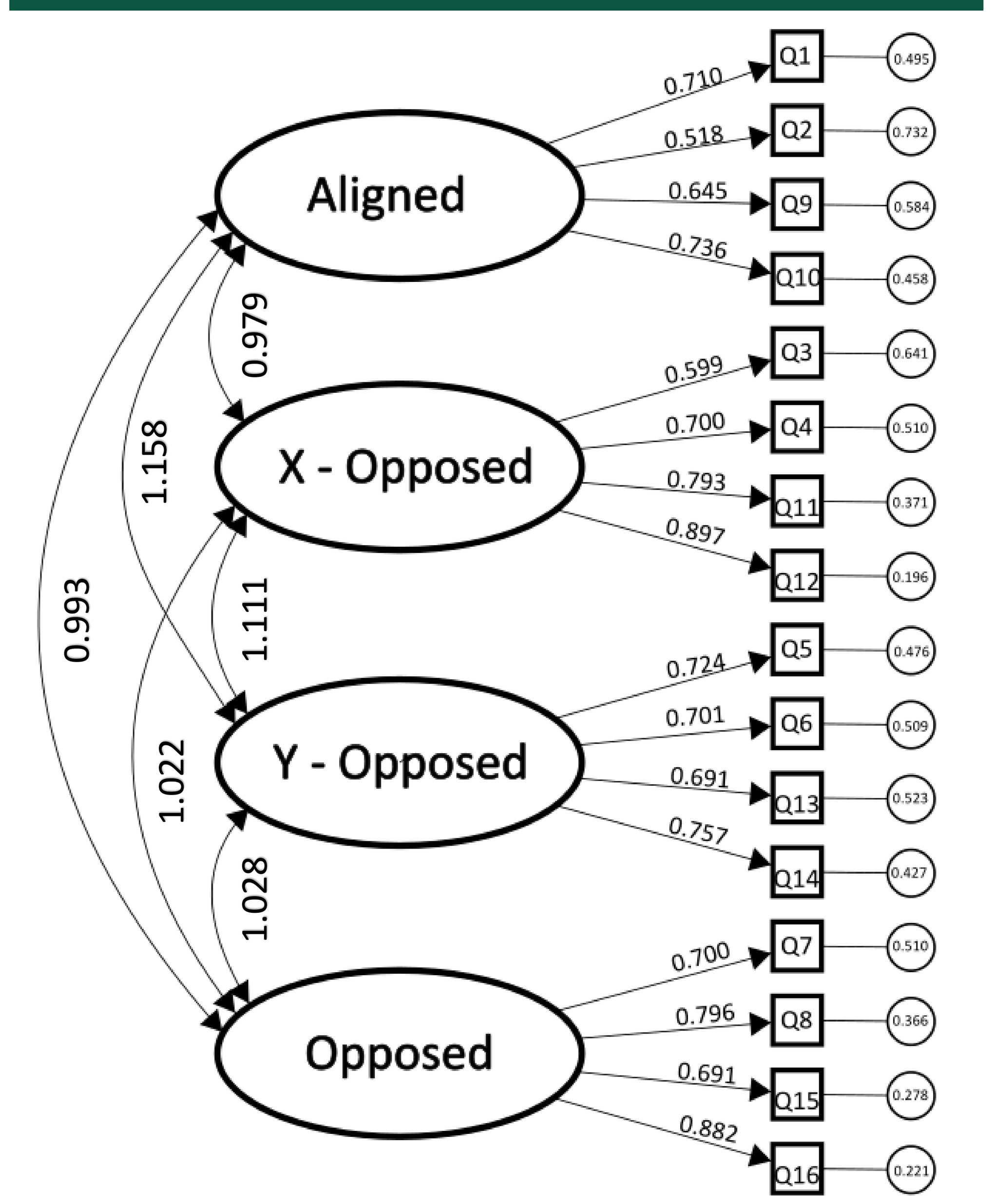


Question	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
Factor 1	0.830	0.819	0.515	0.623	0.723	0.821	0.501	0.625	0.389	0.166	0.09	0.207	0.124	- 0.12	0.229	0.053
Factor 2	-0.015	- 0.24	0.386	0.263	0.142	0.03	0.359	0.242	0.476	0.686	0.683	0.696	0.677	1.023	0.667	0.930

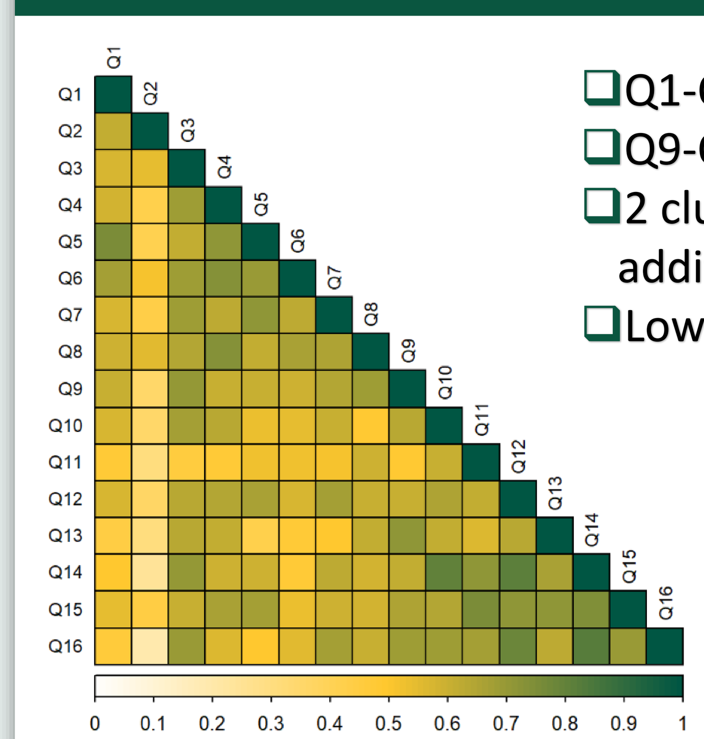
CFA 1: Operation



CFA 2: Orientation



Correlation Matrix



- Q1-Q8 = addition questions
- Q9-Q16 = subtraction questions
- 2 clusters that match with addition and subtraction.
- Low correlations on Q2.

Equation of the Model

$$\begin{bmatrix} Q1 \\ Q2 \\ Q3 \\ Q4 \\ Q5 \\ Q6 \\ Q7 \\ Q8 \\ Q9 \\ Q10 \\ Q11 \\ Q12 \\ Q13 \\ Q14 \\ Q15 \\ Q16 \end{bmatrix} = \begin{bmatrix} 0.754 & 0 \\ 0.548 & 0 \\ 0.632 & 0 \\ 0.743 & 0 \\ 0.799 & 0 \\ 0.777 & 0 \\ 0.725 & 0 \\ 0.834 & 0 \\ 0 & 0.668 \\ 0 & 0.759 \\ 0 & 0.819 \\ 0 & 0.928 \\ 0 & 0.746 \\ 0 & 0.816 \\ 0 & 0.858 \\ 0 & 0.889 \end{bmatrix} \begin{bmatrix} Addition \\ Subtraction \end{bmatrix} + \begin{bmatrix} 0.432 \\ 0.699 \\ 0.600 \\ 0.448 \\ 0.361 \\ 0.396 \\ 0.474 \\ 0.304 \\ 0.554 \\ 0.423 \\ 0.330 \\ 0.139 \\ 0.444 \\ 0.335 \\ 0.264 \\ 0.209 \end{bmatrix}$$

- Intercept is set to zero in model identification.

Results & Discussion

Statistic	χ^2 / DF	TLI	RMSEA	CFI	SRMR	Covariance	Eigenvalues Factor(1:2)
EFA	35.51 >> 2	0.692 << 0.9	0.207 > 0.2			0.792	5.76 : 4.98
CFA 1	1.11 < 2	0.998 >> 0.9	0.021 << 0.2	0.998 >> 0.9	0.071	0.881	0.71 : 0.12
CFA 2	1.31 < 2	0.995 >> 0.9	0.035 << 0.2	0.996 >> 0.9	0.075	See above	See right

CFA 2	EV
AL	4.15
X - Opp	0.05
Y – Opp	-0.01
Opp	-0.19

- PA suggests 2 factors.
- EFA results suggest an +/- split. EFA statistical values are not significant.
- 2nd CFA is not a possible model.
- All statistical values are significant; yet covariance matrix in not positive definite. Additionally, the covariances between all factors in the model are extremely high.
- The 1st CFA is a possible factor model. The statistics of the 1st CFA are all significant.
- Our assessment tests two separate topics as suspected. More importantly these two topics are vector addition and subtraction.
- We would also like to report our potential concerns with the first CFA model. It is unexpected that the CFA with fewer parameters would produce a closer fitting model. We hope to investigate this concern more to validate the conclusions of the study.
- We are not confident in the extraction of eigenvalues from the CFA models. We plan to investigate this further.

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