Non-construct Item Features and Response Processes in Computer Science Assessments: Evidence From Think-Alouds and Sequence Analysis

AERA 2021 Annual Meeting

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Automatically Synthesizing Valid, Personalized, Formative Assessments of CS1 Concepts (NSF-1735123)

UNIVERSITY *of* WASHINGTON | COLLEGE OF EDUCATION

Land Acknowledgement

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The University of Washington, and all of our lives and institutions, exists on Indigenous land. I acknowledge that I work and live on the ancestral homelands of the Coast Salish Peoples who have lived here from time immemorial. This land acknowledgement is one small act in the ongoing process of working to be in good relationship with the land and the people of the land and, ultimately, toward decolonization.

Adapted from the Banks Center for Educational Justice, https://www.education.uw.edu/cej/

Response processes

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- Underexplored source of validity evidence

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- Research on CS assessments focused on content validity

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***Research Question*: How does varying non-construct item features influence response processes?**

Item features framework

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Dimension
Cognitive Demands
Openness
Evidence of thinking

Item features framework

Dimension	*Category*			
Cognitive Demands	Reading Syntax	Reading Templates	Writing Syntax	~~Writing Templates~~
Openness				
Evidence of thinking				

Note: Cells with a line through them were not tested as part of this study

Item features framework

Dimension	*Category*			
Cognitive Demands	Reading Syntax	Reading Templates	Writing Syntax	~~Writing Templates~~
Openness	Closed	~~Semi-open~~		Open
Evidence of thinking				

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Thinkalouds → Qualitative Codes

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Process Category
Monitoring
Problem Solving
Reading Semantics
Reading Templates
Writing Semantics
Writing Syntax

Thinkalouds → Qualitative Codes

Process Category	*Detailed Sub-codes (e.g.)*
Monitoring	applying strategy; noticing confusion
Problem Solving	read task requirements; eliminate answers
Reading Semantics	multistructural reading; tracing values
Reading Templates	relational reading; recognizing template
Writing Semantics	global planning; revising semantics
Writing Syntax	typing syntax; revising syntax

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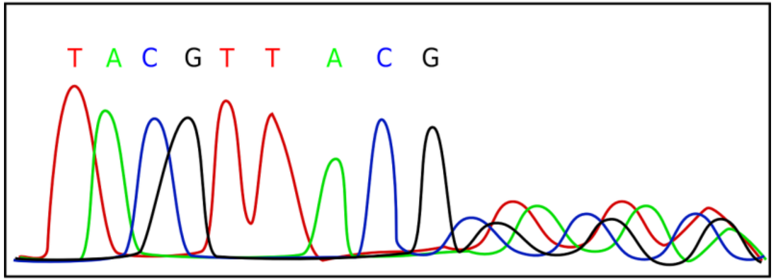
Data Analysis

Data Analysis

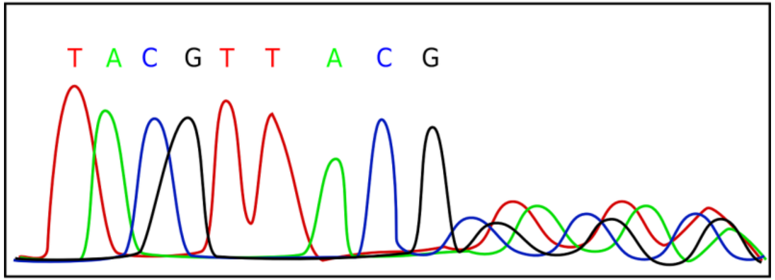
- Proportional frequency



Data Analysis

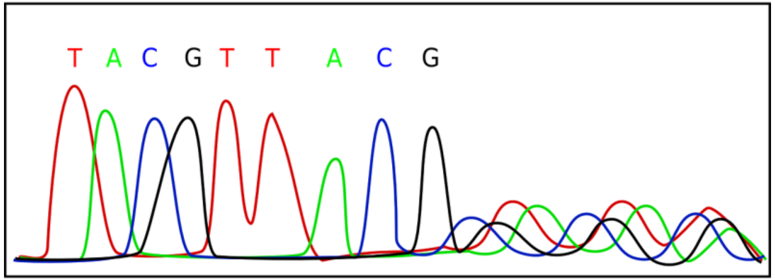
> Proportional frequency

> Sequence Dissimilarity



Data Analysis

- Proportional frequency
- Sequence Dissimilarity
- Sequential Pattern Mining



Proportional frequency

test for the frequency of each process category

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Broad differences in sequences, ignoring order

Proportional frequency

Broad differences in sequences, ignoring order

> ***yrogetac ssecorp hcae fo ycne***
> ***test for the frequency of each process category***

	Monitoring	Problem Solving	Reading Semantics
Open	.67	.75	.42
Closed	.23	.65	.34

Proportional frequency

Broad differences in sequences, ignoring order

- > *yrogetac ssecorp hcae fo ycne*
  test for the frequency of each process category
- > ***p*-value correction within each item feature**

	Monitoring	Problem Solving	Reading Semantics
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Closed	.23	.65	.34

Sequence Dissimilarity

$= +$

Sequence Dissimilarity

= +

Broad differences in sequences, taking order into account

Sequence Dissimilarity

Broad differences in sequences, taking order into account

= +

A: Monitoring – RS – RT – Problem Solving

B: Monitoring – RS – WS – Monitoring

C: Problem Solving – RS – WS - RT

Sequence Dissimilarity

Broad differences in sequences, taking order into account

A: Monitoring – RS – RT – Problem Solving

B: Monitoring – RS – WS – Monitoring

C: Problem Solving – RS – WS - RT

> $\boldsymbol{LCS}\ \mathbf{A, B}$

> $\boldsymbol{BBLLCCSS}\ \ \boldsymbol{LCS}\ \mathbf{A, B\ AA,}\ \ \boldsymbol{LCS}\ \mathbf{A, B}\ \ *$
$\mathbf{2} - \boldsymbol{L}\ \mathbf{B}\ \boldsymbol{LL}\ \boldsymbol{L}\ \mathbf{B\ BB}\ \boldsymbol{L}\ \mathbf{B}\ \ \ \boldsymbol{L}\ \mathbf{A}\ \boldsymbol{LL}\ \boldsymbol{L}\ \mathbf{A\ AA}\ \boldsymbol{L}\ \mathbf{A} + =$
$\mathbf{BB}\ \boldsymbol{distance}\ \mathbf{A, B}\ \ \ \boldsymbol{distance}\ \mathbf{A,}\ \boldsymbol{stance}\ \mathbf{A, B\ A, B}$
$= \boldsymbol{L}_{\mathbf{A}} + \boldsymbol{L}_{\mathbf{B}} - \mathbf{2} * \boldsymbol{LCS}_{\mathbf{A,B}}$

Sequence Dissimilarity

Broad differences in sequences, taking order into account

A: Monitoring – RS – RT – Problem Solving

B: Monitoring – RS – WS – Monitoring

C: Problem Solving – RS – WS - RT

- $LCS\ \mathrm{A, B}$
- $BBLLCCSS\ \ LCS\ \mathrm{A, B\ AA},\ \ LCS\ \mathrm{A, B}\ \ *$
  $2 - \ L\ \mathrm{B}\ LL\ L\ \mathrm{B\ BB}\ L\ \mathrm{B}\quad L\ \mathrm{A}\ LL\ L\ \mathrm{A\ AA}\ L\ \mathrm{A}+=$
  $\mathrm{BB}\ distance\ \mathrm{A, B}\quad distance\ \mathrm{A},stance\ \mathrm{A, B\ A, B}$
  $= L_{\mathrm{A}} + L_{\mathrm{B}} - 2 * LCS_{\mathrm{A,B}}$

	A	**B**	**C**
A	-	2	4
B	2	-	2
C	4	2	-

Sequence Dissimilarity

Broad differences in sequences, taking order into account

A: Monitoring – RS – RT – Problem Solving

B: Monitoring – RS – WS – Monitoring

C: Problem Solving – RS – WS - RT

- LCS A, B
- $BBLLCCSS$ LCS A, B AA, LCS A, B $*$
  2 – L B LL L B BB L B L A LL L A AA L A+ =
  BB $distance$ A, B $distance$ A, $stance$ A, B A, B
  $= L_{A} + L_{B} - 2 * LCS_{A,B}$
- $SS =$ sum of pairwise distances

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A	-	2	4
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Sequence Dissimilarity

Broad differences in sequences, taking order into account

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B: Monitoring – RS – WS – Monitoring

C: Problem Solving – RS – WS - RT

- $SS\ within\ SSSS\ SS\ within\ wwiitthhiinn\ SS\ within$
- $SS\ between\ \ /\ \ LCS\ \mathrm{A,B}$
- $BBLLCCSS\ \ LCS\ \mathrm{A,B\ AA},\ \ LCS\ \mathrm{A,B}\ \ *$
  $2 - \ L\ \mathrm{B}\ LL\ L\ \mathrm{B\ BB}\ L\ \mathrm{B}\ \ \ L\ \mathrm{A}\ LL\ L\ \mathrm{A\ AA}\ L\ \mathrm{A} + =$
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C	4	2	-

- $F = \ SS\ between\ en\ between\ /\ SS_{within}$

Sequential Pattern Mining

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Subsequences that are associated with an item feature

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> **Discover frequent subsequences**

Sequential Pattern Mining

Subsequences that are associated with an item feature

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  - **50% support**

Sequential Pattern Mining

Subsequences that are associated with an item feature

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Sequential Pattern Mining

Subsequences that are associated with an item feature

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- **χ 2 2 2 2 test for each subsequence**

Sequential Pattern Mining

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Subseq 1	Present	Absent
Open	58	20
Closed	13	39

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Sequential Pattern Mining

Subsequences that are associated with an item feature

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- χ 2   2 2 2 test for each subsequence

Subseq 1	Present	Absent
Open	58	20
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Subseq 2	Present	Absent
Open	39	39
Closed	30	22

Results

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> **Openness**

Results

> **Openness**

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Results

- Openness
- Evidence of thinking
- Cognitive demands

Results: Proportional Frequency

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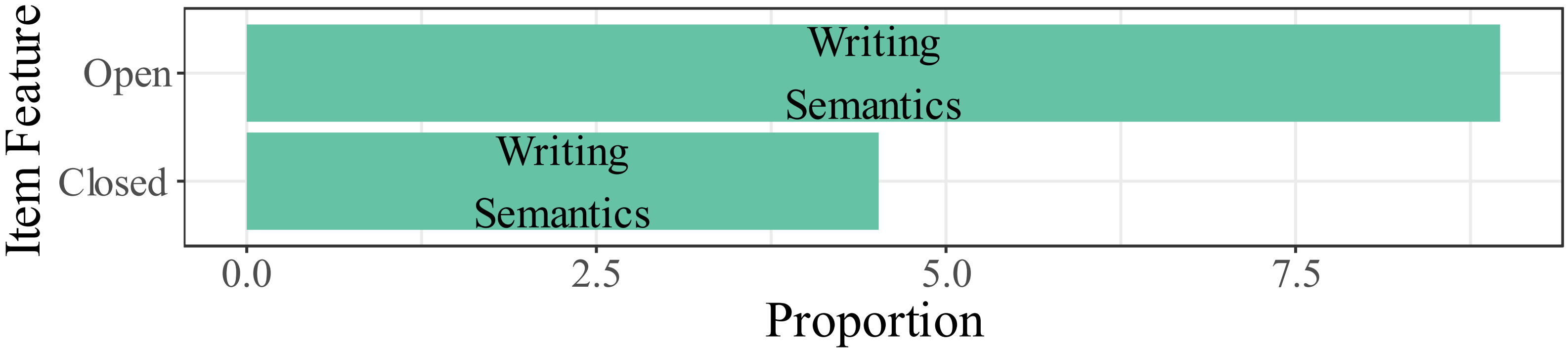

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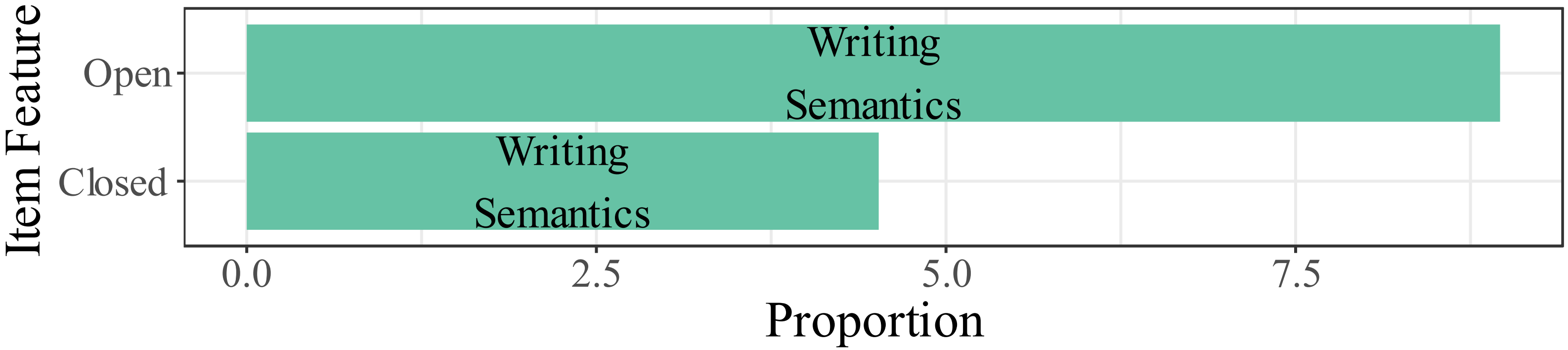

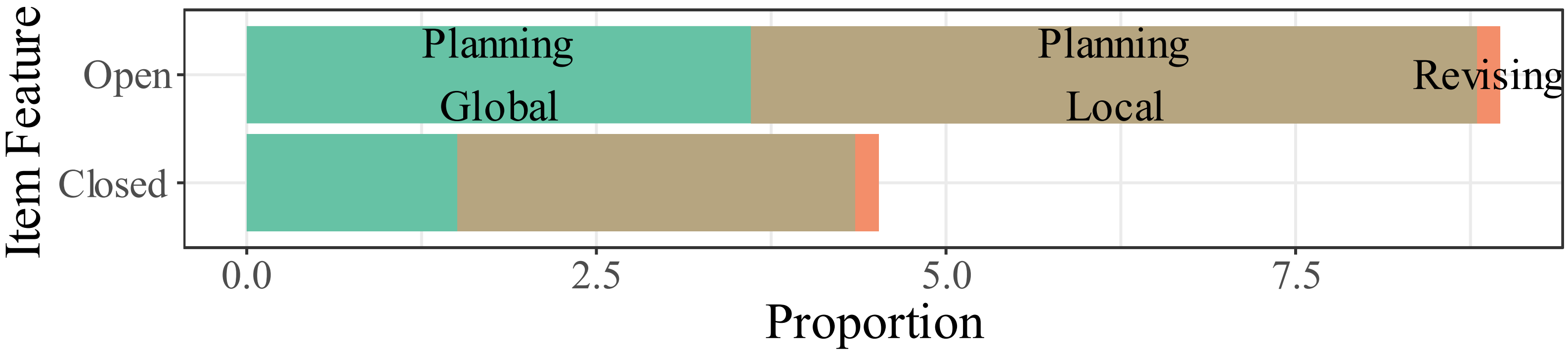

Results: Sequence Dissimilarity

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Summary of Pseudo-ANOVA results for sequence dissimilarity measure

	Sum of Squares	*df*	Mean Square	*pseudo- F*	*p*
Openness (open, closed)					
Explained	0.56	1	0.55	2.42	0.004
Residual	29.74	129	0.23		
Evidence (inferred, explicit)					
Explained	0.31	1	0.31	1.32	0.141
Residual	29.99	129	0.23		
Cognitive Demands (RS, RT, WS)					
Explained	5.17	2	2.59	13.18	0.001
Residual	25.13	128	0.20		

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Results: Sequential Pattern Mining

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Subsequences that discriminated best between open and closed writing items

Subsequence	*p*	Open	Closed
(typing syntax)-(planning: local)-(reread program specification)	0.23	0.75	0.19
(planning: local)-(typing syntax)-(reread program specification)	0.44	0.71	0.19
(planning: local)-(reread program specification)	0.61	0.75	0.25
(read program specification)-(planning: local)-(reread program specification)	0.61	0.75	0.25
(read task requirements)-(planning: local)-(reread program specification)	0.61	0.75	0.25
(typing syntax)-(planning: local)-(planning: local)	0.61	0.75	0.25
(planning: local)-(reread program specification)-(%)	0.87	0.71	0.25
(planning: local)-(reread program specification)-(typing syntax)	0.87	0.71	0.25
(typing syntax)-(reread program specification)-(planning: local)	0.95	0.75	0.31
(planning: local)-(typing syntax)-(typing syntax)	1.00	0.86	0.50

Results: Sequential Pattern Mining

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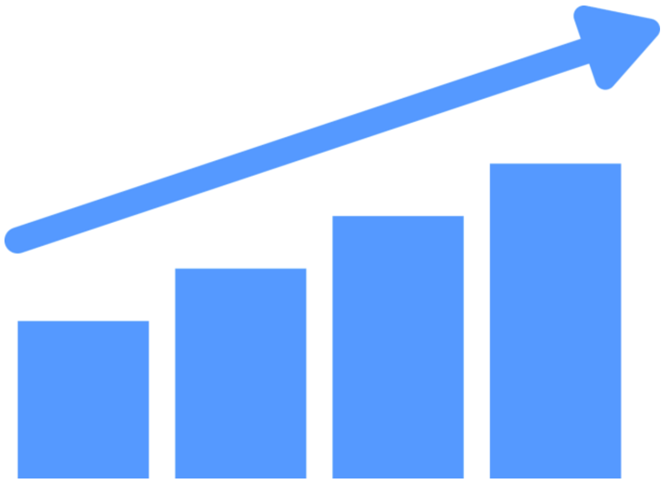

Conclusions

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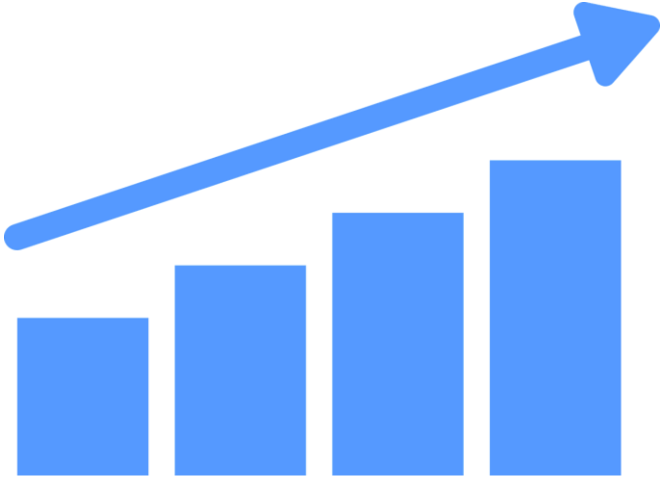
- Implications for the construct



Conclusions

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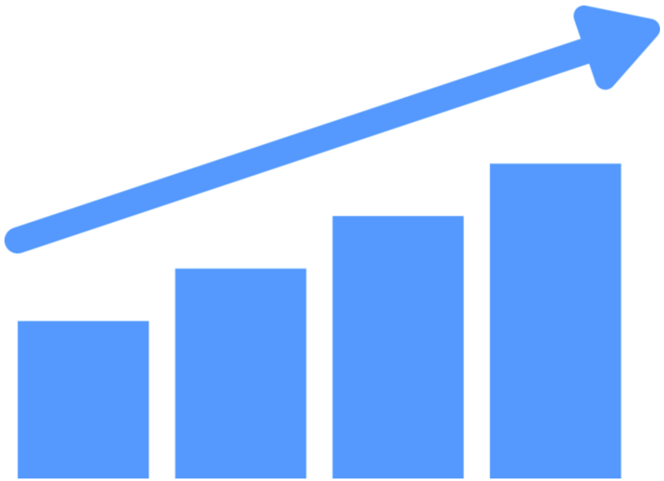
> Implications for the construct

> Response process validity



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> **Varying an item's openness influenced students planning and writing processes on code writing items.**

> **Sequence analysis techniques can be used to analyze response process data.**

More details about the methods in blog post at:

bit.ly/AERA21-sequences

Details on qualitative codes and results for all item features in the iPresentation:

bit.ly/AERA21-poster