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 the ancestral homelands of those who walked here before me and those who still walk here, keeping in mind the integrity of this territory where area Native peoples identify as the Duwamish, Suquamish, Snoqualmie, and Puyallup, as well as the tribes of the Muckleshoot, Tulalip, other Coast Salish peoples, and their descendants. I am grateful to respectfully live and work on these lands and to follow the leadership of community members who are Native and Indigenous, particularly those who are from these territories. 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

Response processes

- **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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Item features framework

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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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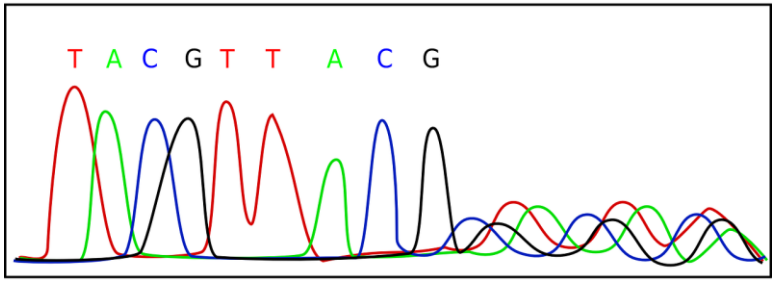
Data Analysis

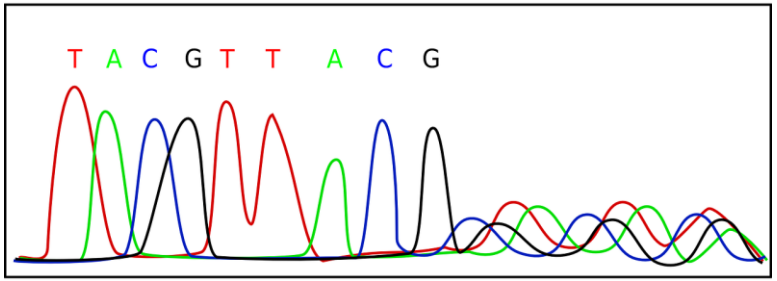
Data Analysis

- **Proportional frequency**



Data Analysis

- **Proportional frequency**
- **Sequence Dissimilarity**



Data Analysis

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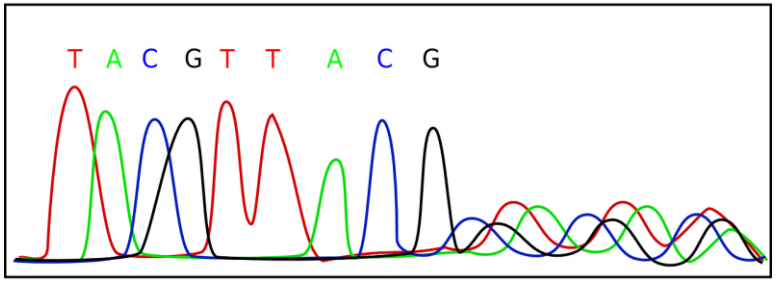

Proportional frequency

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
Open	.67	.75	.42
Closed	.23	.65	.34

Sequence Dissimilarity

= +

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= +

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

> $LCS\ \mathrm{A}, \mathrm{B}$

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

Sequence Dissimilarity

Broad differences in sequences, taking order into account

A: Monitoring – RS – RT – Problem Solving

B: Monitoring – RS – WS – Monitoring

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	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

	A	B	C
A	-	2	4
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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

- $SS\ within\ SSSS\ SS\ within\ wwiitthhiinn\ SS\ within$
- $SS\ between\ /\ LCS\ \mathrm{A}, \mathrm{B}$
- $BBLLCCSS\ \ LCS\ \mathrm{A}, \mathrm{B}\ \mathrm{AA},\ \ LCS\ \mathrm{A}, \mathrm{B}\ \ *$
  $2 - L\ \mathrm{B}\ LL\ L\ \mathrm{B}\ \mathrm{BB}\ L\ \mathrm{B}\quad L\ \mathrm{A}\ LL\ L\ \mathrm{A}\ \mathrm{AA}\ L\ \mathrm{A} + =$
  $\mathrm{BB}\ distance\ \mathrm{A}, \mathrm{B}\ \ distance\ \mathrm{A}, stance\ \mathrm{A}, \mathrm{B}\ \mathrm{A}, \mathrm{B}$
  $= L_{\mathrm{A}} + L_{\mathrm{B}} - 2 * LCS_{\mathrm{A,B}}$
- $SS =$ sum of pairwise distances
- $F = SS\ between\ en\ between\ /\ SS\ within$

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

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

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  - **50% support**

Sequential Pattern Mining

Subsequences that are associated with an item feature

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  - **Max length of 3**

Sequential Pattern Mining

Subsequences that are associated with an item feature

- **Discovertest for each subsequence**
  - **50% support**
  - **Max length of 3**

- **$\chi 2$ 2 2 2 test for each subsequence**

Sequential Pattern Mining

Subsequences that are associated with an item feature

- **Discovertest for each subsequence**
  - **50% support**
  - **Max length of 3**

Subseq 1	Present	Absent
Open	58	20
Closed	13	39

- $\chi 2 \;\; 2\,2\,2$ **test for each subsequence**

Sequential Pattern Mining

Subsequences that are associated with an item feature

- **Discovertest for each subsequence**
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- $\chi 2$ 2 2 2 **test for each subsequence**

Subseq 1	Present	Absent
Open	58	20
Closed	13	39

Subseq 2	Present	Absent
Open	39	39
Closed	30	22

Results

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- **Openness**

Results

- **Openness**
- **Evidence of thinking**

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- **Evidence of thinking**
- **Cognitive demands**

Results: Proportional Frequency

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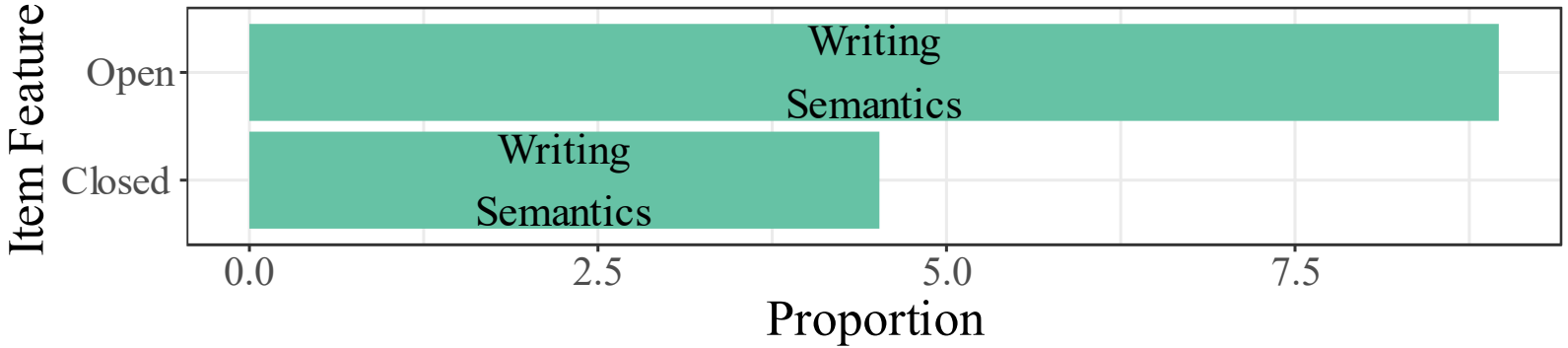

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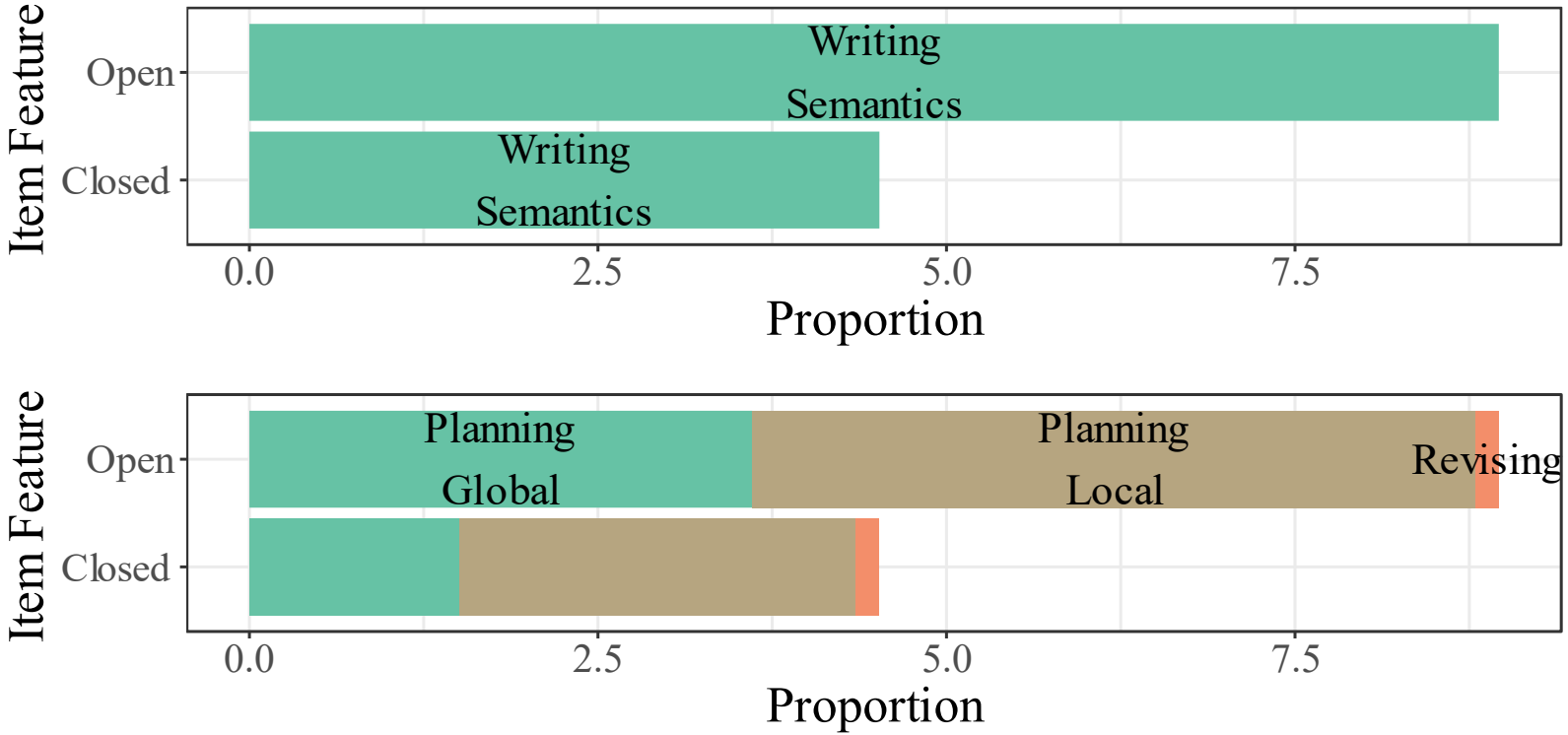

Results: Sequence Dissimilarity

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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

Subsequences that discriminated best between open and closed writing items

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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

Example Item

Consider the class:

```
public class Employee {
    int role;
    float salary;
}
```

Create a method with the following method header:

```
public int verifyEmployee(Employee e1, Employee e2);
```

The method has to obey the following rules:

R1: return -1 if e1's role is less than e2's and e1's salary is also less than e2's.

R2: return 0 if e1 and e1 have the same roles and salaries

R3: return 1 if e1's role is greater than e2's and e1's salary is also greater than e2's.

R4: return 2 if none of the previous rules could be verified

Write your code below.

Consider the class:

```
public class Employee {
    int role;
    float salary;
}
```

Write code to:

1. Create a method `verifyEmployee` that takes parameters `Employee e1` and `Employee e2`
2. Write a statement that returns a -1 if e1's role is less than e2's and e1's salary is also less than e2's
3. Write another statement that returns 0 if e1 and e1 have the same roles and salaries
4. Write another statement that returns a 1 if e1's role is greater than e2's and e1's salary is also greater than e2's.
5. Write a final line that returns a 2 if none of the previous rules could be verified

Write your code below.