Benefits of Ontologies for Collaborative Problem Solving Assessment

Jessica Andrews Todd

CRESSTCON'18

10/16/2018
Collaborative Problem Solving (CPS)

• CPS is a skill critical for success in the 21st century workforce

• Increased attention in the assessment community in the assessment of CPS
CPS and Assessment

• Focus for assessment:
  • Conceptualizing the construct
  • **Designing** environments that provide opportunities to display CPS skills
  • Determining **methods** for making **inferences** about individuals’ CPS skills

• No easy solutions given the complexity of CPS
In-Task Assessment Framework

I-TAF provides additional support for instantiating the student model, task model, and evidence model of evidence-centered design.
I-TAF in ECD

How do task affordances impact measurement?

How can the construct be operationalized in terms of behavior?

How can observables be identified in the data?

What components of the model are observable?
I-TAF Procedures

1. Generate an Ontology
   ✓ Delineate concepts and relationships

2. Expand to a Behavioral Ontology
   ✓ Identify potential strategies

3. Expand to a Cognitively Enhanced Ontology
   ✓ Link to tactics allowed by the task

4. Extract Features
   ✓ Identify relevant sections of log data

5. Create Chains-of-Evidence
   ✓ Link features to ontological concepts
Example Application

Teaching Teamwork: Level D
Circuit 1 (User: Lion, Group: Animals)

E is unknown, R0 is unknown, your goal is to make your voltage 9.23 volts.

Welcome! You can find your goal at the top of the screen. Use this area to chat with your teammates.

System: Lion has joined on Circuit 1. One of three users is here.

Enter chat message here...

Send Chat Message

Enter unknown values:
B:
R0:
Submit unknown values

[Diagram of a circuit with resistors and a multimeter]
Step 1: Generate an Ontology
Step 2: Expand to a Behavioral Ontology

[Diagram showing a hierarchical structure with nodes such as 'Collaborative Problem Solving', 'Sharing Information', 'Perspective Taking', 'Establish Shared Understanding', 'Share Status Update', 'Share Resources', 'Share Goals', 'Presentation Phase', 'Acceptance Phase', 'Make Status Statement', 'Make Resource Statement', 'Make Goal Statement', 'Disagree', 'Agree', 'Ask Clarify']
Step 3: Expand to a Cognitively Enhanced Ontology

- Latent or calculated variables
- Relationships between nodes
- Strategies
- Observed Actions
- Features
Uses for Ontologies
Develop Rubrics
<table>
<thead>
<tr>
<th>Dimension</th>
<th>Skill</th>
<th>Sub-Skill1</th>
<th>Sub-Skill2</th>
<th>Definition</th>
<th>Examples</th>
<th>Action Type</th>
</tr>
</thead>
</table>
| Cognitive   | Planning               | Develop Strategies                                                        |                                                                           | Devise a plan or strategy to reach the goal state, including the steps to be undertaken                         | • "Using the current we find E and we can do what we did last time"  
• "Ok now V=IR"  
• "Then we can find our R values using Ohm's Law"  
• "we set our values to R and find the current"  
• "Let's add up our values" | chat                                                                 | chat                                                                                                           |
|             |                        | Revise Strategies                                                          |                                                                           | Change to a different plan or strategy to solve the problem                                                  | • "Let's break the circuit instead"  
• "Let's try something else"  
• "Let's go higher"                                                       | chat                                                                                                           |
| Executing   |                        | Enact Strategies                                                           |                                                                           | Carry out the plan or strategy that has or has not been explicitly verbalized                                 | • "Engage in the behaviors consistent with the stated plan for the level (e.g., change resistor to the suggested resistance value, carry out suggested calculation in calculator); does not always have to occur after a stated plan (e.g., participant may carry out Ohm's Law strategy before informing teammates)" | exchange resistor; take measurement; calculate |
|             |                        | Suggest/Direct Actions                                                     |                                                                           | Make suggestion for action for teammate to carry out                                                        | • "Don't change anything"  
• "Enter your E and R values Bear"  
• "Adjust yours to 300 ohms"  
• "Sleet try now!"  
• "Wait!"  
• "Give me a sec"                                                                                     | chat                                                                                                           |
|             |                        | Report Actions                                                             |                                                                           | Communicate own actions being taken to carry out the plan                                                   | • "I set mine to 120°"  
• "I'm going to set mine higher"  
• "I used 100 ohms like you said"  
• "Let me go a little lower and then readjust"                                                           | chat                                                                                                           |
|             |                        | Monitor Success                                                            |                                                                           | Monitor progress toward the goal, including checking intermediate and final results, detecting unexpected events, and taking remedial action when required | • "State where you are or team is in relation to the goal state ("I'm good", "I got it", "We got it", "I'm too high", "I'm still a little low", "we're good")"  
• Click submit (submit values)                                                                                       | chat, click submit                                                                                             |
|             |                        | Monitor Group                                                              |                                                                           | Monitor whether teammates are present, following the rules of engagement, roles, completing tasks           | • "Prompt teammates to perform tasks ("Come on Snow", "You forgot to put in the voltage", "Let's get a move on Sleet", "Now")"  
• "Calling on teammates ("Lion", "Saagull", "Jessica")"  
• "Check on the status of teammates ("Where is Rain?")"  
• "Adapt team organization/roles"  
• "We need to figure this out"                                                                                       | open/close zoom; view board in zoom; chat                                                                 |

Measuring the Power of Learning.
Evidence Identification
Step 4: Extract Features

- Black: Color_of → Attach Probe → Location_of → Resistor
- Red: Color_of → Attach Probe
- Volts: Unit_of → Move DMM Dial
- Resistor: Location_of → Use Voltmeter
- Use Voltmeter: Prerequisite_for → Chat Value
- Chat Value: Value_of → Share Voltage Status
Feature Extraction Example

- **Resistor**: Location_of
- **Black**: Color_of
- **c20**: Prerequisite_for
- **V**: Value_of
- **Volts**: Unit_of
- **dcv_20**: Prerequisite_for
- **c14**: Color_of
- **Red**: Prerequisite_for
- **"my voltage went up to 4.78"**: Evidence_for
- **Share Voltage Status**: Value_of
Statistical and Psychometric Modeling
Modeling with I-TAF

• Use the ontology to generate a Student Model
• Compute aggregate features
  • Count, mean, etc
• Use aggregate features as “observables” in the Stat Model
Bayesian Networks

CPS Skill
- Excellent
- Good
- Fair
- Poor

Feature Frequency
- Frequent
- Average
- Rare

Feature Occurrence
- Present
- Absent

Predicted → Learned → Calculated
Generalizability
I-TAF Generalizability

- Use the same ontology & behavioral ontology
- Update dark gray nodes in the cognitively enhanced ontology
  - To represent different affordances in new task
- Update features
- Update chains-of-evidence
  - To extract the SAME observables
CPS Ontology for New Task

T-Shirt Math Task

The student council at Benuch Middle School is planning to sell school t-shirts to the students in the 8th grade class. There are about 300 students in the 8th grade class, but the student council does not expect that everyone will buy a t-shirt. The student council is considering three different companies to make the t-shirts.

1. **EZ Tees** charges $8 per shirt, and has a one-time setup fee of $200.
2. **Perfect Printing** charges $4 per shirt, and has a one-time setup fee of $500.
3. **Shirts For Less** charges a flat fee of $1,500 for up to 350 shirts.

1. Please talk with your partner and discuss which company you want to recommend. Write your recommendation and an explanation of why you chose that company below:

```markdown
No recommendation. We decided to use Shirts for Less, because the school estimated that not every student would buy a shirt, so we decided to use an estimate of 100 students buying a shirt. Because of this, it would be unreasonable to use Shirts for Less.
```

Next.
Conclusions

• I-TAF provides a principled approach for assessment of complex constructs in digital environments

• Ontologies are the main component of I-TAF
  • Help lay out the constructs we wish to measure in a principled way
  • Can serve as an anchor representation for other components of assessment such as scoring rubrics, evidence identification, and task design.
Acknowledgements

This material is based upon work supported by the Institute of Education Sciences under grant R305A170432 and the National Science Foundation under Grant 1535224. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Institute of Education Sciences or National Science Foundation.

This research is based upon collaborative efforts from Educational Testing Service (ETS), The Center for Occupational Research & Development (CORD), The Concord Consortium, the University of Colorado Boulder, and CRESST.