Using Semi-Structured Interviews and Multi-Layered Concept Maps to Generate an Initial Model of Physics Faculty Beliefs about Problem Solving *

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Generation and Modification of Explanatory Theoretical Models

Methodological and Theoretical Commitments and Prior Knowledge

Observations

Key:
Followed by

Stronger Influence

Weaker Influence

Generation of Initial Model

Rational and Empirical Criticism and Evaluation of Model

Modification of Model

Generation and Modification of Explanatory Theoretical Models

Generative Studies: Focus on formulating new constructs and new elements of a theoretical model.

Convergent Studies: Focus on providing reliable empirical findings to test and modify a theoretical model.

Explanatory theoretical models are more than just summaries of empirical observations, they are inventions that contribute new concepts. A useful explanatory model allows scientists to make predictions in other contexts and can lead to the creation of new lines of research.

Examples of explanatory models in physics: Waves, Fields

Why are Faculty Conceptions Important?

1. **Subject** (i.e., knowledge and beliefs about the subject they are teaching)
2. **Teaching and Learning** (e.g., pedagogical knowledge, orientation towards teaching)
3. **Context** (e.g., perceptions of student capabilities, perceptions of administrative constraints)

*e.g. Prosser & Trigwell (1999), Understanding Learning and Teaching*
Faculty Conceptions About Problem Solving

**Faculty Conceptions**

1. **Subject** (i.e., knowledge and beliefs about the subject they are teaching)
2. **Teaching and Learning** (e.g., pedagogical knowledge, orientation towards teaching)
3. **Context** (e.g., perceptions of student capabilities, perceptions of administrative constraints)

Faculty knowledge and beliefs about the problem solving process can shape:

- How they model/explain problem solving to students
- How they expect students to solve problems
- How they expect students to learn how to solve problems
- Their attitudes towards curricular materials
Semi-Structured Interview

- 3 types of artifacts
- 4 different situations

Different contexts allow for triangulation and may elicit different conceptions
1½ - 2 hour interview based on instructional artifacts

1st) 3 Instructor solutions: varied in the details of their explanation, physics approach, and presentation structure

2nd) 5 Student solutions: based on actual final examination solutions at the University of Minnesota to represent features of student practice

3rd) 4 Problem types: represent a range of the types of problems used in introductory physics courses

All artifacts were based on one problem -- instructors were given the problem and asked to solve it on their own before the interview.
Multi-Layered Concept Map Analysis

Individual Interview Statements → Individual Concept Maps → Combined Concept Maps
Analysis Flow Chart

Video- & audiotapes of interviews (~9 hrs)

Interview transcripts (~180 pages)

Statements (~2400)

Participant Concept Maps (15 x 6 = 90)

Composite Concept Maps (15)

Concept Maps allow for:

- the **reduction** of complex data into visual representations
- **explicit connections** to be made between ideas that can then be tested
Individual Faculty Conceptions about Problem Solving

Six research university faculty randomly selected

<table>
<thead>
<tr>
<th>Interview Participants</th>
<th>Gender</th>
<th>Years of Teaching Experience</th>
<th>Number of Times Taught an Introductory Calculus-Based Physics Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructor 1</td>
<td>M</td>
<td>~10</td>
<td>10</td>
</tr>
<tr>
<td>Instructor 2</td>
<td>M</td>
<td>No answer</td>
<td>More than 50</td>
</tr>
<tr>
<td>Instructor 3</td>
<td>M</td>
<td>Less than 5</td>
<td>1</td>
</tr>
<tr>
<td>Instructor 4</td>
<td>M</td>
<td>~40</td>
<td>15</td>
</tr>
<tr>
<td>Instructor 5</td>
<td>M</td>
<td>~20</td>
<td>5</td>
</tr>
<tr>
<td>Instructor 6</td>
<td>M</td>
<td>~30</td>
<td>1</td>
</tr>
</tbody>
</table>

Interviews were videotaped and the audio portion transcribed:
~ 30 pages of text/interview
Combined Faculty Conceptions about Problem Solving
The Initial Model:

Three distinct views of problem solving
The Problem Solving Process

**the PER perspective***

1. **Qualitative Analysis**
   - Visualize what is happening
   - Draw diagrams
   - Identify goal

2. **Construct Solution**
   - Sequentially choose sub problems that reduce the gap between goal and known information
   - Identify Options (e.g., principles or definitions)
   - Pick Useful Option
   - Implement
   - Check Progress

3. **Check**
   - Goal attained?
   - Well specified?
   - Self consistent? (units, signs)
   - Consistent with other information? (e.g., special cases)
   - Optimal? (as clear and simple as possible)

Options limited by:
1) Well organized knowledge structure
2) Ability to recognize similarities with previously solved problems

*Based largely on Reif (1995) in AJP*
### Three Distinct Views of Problem Solving (The Initial Model Generated in This Study)

<table>
<thead>
<tr>
<th>View 1: A linear decision-making process (backtracking is not necessary) (3 of 6)</th>
<th>View 2: A process of exploration and trial and error process (2 of 6)</th>
<th>View 3: An art form that is different for each problem (1 of 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1: Decide on physics principles</td>
<td>Step 1: Decide where to start (e.g., target to known)</td>
<td>(no process)</td>
</tr>
<tr>
<td>Step 2: Clarify thinking (e.g. by using diagrams)</td>
<td>Step 2: Explore the problem and come up with approaches to try</td>
<td></td>
</tr>
<tr>
<td>Step 3: Use tools (e.g., algebra, FBD) to get answer</td>
<td>Step 3: Try most promising approach</td>
<td></td>
</tr>
<tr>
<td>Step 4: Evaluate answer</td>
<td>Step 4: Evaluate progress (return to step 2 if necessary)</td>
<td></td>
</tr>
</tbody>
</table>
The Problem Solving Process
Conception 1: A linear decision-making  (3 instructors)

? – How are the correct physics principles selected?
The Problem Solving Process

Conception 2: A process of exploration and trial and error

1. Explore the problem
2. Come up with possible approaches to try
   - Try most promising approach
3. Check

Options limited by:
1) Well organized knowledge structure
2) Ability to recognize similarities with previously solved problems

? – How are the number of possible approaches limited?
The Problem Solving Process

Conception 3: An art form that is different for each problem

(1 instructor)
Conclusions
There are differences between the PER view of the PS process and the five instructors who identified a process:

- Main difference is the identification of choices in decision making

No choices – predetermined (algorithm)

Linear Decision Making (3 instructors)
Experience is everything

PER – Strategic Decision Making
- Knowledge Structure
- Strategy

Monitoring progress is everything

Trial & Error (2 instructors)

Infinite choices (random)
### Implications for Instruction

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<th>Teaching Activity</th>
<th>Learning Activity</th>
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<td>No choices – predetermined (algorithm)</td>
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### Linear Decision Making (3 instructors)
- Instruction likely to emphasize error-free and mechanical performance
- Students likely adopt strategy of rote memorization

### PER – Strategic Decision Making
- Instruction likely to emphasize knowledge organization and PS strategy
- Students likely adopt strategy of rote memorization

### Trial & Error (2 instructors)
- Instruction likely to treat making choices as “magic”
- Students likely adopt strategy of rote memorization
Implications for Curriculum/Professional Development Providers

1. There are things to build on: basic building blocks of problem solving process are there.

2. There are opposite views within the community. Through collaboration it’s easier to move towards the center than towards an extreme.
This Method is Well-Suited for Generative Studies

Advantages:
• Use of concrete artifacts allows interview to elicit implicit as well as explicit conceptions
• Different situations provide triangulation
• Concept map analysis:
  • provides a powerful representation tool to show complex interrelations between conceptions
  • forces the researchers to be explicit about claimed interrelations in the data
  • establishes a transparent link between the results and the raw data.

Disadvantages
• Analysis is time consuming → limits sample size
• Interviews are lengthy and must be done in person → limits potential participants