Faculty Conceptions About the Teaching and Learning of Problem Solving*

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http://www.physics.umn.edu/groups/physed/

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Recent Graduates
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Dr. Laura McCullough (2000), Assistant Professor, UW-Stout

Some Current Projects:
• Curriculum development at the introductory level: Problem Solving Focus (Cooperative Group Problem Solving, Problem Solving Laboratories, Problem Solving Framework w/ Context Rich Problems)
• Research into stability of curricular changes and faculty adoption of innovative curricula (Faculty Conceptions)
• Student-Centered Curriculum Development (CPU - high school and college; CIPS – middle school)
Overview

1. Why study faculty conceptions?
2. Research Methods
   - The Interview Tool
   - Selecting Faculty for Interviews
   - Analyzing Interview Data
3. What can we do with the results?
The Instructional Problem

Initial State of Learner → Transformation Process (i.e. Instruction) → Desired Final State of Learner

Instructor

Reif (1995), *AJP 63(1)*
What do we know from Physics Education Research?

Misconceptions
Formula-Based Problem Solving

Appropriate Instruction

Correct Physics Content
Principle-Based Problem Solving

Misconceptions
Formula-Based Problem Solving

Appropriate Instruction

Correct Physics Content
Principle-Based Problem Solving

Cooperative Group Problem Solving (Heller et. al.)
Overview, Case Study (Van Heuvelen et. al.)
Personal Assistants for Learning (Reif et. al.)

Peer Instruction (Mazur et. al.)
Tutorials (McDermott et. al.)
Minds on Physics (Mestre et. al.)
Workshop Physics (Laws et. al.)
What is the difficulty with these research-based curricular materials? Why aren’t they widely used?

• Our theory: The available curricular materials do not fit well with faculty conceptions (i.e. beliefs, values, knowledge, etc.) of teaching and learning

• If this is the case then we have two choices:

  1. Change the curricular materials
     (curricular materials built on faculty conceptions are more likely to be used and more likely to be used appropriately)

  2. Change the faculty conceptions
     We know from students:
     • Changing conceptions is hard.
     • In order to change conceptions it is first necessary to determine what the current conceptions are.
Goal of this Study

- Begin the process of building a model of faculty conceptions (beliefs and values) about the teaching and learning of problem solving in introductory calculus-based physics.
  - Can (how can) faculty conceptions be measured?
  - Can (how can) a model be constructed to describe these conceptions?
    - What are the important parts of this model?
    - How are these parts related?

- The focus of this study is on problem solving because the Physics Education Research Group at UMN is interested in problem solving.
The Interview Tool

To investigate faculty conceptions, we developed a 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.
Example - Part 1, Instructor solution

Q1: In what situations [during lecture, after test...] are students provided with examples of solved problems in your class. How does this work?
Q2: How would you like your students to use the solved examples you give them in these different situations? Why?

Abstract/General

Q3: Scan through each of these instructor solutions. Please describe how these solutions are similar or different to your solutions. Please explain your reasons for writing solutions the way you do.

Concrete/Specific Artifacts

Q4: Looking at the instructor solutions, what aspects/components that you consider important in problem solving are represented in these instructor solutions, and what aspects are not represented?

Conceptions of Problem Solving
Selecting Faculty for Interviews

Physics faculty in Minnesota (~107 meet selection criteria):

• taught introductory calculus-based physics course in the last 5 years
• could be visited and interviewed in a single day

Sample Randomly Selected:

30 faculty members
(From 35 contacted, 5 declined to be interviewed)

Roughly evenly divided among:
1) Community College (CC) N = 7
2) Private College (PC) N = 9
3) Research University (RU) N = 6
4) State University (SU) N=8

Interviews were videotaped and the audio portion transcribed:

~ 30 pages of text/interview
Data Analysis

Phase I: 1. Determine if the conceptions of 6 UMN faculty are coherent enough to allow a model to be developed.
2. If so, develop an initial model of faculty conceptions based on these 6 faculty.
   (My Thesis!)

Phase II: Refine and expand the initial model based on remaining 24 faculty from different institutions.
   (Vince Kuo’s Thesis)

Phase III: Determine the distribution of conceptions among faculty using a larger national sample.
Phase I: Final Product

Final product is a concept map that describes an initial, testable model of how faculty think about the teaching and learning of problem solving.
Main Concept Map – Learning of Problem Solving

- Some College Students
  - learn how to
  - Students' Current State
  - affects how they
  - Engage in Learning Activities
    - while they
    - Working
      - while/after
      - on the
      - appropriate problems
        - to (Path A)
      - individualized responses
        - to (Path B)
      - can be
    - Feedback
      - of using
    - Looking/Listening
      - can be
      - can be
      - can be
      - to (Path C)
    - Lectures
      - can be
    - appropriate knowledge
      - get the
Main Concept Map – Teaching and Learning of Problem Solving
Feature Maps Contain Details:

1. Some College Students

- who have not enough natural ability (RU2, RU3-unclear, RU4, RU6)
- who have enough natural ability (RU2-unclear, RU4, RU5, RU6)
- more than enough natural ability (RU1-unclear, RU3, RU6)

characteristics detrimental to learning (RU2, RU3, RU4, RU5, RU6)

- cannot be helped much by instructor and
- do not learn

characteristics beneficial to learning (RU1, RU2, RU4, RU5, RU6)

- and have
- do learn

2. Solve Physics Problems

- how to
- do not need much instructor help and
Feature Maps Contain Details:

1. Some College Students

- who have
  - not enough natural ability (RU2, RU3-unclear, RU4, RU6)
- who have
  - enough natural ability (RU2-unclear, RU4, RU5, RU6)
- who have
  - more than enough natural ability (RU1-unclear, RU3,)

2. Solve Physics Problems

- do not learn
  - characteristics detrimental to learning (RU2, RU3, RU4, RU5, RU6)
  - Don't Care/ Not Hard Working (RU2, RU3, RU4, RU5, RU6)
  - Poor Study Habits (Reflection) (RU2, RU3, RU4, RU6)
  - Personal Characteristics (RU1, RU6)
  - No Interest in Physics (RU2, RU5)
  - cannot be helped much by instructor and
- do learn
  - characteristics beneficial to learning (RU1, RU2, RU4, RU5, RU6)
  - Motivation/ Hard Working (RU1, RU2, RU4, RU5, RU6)
  - Good Study Habits (Reflection) (RU2, RU4, RU5)
  - Personal Characteristics (RU1, RU5, RU6)
  - Interest in Physics (RU2, RU6)
  - do not need much instructor help and

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Feature Maps Contain Details:

1. Some College Students

- Not enough natural ability (RU2, RU3-unclear, RU4, RU6)
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  - Poor Study Habits (Reflection) (RU2, RU3, RU4, RU6)
  - Personal Characteristics (RU1, RU6)
  - No Interest in Physics (RU2, RU5)
- Characteristics detrimental to learning (RU2, RU3, RU4, RU5, RU6)
- Think they can't do it (RU6)
- Cannot be helped much by instructor and... (RU2, RU5)

2. Solve Physics Problems

- How to...

3. Characteristics beneficial to learning (RU1, RU2, RU4, RU5, RU6)

4. More than enough natural ability (RU1-unclear, RU3,)

- Motivation/ Hard Working (RU1, RU2, RU4, RU5, RU6)
- Personal Characteristics (RU1, RU5, RU6)
- Interests in Physics (RU2, RU6)
- Enjoy a Challenge (RU6)
- Being Outgoing (RU1)
- Maturity (RU5)
- Ability to admit they don't know something (RU5)
- Analyze quiz mistakes to learn from them (RU2)
- Relying on formulas rather than a real understanding (RU6)
- Do not look at posted solutions (RU3)

- Do not need much instructor help and... (RU2, RU5, RU6)
- Do learn
- Characteristics beneficial to learning (RU1, RU2, RU4, RU5, RU6)
- Enthusiasm (RU1)
- Good Study Habits (Reflection) (RU2, RU4, RU5)
- Personality Characteristics (RU1, RU5, RU6)
- Interest in Physics (RU2, RU6)
- Personal Characteristics (RU1, RU5, RU6)
- Interests in Physics (RU2, RU6)
- Enjoy a Challenge (RU6)
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- Do not learn
- Characteristics detrimental to learning (RU2, RU3, RU4, RU5, RU6)
- Think they can't do it (RU6)
- Cannot be helped much by instructor and... (RU2, RU5)

- And have
- And have
Feature Maps Contain Details:

1. Some College Students
   - who have not enough natural ability (RU2, RU3-unclear, RU4, RU6)
   - who have most students (RU3, RU5)
   - who have ~33% of students (RU6)

   characteristics detrimental to learning (RU2, RU3, RU4, RU5, RU6)
   - Poor Study Habits (Reflection) (RU2, RU3, RU4, RU6)
   - Personal Characteristics (RU1, RU6)
   - No Interest in Physics (RU2, RU5)
   - do not look at posted solutions (RU3)
   - relying on formulas rather than a real understanding (RU6)
   - think they can't do it (RU6)

   do not learn

   how to

2. Solve Physics Problems
   - 10-15% of students (RU2)
   - ~25% of students (RU4)
   - ~33% of students (RU6)

   Motivation/ Hard Working (RU1, RU2, RU4, RU5, RU6)
   - Good Study Habits (Reflection) (RU2, RU4, RU5)
   - Personal Characteristics (RU1, RU5, RU6)
   - Interest in Physics (RU2, RU6)
   - analyze quiz mistakes to learn from them (RU2)
   - ability to admit they don't know something (RU5)
   - maturity (RU5)
   - enjoy a challenge (RU6)
   - being outgoing (RU1)
   - ~25% of students (RU4)
   - ~33% of students (RU6)
   - a few students (RU3, RU5)
   - do not need much instructor help and
   - do not look at posted solutions (RU3)
   - relying on formulas rather than a real understanding (RU6)
   - think they can't do it (RU6)

   characteristics beneficial to learning (RU1, RU2, RU4, RU5, RU6)
   - Don't Care/ Not Hard Working (RU2, RU3, RU4, RU5, RU6)
   - ~33% of students (RU6)

   do learn

   do not need much instructor help and

   ~33% of students (RU6)
Feature Maps Contain Details:

1. Some College Students

- not enough natural ability (RU2, RU3, RU4, RU6)
  - do not look at posted solutions (RU3)
  - reliance on formulas rather than real understanding (RU6)
  - think they can't do it (RU6)
- most students (RU3, RU5)
- ~33% of students (RU6)
- personal characteristics (RU1, RU6)
- no interest in physics (RU2, RU5)

- characteristics detrimental to learning (RU2, RU3, RU4, RU5, RU6)
  - Don't Care/ Not Hard Working (RU2, RU3, RU4, RU5, RU6)
  - poor study habits (reflection) (RU2, RU3, RU4, RU6)
- characteristics beneficial to learning (RU1, RU2, RU4, RU5, RU6)
  - motivation/hard working (RU1, RU2, RU4, RU5, RU6)
  - good study habits (reflection) (RU2, RU4, RU5)
  - personal characteristics (RU1, RU5, RU6)
  - interest in physics (RU2, RU6)

- do not learn
  - cannot be helped much by instructor and
- do learn
  - do not need much instructor help and

2. Solve Physics Problems

- ~10-15% of students (RU2)
- ~25% of students (RU4)
- ~33% of students (RU6)
- more than ~33% of students (RU6)
- a few students (RU3, RU5)

- motivation/hard working (RU1, RU2, RU4, RU5, RU6)
- good study habits (reflection) (RU2, RU4, RU5)
- personal characteristics (RU1, RU5, RU6)
- interest in physics (RU2, RU6)

- analyze quiz mistakes to learn from them (RU2)
- ability to admit they don't know something (RU5)
- maturity (RU5)
- enjoy a challenge (RU6)
- being outgoing (RU1)
Phase I:

Procedure

(an iterative process)
Video- & audiotapes of interviews (~9 hrs)

Why Concept Maps?

Interview transcripts (~180 pages)

Statement (~2400)

Concept Maps (15 x 6 = 90)

Combined Concept Map (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
What Can We Do With this Model of Faculty Conceptions?

• Explore faculty conceptions about how students learn and how faculty can help students learn.
What do Faculty Talk About?

![Bar Chart](chart.png)

- **Path A - Working**: 
  - Student Learning Activities: 8
  - Instructor Management Activities: 12

- **Path B - Using Feedback**: 
  - Student Learning Activities: 25
  - Instructor Management Activities: 30

- **Path C - Looking/Listening**: 
  - Student Learning Activities: 5
  - Instructor Management Activities: 10

Legend:
- Blue: Student Learning Activities
- Light Purple: Instructor Management Activities
## Summary of Management Activities

<table>
<thead>
<tr>
<th>Setting Constraints</th>
<th>Making Suggestions</th>
<th>Providing Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Working (Path A)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On problems that students work (6 of 6)</td>
<td></td>
<td>Of appropriate problems (6 of 6)</td>
</tr>
<tr>
<td>On situations in which students work problems (3 of 6)</td>
<td>That students work on problems (3 of 6)</td>
<td></td>
</tr>
<tr>
<td><strong>Using Feedback (Path B)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>That students work on problems by collecting solutions: test (6 of 6), in-class work (2 of 6), HW (1 of 6)</td>
<td>That students work on problems (HW) (4 of 6)</td>
<td>Of grades on students solutions (6 of 6)</td>
</tr>
<tr>
<td>By arranging class time for small group work (4 of 6)</td>
<td></td>
<td>Of appropriate example solutions (6 of 6)</td>
</tr>
<tr>
<td></td>
<td>That students come to office hours (3 of 6)</td>
<td>Of peer coaching (4 of 6)</td>
</tr>
<tr>
<td><strong>Looking/Listening (Path C)</strong></td>
<td></td>
<td>Of solving problems on the board during lecture to convey information (6 of 6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Of talking about problem solving techniques (4 of 6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Of solving problems on the board during lecture to develop student interest (2 of 6)</td>
</tr>
</tbody>
</table>
Conclusion (so far)

• Faculty seem to see their job as setting up situations in which students can learn (providing resources, not setting constraints)
  ▪ Students are expected to take responsibility for their own learning (similar to findings of Gallagher & Tobin, 1987)
  ▪ Implication → Faculty will likely be reluctant to use curricular materials/methods that place more emphasis on setting constraints

• Faculty did not talk much about what students need to do to learn
  ▪ They appear to think that path B (student uses feedback while/after solving problems) is the most effective way to learn, but don’t give many details.
  ▪ Implication → Faculty may lack an explicit understanding about how students learn (similar to findings of Prosser & Trigwell, 1999)
The Resource of Example Problem Solutions

• All six instructors described their management related to this resource as:
  • Assigning test or homework problems for students to work on and then provide written solutions (path B – working and then using feedback)
    • Instructors think that students will learn by comparing these EPS to their test/HW solutions – but, they don’t believe students do this
    • Instructors don’t attempt to manage the situation further
  • Working example problems (that students have not previously seen) on the board during lecture (path C – looking)
    • Instructors don’t talk much about what students do in this situation or how this leads to learning
    • Instructors don’t attempt to manage the situation further
“Bare-Bones Solution”

The tension does no work

Conservation of energy between point A and B

\[ \frac{1}{2} m v_A^2 = mgh \]

\[ v_A^2 = 2gh \]

At point A, Newton’s 2\textsuperscript{nd} Law gives us:

\[ T - w = ma \]

\[ T - w = \frac{mv_A^2}{R} \]

\[ T = 18N + 2 \cdot 18 \cdot 23 \text{m} \cdot \frac{.65}{m} = 1292N \]
Include clarifying comments.

Each step explicitly written and goal clearly stated.

"Emphasis on Details"
“Emphasis on Reasoning”

Restating the question in physics terms

Planning the solution – including reasoning for each step

Starts from the target quantity (Tension)

Evaluation of final answer
Providing Resources of Example Problem Solutions

• All 6 instructors:
  • Distinguish between:
    • less detailed solution (IS1)
    • more detailed solutions (IS2, IS3)
  • Favored using solutions more detailed than IS1

• 4 of the 6 instructors:
  • Said that their solutions were similar to IS1
### Factors Affecting an Instructor’s Choice of Example Problem Solutions

<table>
<thead>
<tr>
<th>How will it affect student learning?</th>
<th>Less Detailed (IS1)</th>
<th>More Detailed (IS2, IS3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students who were not able to do the problem might not be able to understand the solution (1 of 6)</td>
<td>Makes it clear what is happening so students who had trouble can understand (6 of 6)</td>
<td>Can confuse students by discussing complications that some will not think of (3 of 6)</td>
</tr>
<tr>
<td>Makes the solution seem easier so students might read it (2 of 6)</td>
<td>Can scare off students by having too many steps (4 of 6)</td>
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<td>Easy to write or find in solution manual (4 of 6)</td>
<td>I’m not good at spelling things out in detail like that (1 of 6)</td>
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<th>Will students use it?</th>
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</table>

<table>
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<tr>
<th>How hard is it to create?</th>
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**Notes:**
- Makes it clear what is happening so students who had trouble can understand (6 of 6)
- Can confuse students by discussing complications that some will not think of (3 of 6)
- Can scare off students by having too many steps (4 of 6)
- I’m not good at spelling things out in detail like that (1 of 6)
What Types of Details do Instructors Prefer?

5 of the 6 instructors favored IS3 (over IS2)

<table>
<thead>
<tr>
<th>IS2 (Emphasis on Details)</th>
<th>IS3 (Emphasis on Reasoning)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Clear Steps</td>
<td>• Plans before execution</td>
</tr>
<tr>
<td></td>
<td>• Evaluates answer</td>
</tr>
<tr>
<td>• Starts from known quantity</td>
<td>• Explains reasoning</td>
</tr>
<tr>
<td>• Jumps right in with calculations</td>
<td>• Starts from target quantity</td>
</tr>
<tr>
<td>• Systematic approach implies that there is a standard way to do problems</td>
<td></td>
</tr>
</tbody>
</table>
### Instructor Solution 3 Has Features of Expert Problem Solving

<table>
<thead>
<tr>
<th>Features of Expert Problem Solving in Instructor Solution 3:</th>
<th>Instructors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Restates problem in physics terms</td>
<td>1</td>
</tr>
<tr>
<td>2. Starts from target (goal) quantity</td>
<td>✓</td>
</tr>
<tr>
<td>3. Plans first then executes</td>
<td>✓</td>
</tr>
<tr>
<td>4. Evaluates answer</td>
<td></td>
</tr>
</tbody>
</table>

**All features of expertise noticed were described as desirable**
Conclusions – Faculty Management

• Faculty do little to actively manage student use of problem solutions – they simply provide the resource of example problem solutions.
• Faculty consider three factors when deciding what types of solutions to use:
  • How hard is it to create the solution? (Good predictor of use)
  • How will the solution affect student learning?
  • Will students use the solution?
Conclusions – Resource of Example Problem Solutions

• Faculty are dissatisfied with the solutions that they currently use.

• Implications: This is an opportunity for curriculum developers to influence the current practice by developing solutions that:
  
  • Make reasoning clear (especially by showing planning)
  
  • But are not
  
  • Too complicated \(\rightarrow\) Confuse students
  
  • Too long \(\rightarrow\) Scare students
Conclusions – Features of Expertise

• Faculty value features of expertise that they recognize in problem solutions.

• Faculty do not appear to recognize all features of expertise in problem solutions.
  • Many notice planning before execution
  • Few notice restating the problem in physics terms
  • Some notice:
    • starting from target quantity
    • evaluating answer

• Implications: Faculty may be unable to model features of expert problem solving in their problem solutions. (Similar to research on expertise -- experts solve problems with little conscious thought and have trouble making their thinking explicit – see Dreyfus & Dreyfus, 1986.)
Summary

• It’s important to find out about faculty conceptions because these conceptions strongly influence their instructional choices.

• Based on the initial model developed from a detailed analysis of 6 University of MN professors:
  • Faculty seem to see their job as setting up situations in which students can learn (providing resources, making suggestions) rather than setting constraints that require students to do certain things.
  • Faculty may lack an explicit understanding about how students learn.
  • Because they are expert problem solvers, faculty may not have an explicit understanding of the problem solving process. This makes it difficult for them to explain this process to students.
Summary - Continued

• Faculty consider three factors when deciding what types of solutions to use (these same three factors hold true for the other resources):
  • How hard is it to create the solution? (Good predictor of use)
  • How will the solution affect student learning?
  • Will students use the solution?
The End

For more information, visit our web site at:

http://www.physics.umn.edu/groups/physed/