University of North Dakota, Grand Forks

Instructor's Ideas about Problem Solving*

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*Supported in part by NSF grant #DUE-9972470

UMN
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Faculty
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Recent Graduates
Dr. Charles Henderson (2002), Assistant Professor, UWM
Dr. Tom Foster (2000), Assistant Professor, SIUE
Dr. Laura McCullough (2000), Assistant Professor, UW-Stout

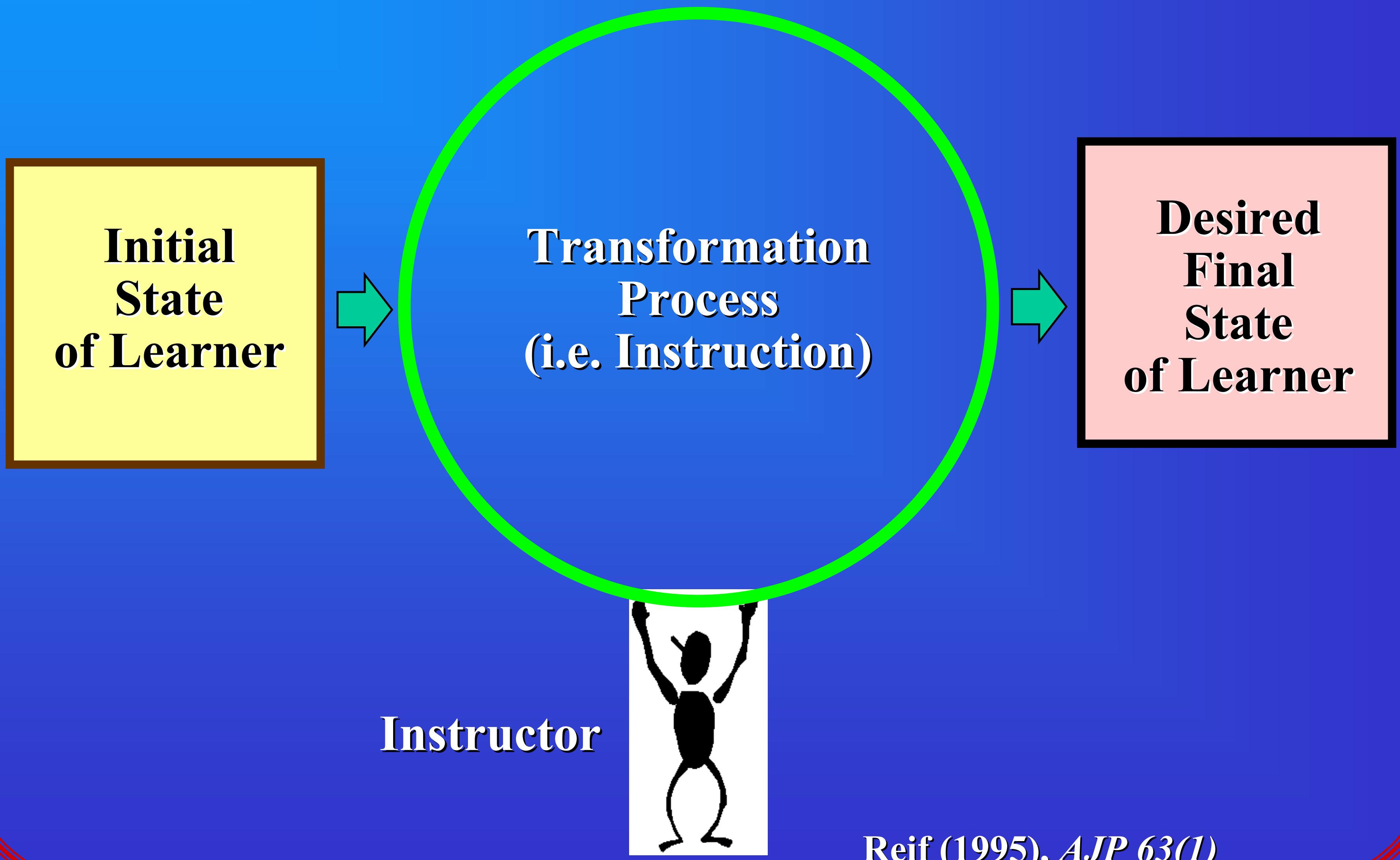
Some Current Projects:

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

Overview of talk

1. Why study faculty conceptions?
2. Research Methods
   - The Interview Tool
   - Selecting Faculty for Interviews
   - Analyzing Interview Data
3. Preliminary Results – first stage
4. Current stage
5. Hypotheses & Implications

The Instructional Problem



Reif (1995), *AJP 63(1)*

Ideal Introductory Physics

Transformation Process

Misconceptions

Formula-Based Problem Solving

Appropriate Instruction

Correct Conceptions

Principle-Based Problem Solving

Instructor

Van Heuvelen (1991), *AJP 59(10)*

Traditional Introductory Physics

Transformation Process

Misconceptions

Formula-Based Problem Solving

→

Traditional Instruction

(i.e. teacher-centered lecture, verification labs, textbook problems)

→

Misconceptions

Formula-Based Problem Solving

Instructor

Van Heuvelen (1991), *AJP 59(10)*

Physics Education To The Rescue

Transformation Process

Misconceptions

Formula-Based Problem Solving

Traditional Instruction
(i.e. teacher-centered lecture, verification labs, textbook problems)

Misconceptions

Formula-Based Problem Solving

Overview, Case Study
(Van Heuvelen et. al.)

Cooperative Group Problem Solving
(Heller et. al.)

Peer Instruction
(Mazur et. al.)

Personal Assistants for Learning
(Reif et. al.)

Instructor

Minds on Physics
(Mestre et. al.)

Tutorials
(McDermott et. al.)

Workshop Physics
(Laws et. al.)

Why don't more faculty stop using traditional instruction and start using research based curricular materials?

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

If this is the case then we need to either:

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

Why are Faculty Conceptions Important?

Faculty Conceptions → Influence* → **Faculty Teaching Activities** → Influence* → **Student Learning**

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)

1. Selection of teaching approach
2. Selection of teaching materials
3. Evaluation of teaching

*e.g. Prosser & Trigwell (1999), Understanding Learning and Teaching

Focus of This Talk

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

Influences

1. How they model/explain problem solving to students
2. How they expect students to solve problems
3. How they expect students to learn how to solve problems
4. Their attitudes towards curricular materials

Who Needs to Understand Faculty Conceptions?

Curriculum Developers Need to Understand Faculty Conceptions:

- Instructional materials and/or strategies may not align with faculty conceptions:
  - Non Use by faculty
  - Inappropriate Use by Faculty

Professional Development Providers Need to Understand Faculty Conceptions:

- Identify faculty strengths (build on p-prims)
- Identify "gaps" in faculty conceptions (help bridge gap)
- Identify conflicting conceptions (promote disequilibrium)

Overview of Study

Exploratory Study – Small Sample

- Initial model based on 6 UMN faculty
- Refine and expand the initial model based on 24 interviews with faculty from different institutions in the state of MN
- Determine the distribution of conceptions among faculty using a larger national sample
- Sharpen understanding using an international sample

Focused Study – Large Sample

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.

Problem Used in the Interview

You are whirling a stone tied to the end of a string around in a vertical circle having a radius of 65 cm. You wish to whirl the stone fast enough so that when it is released at the point where the stone is moving directly upward it will rise to a **maximum height of 23 meters** above the lowest point in the circle. In order to do this, **what force will you have to exert on the string** when the stone passes through its lowest point one-quarter turn before release? Assume that by the time that you have gotten the stone going and it makes its final turn around the circle, you are holding the end of the string at a fixed position. **Assume also that air resistance can be neglected.** The stone weighs 18 N.

Final examination question (Fall, 1997)

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

Overview of Study

Exploratory Study – Small Sample

First

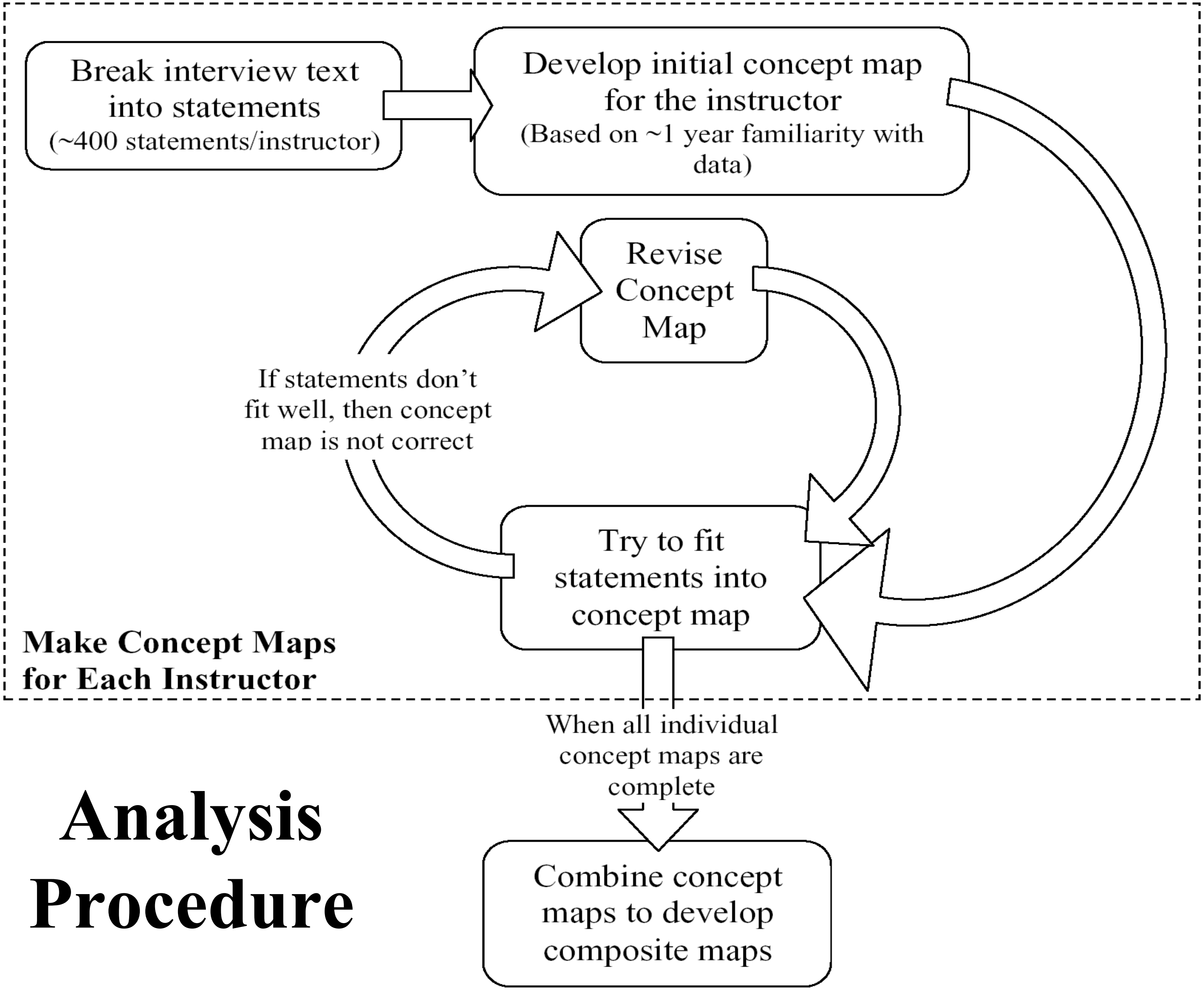
• Initial model based on 6 UMN faculty

• Refine and expand the initial model based on 24 interviews with faculty from different institutions in the state of MN

• Determine the distribution of conceptions among faculty using a larger national sample

• Sharpen understanding using an international sample

Focused Study – Large Sample



Analysis Procedure

Why Concept Map?

Video- & audiotapes of 6 interviews **(> 9 hrs)**

→ Interview transcripts **(>180 pages)**

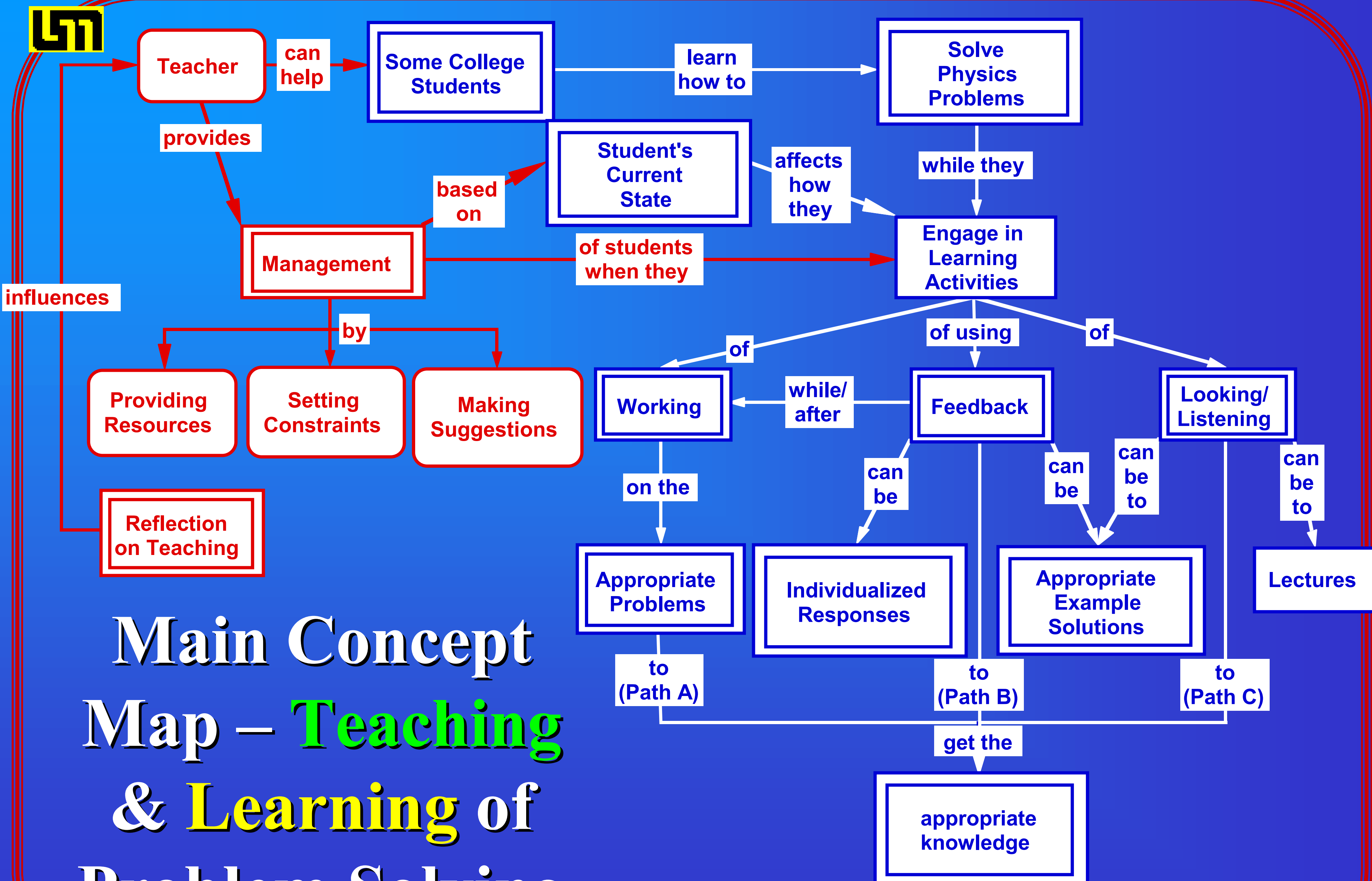
↓ Statements **(>2400)**

↓ Concept Maps **(15 x 6 = 90)**

↓ Combined Concept Map **(15)**

Concept Maps allow for:

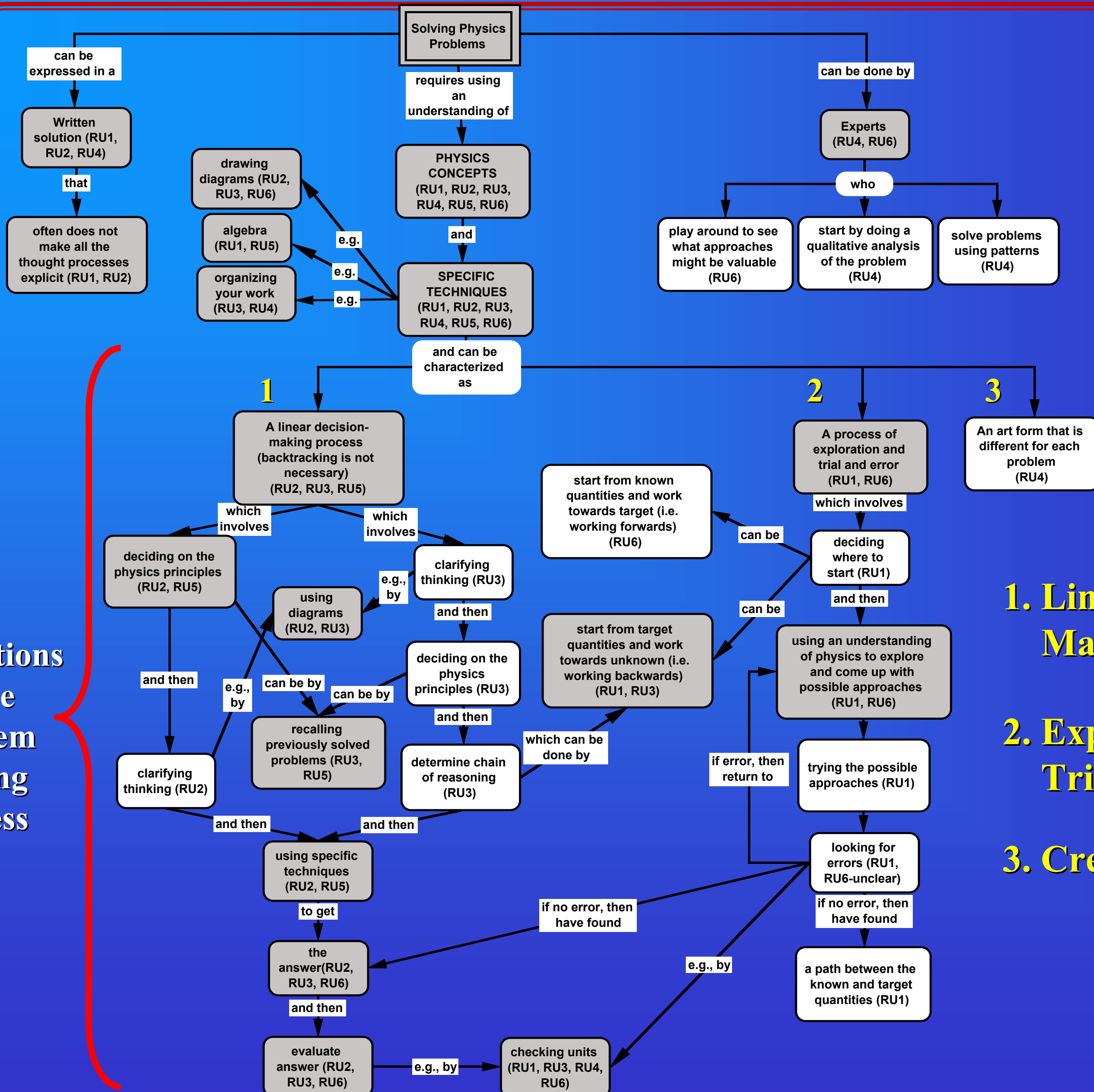
- **reduction** of complex data into visual representations
- **explicit connections** to be made between ideas that can then be tested



Main Concept Map – Teaching & Learning of Problem Solving


Teacher
can help
Some College Students
learn how to
Solve Physics Problems
provides
based on
Student's Current State
affects how they
while they
Management
of students when they
Engage in Learning Activities
influences
by
of
of using
of
Providing Resources
Setting Constraints
Making Suggestions
Working
while/ after
Feedback
Looking/ Listening
on the
can be
can be
can be to
can be to
Reflection on Teaching
Appropriate Problems
Individualized Responses
Appropriate Example Solutions
Lectures
to (Path A)
to (Path B)
to (Path C)
get the
appropriate knowledge

This talk …



3 Conceptions of the Problem Solving Process

1. Linear Decision Making

2. Exploration and Trial & Error

3. Creative Process

The Problem Solving Process

the Cognitive Psychology perspective*

Check Progress

(Metacognition)

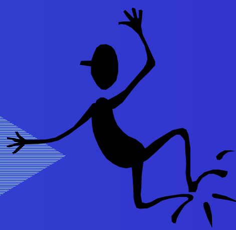
Problem

1 Qualitative Analysis

2 Quantitative Analysis

3 Answer

4 Evaluate Answer



Solution

- Visualize what is happening
- Identify Options (e.g., principles or definitions)
- Draw diagrams
- Identify goal

- Sequentially choose sub problems that reduce the gap between goal and known information
- Implement

For experts, choices limited by:

1) knowledge structure
2) experience

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

*Based largely on Reif (1995) in AJP & Polya (1957) in *How to Solve it*

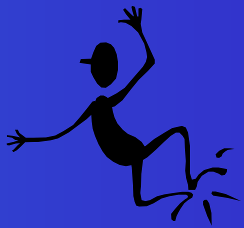
The Problem Solving Process

Conception 1: A linear decision-making

Problem

1 ? → 2 3 4

Quantitative Analysis | Qualitative Analysis | Answer | Evaluate Answer



Solution

- "Know" principle(s) to use

- Clarify thinking
- Apply principles at points of interest
- Implement mathematical tools

? – How are the correct physics principles selected?

The Problem Solving Process

Conception 2: A Process of Exploration

Problem

1 Qualitative Analysis

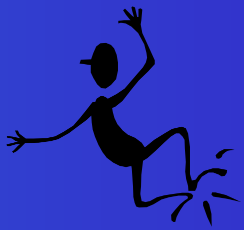
- Explore the problem

2 Quantitative Analysis

?

- Come up with possible approaches to try
- Try most promising approach

3 Answer



Solution

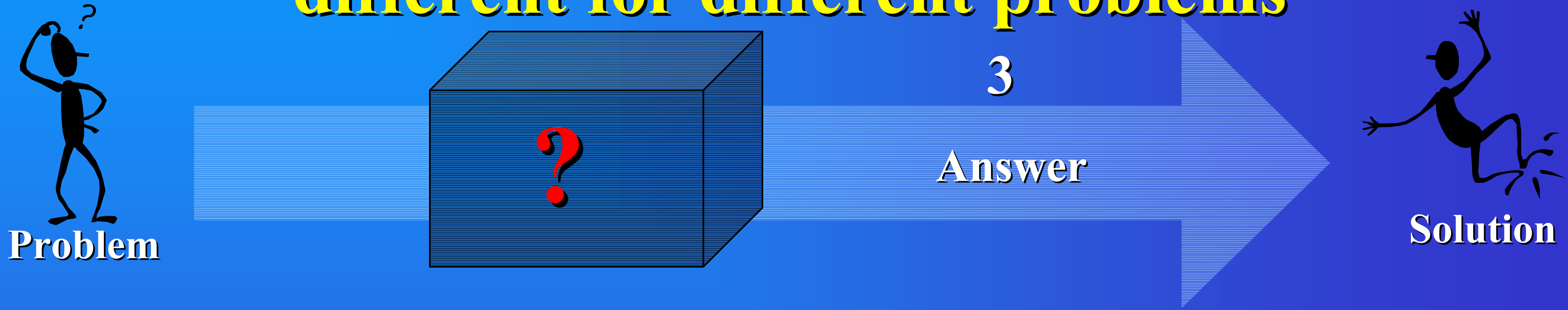
Options limited by:

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: A Creative Process that is different for different problems



The Problem Solving Process

six research university instructors

Conception 1: A linear decision-making process (backtracking is not necessary)	Conception 2: A process of exploration and trial and error process	Conception 3: A creative process that is different for each problem
Step 1: "Know" physics principle(s) to use	Step 1: Decide on goal (e.g., target to known)	(no process given)
Step 2: Clarify thinking (e.g. by using diagrams)	Step 2: "Explore" the problem and "decide" on possibly useful approaches or principles	
Step 3: Use tools (e.g., algebra, FBD) to get answer	Step 3: Try most promising approach	
Step 4: Evaluate answer	Step 4: Evaluate progress (return to step 2 if necessary)	

Preliminary Conclusions

There are similarities between the Cognitive Psychology view of the PS process and the five instructors who identified a process:

- Main "units" of the problem solving process are similar.
  - Qualitative analysis/clarification phase
  - Decision about approach/principles
  - Implementation
  - Evaluation
- Although the ordering and some details were different.

Preliminary Conclusions

There are differences between the Cognitive Psychology 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)

Instructors not familiar with expert/novice PS research

Infinite choices (random)

Linear Decision Making

Strategic Decision Making

Trial & Error

Experience is everything

- Knowledge Structure
- Strategy

Monitoring progress is everything

Implications for Curriculum Developers

No choices – predetermined (algorithm)

Infinite choices (random)

	Linear Decision Making	Strategic Decision Making	Trial & Error
Teaching Activity	Instruction likely to emphasize error-free and mechanical performance	Instruction likely to emphasize knowledge organization and PS strategy	Instruction likely to treat making choices as “magic”
Curricular Material	Lots of “Drill & kill” single concept problems	PS Strategy, Framework for organizing and using physics knowledge	Strategy for evaluating progress

Implications for Professional Development Providers

1. There are things to build on: basic building blocks of problem solving process are there.
2. There are opposite views.
   - Good situation for professional development.

No choices – predetermined (algorithm)

Infinite choices (random)

Linear Decision Making → PER – Strategic Decision Making ← Trial & Error

Overview of Study

Exploratory Study – Small Sample

That was … → • Initial model based on 6 UMN faculty

• Refine and expand the initial model based on 24 interviews with faculty from different institutions in the state of MN

• Determine the distribution of conceptions among faculty using a larger national sample

• Sharpen understanding using an international sample

Focused Study – Large Sample

Overview of Study

Exploratory Study – Small Sample

• Initial model based on 6 UMN faculty

•PERC Proceedings (2001)
•PERC Proceedings (2002)
•Henderson Dissertation (2002)

Now

• Refine and expand the initial model based on 24 interviews with faculty from different institutions in the state of MN
(Community College, Private College, State University)

• Determine the distribution of conceptions among faculty using a larger national sample

• Sharpen understanding using an international sample

Focused Study – Large Sample

Now …

We have interviewees that teach in different situations

- Are there similarities / differences in their conceptions of the process of solving physics problems in the context of an introductory physics course?

In the first stage

- 3 Conceptions

1. Linear Decision-Making
2. Exploration and Trial & Error
3. Creative process

Targeted Analysis

Analyzing interviews are very time consuming

6 interviews → 24 interviews

Target a feature of the initial model and cut down the analysis time

- Problem-solving process (least coherent & most puzzling)
- Identify parts of interview where statements about the problem-solving process were found in previous study
- Analyze additional interviews
  - Code only statements regarding the problem-solving process
  - Generate problem-solving process concept map for each individual interview
- Compare the new conceptions with initial model

(randomly selected, non-research university faculty)

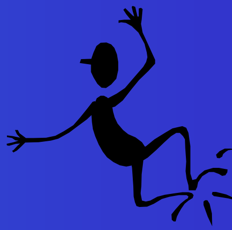
The Problem Solving Process

Conception 1: A linear decision-making (RU)

Problem

1 → 2 3 4

Quantitative Analysis — Qualitative Analysis — Answer — Evaluate Answer



Solution

- "Know" principle(s) to use

- Clarify thinking
- Apply principles at points of interest
- Implement mathematical tools

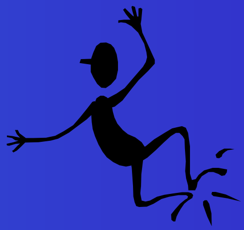
The Problem Solving Process

Conception 1: Linear decision-making (New)

Problem

1 → 2   3   4

Qualitative Analysis → Quantitative Analysis → Answer → Evaluate Answer



Solution

1. Qualitative Analysis

- Visualize the problem
- Think about situation in terms of relevant physics principles
- Identify relevant information

2. Quantitative Analysis

- Make and decide on assumptions, if necessary
- Apply principles at points of interest
- Implement mathematical tools

4. Evaluate Answer

- Check units of final answer
- Evaluate reasonableness of answer
- Evaluate reasonableness of assumptions

The Problem Solving Process

Conception 2: A Process of Exploration (RU)

- Explore the problem

- Come up with possible approaches to try
- Try most promising approach

The Problem Solving Process

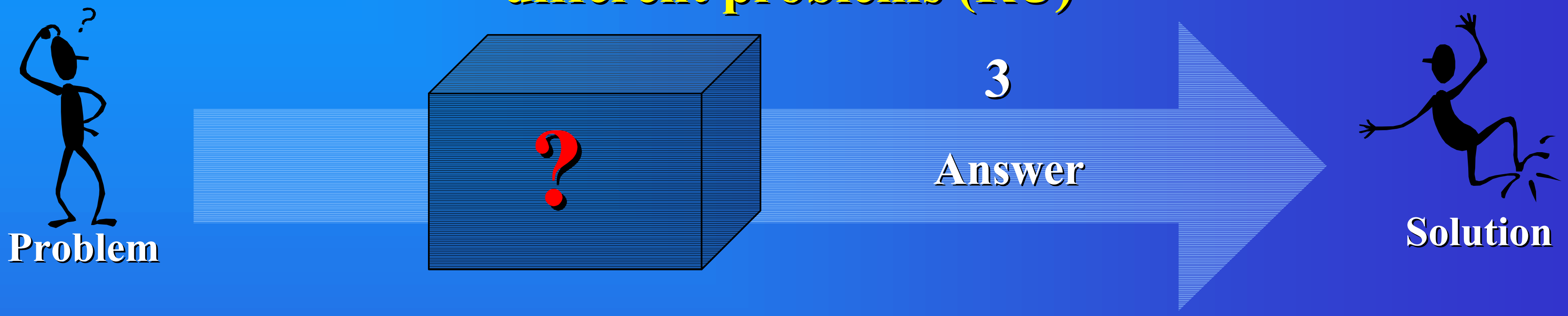
Conception 2: A Process of Exploration (New)

- Understand the problem situation
- Think about principles & techniques that may apply
- Have possible outline in mind of how to start the problem

- Try most promising approach
- If the approach doesn't result in progress towards an answer, use another approach

The Problem Solving Process

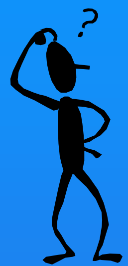
Conception 3: A Creative Process that is different for different problems (RU)



The Problem Solving Process

Conception 3: An Art Form (New)

Back & forth



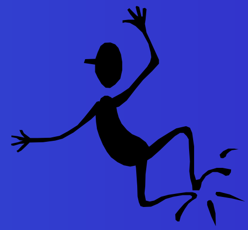
Problem

1 Qualitative Analysis

2 Quantitative Analysis

3 Answer

4 Evaluate Answer



Solution

- While reading the problem, concentrate on separating the relevant information from the "story"
- Brainstorm ideas about principles and techniques

- Analyze
- Organize

(e.g., Painting – draw rough sketch, then organize the mess; Free Writing – write down every relevant idea, then organize)

- Evaluate answer

The Problem Solving Process

additional instructors

Conception 1: A linear decision-making process	Conception 2: A process of exploration and trial & error	Conception 3: An art form
Step 1: Visualize problem	Step 1: Understand problem	Step 1: Identify problem
Step 2: Clarify thinking	Step 2: Decide where to start	
Step 3: "Know" the correct physics principle(s)	Step 3: "Explore" the problem and come up with approaches to try	Step 2: Brainstorm ideas for possible principles, techniques, & approaches
Step 4: Implement mathematics tools	Step 4: Try most promising approach to make progress towards answer	Step 3: Analysis of approach in making progress towards answer
		Step 4: Organize solution
Step 5: Evaluate answer	No evaluation of answer	Step 5: Evaluate answer

So …

In the description of the process of solving physics problems (Research & Non-Research University Faculty):

Similarities

- 3 Conceptions
- Units of Problem Solving
  - Qualitative analysis
  - Decision about approach
  - Implementation of techniques (math, diagrams, etc …)
  - Evaluation of process &/or answer

Differences

- More descriptive details of the problem solving process
- Order of some of the steps

On-going hypothesis generation …

1. Supported the initial model with instructors from different settings
   - Are there only a few ways that physics faculty think about the the process of problem solving in physics?
   - If so,

A smaller number of variations is easier to handle for:

1) developing appropriate curricular material
2) providing proper professional development!

On-going hypothesis generation …

2. Faculty conceptions are more detailed for this population
   – Does this level of complexity depend on the type of institution?

1) Agreement with expert-novice problem solving research – need less professional development!

2) Disagreement with expert-novice problem solving research – more difficult to design proper professional development!

Thank you!

Please visit our website for more information:

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