

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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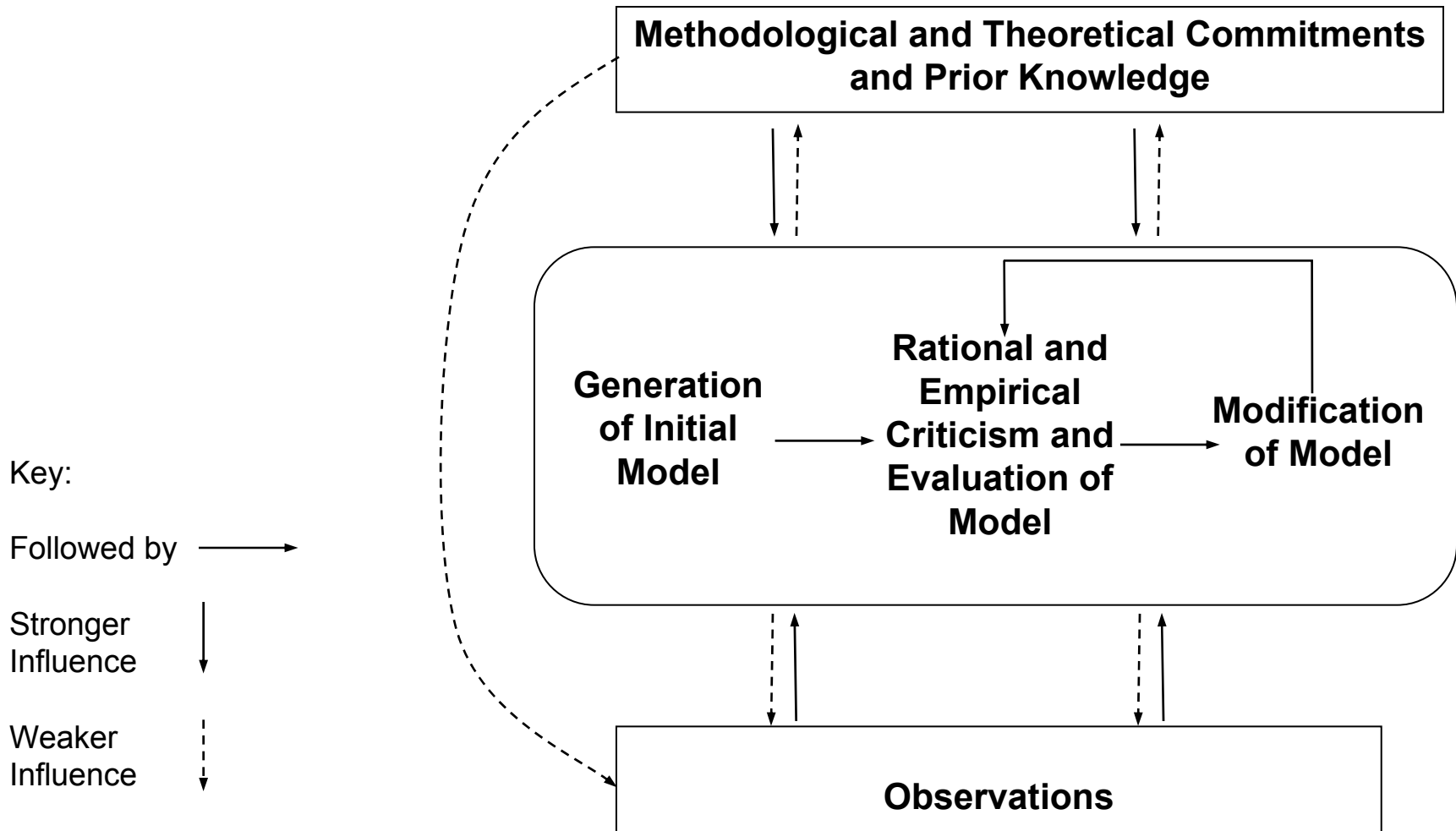
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Generation and Modification of Explanatory Theoretical Models



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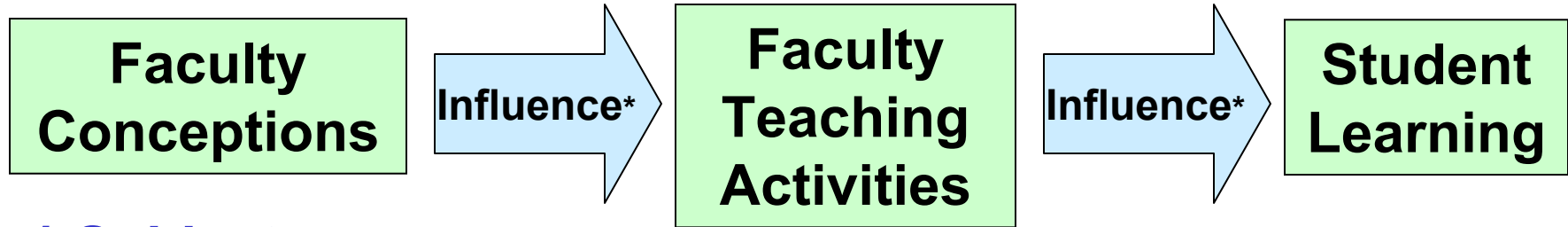
Generative Studies: Focus on **formulating new constructs** and new elements of a theoretical model.

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)

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

Instructor Solutions

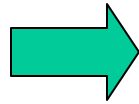
Student Solutions

Problems

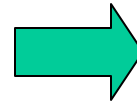
Interview Protocol

Multi-Layered Concept Map Analysis

**Individual
Interview
Statements**



**Individual
Concept Maps**



**Combined
Concept Maps**

**Video- & audiotapes of
interviews (~9 hrs)**



**Interview transcripts
(~180 pages)**



**Statements
(~2400)**



**Participant
Concept Maps
(15 x 6 = 90)**



**Composite
Concept Maps
(15)**

Analysis Flow Chart

**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

Interview Participants

	Gender	Years of Teaching Experience	Number of Times Taught an Introductory Calculus-Based Physics Course
Instructor 1	M	~10	10
Instructor 2	M	No answer	More than 50
Instructor 3	M	Less than 5	1
Instructor 4	M	~40	15
Instructor 5	M	~20	5
Instructor 6	M	~30	1

Interviews were videotaped and the audio portion transcribed:

~ 30 pages of text/interview

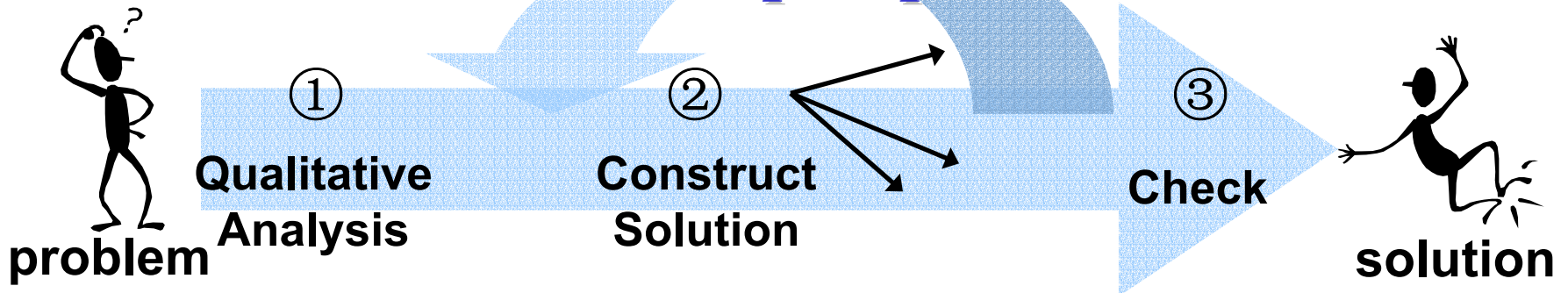
Combined Faculty Conceptions about Problem Solving

The Initial Model:

Three distinct views of problem solving

The Problem Solving Process

the PER perspective*



- Visualize what is happening
- Draw diagrams
- Identify goal

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

- 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

- 1) Identify Options (e.g., principles or definitions)
- 2) Pick Useful Option
- 3) Implement
- 4) Check Progress

*Based largely on Reif (1995) in AJP

Three Distinct Views of Problem Solving (The Initial Model Generated in This Study)

View 1: A linear decision-making process (backtracking is not necessary) (3 of 6)

Step 1: Decide on physics principles

Step 2: Clarify thinking (e.g. by using diagrams)

Step 3: Use tools (e.g., algebra, FBD) to get answer

Step 4: Evaluate answer

View 2: A process of exploration and trial and error process (2 of 6)

Step 1: Decide where to start (e.g., target to known)

Step 2: Explore the problem and come up with approaches to try

Step 3: Try most promising approach

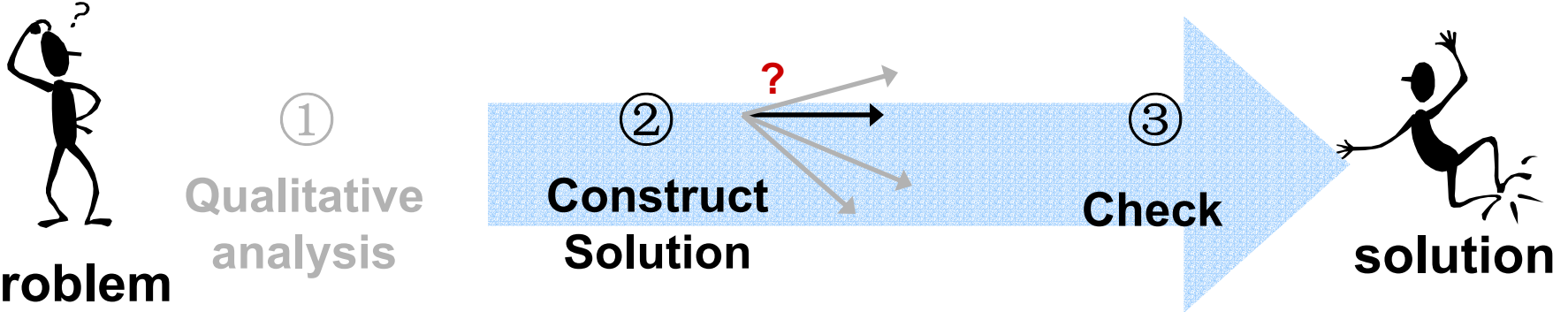
Step 4: Evaluate progress (return to step 2 if necessary)

View 3: An art form that is different for each problem (1 of 6)

(no process)

The Problem Solving Process

Conception 1: A linear decision-making (3 instructors)

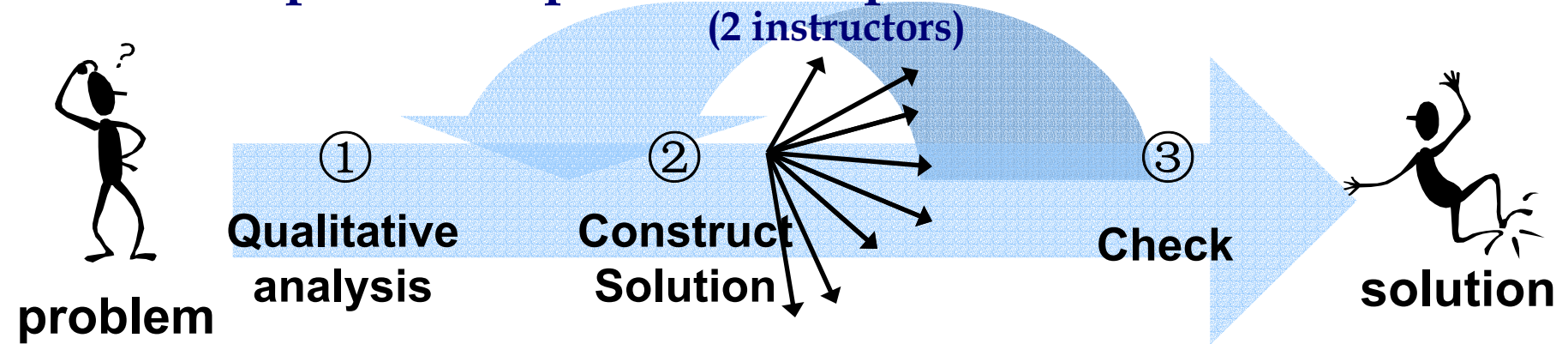


- Decide on options (principles)
- Implement

? – How are the correct physics principles selected?

The Problem Solving Process

Conception 2: A process of exploration and trial and error



- Explore the problem

?

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

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)



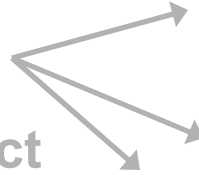
problem

①

Qualitative
analysis

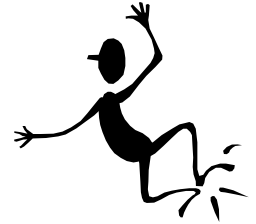
②

Construct
Solution



③

Check



solution

?

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)

Infinite
choices
(random)



Linear
Decision
Making (3
instructors)

Experience is
everything

PER –
Strategic
Decision
Making

• Knowledge
Structure
• Strategy

Trial &
Error (2
instructors)

Monitoring
progress is
everything



Implications for Instruction

No choices –
predetermined
(algorithm)

Infinite
choices
(random)



**Linear
Decision
Making (3
instructors)**

**PER –
Strategic
Decision
Making**

**Trial &
Error (2
instructors)**



**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”

**Learning
Activity**

Students likely adopt strategy of rote memorization

Students likely to adopt organized PS strategy

Students likely adopt strategy of rote memorization

Implications for Curriculum/ Professional Development Providers

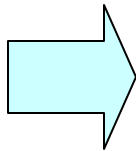
1. There are things to build on: basic building blocks of problem solving process are there.
2. There are opposite views within the community. Through collaboration it's easier to move towards the center than towards an extreme.

No choices –
predetermined
(algorithm)

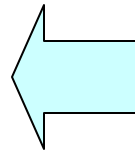
Infinite
choices
(random)



Linear
Decision
Making (3
instructors)



PER –
Strategic
Decision
Making



Trial &
Error (2
instructors)



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