

Focus of research:
Algorithmic Problem-Solving

What is the impact of patterns'
incorporation in instruction
on the development of
Problem-Solving skills ?

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**Pattern Oriented Instruction
and the Enhancement of
Analogical Reasoning**

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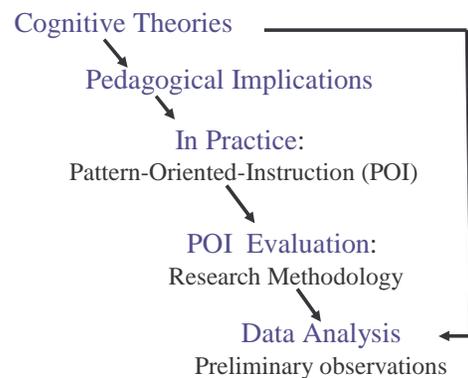
**Schema Theory and
problem-solving**

Our knowledge is organized in **Cognitive Schemas**, stored in memory.

Cognitive Schema – The abstraction of similar experiences.

In problem solving: A schema consists of a **solution plan & related information** - where and how to use it.

Links between pattern's components form a **chunk**.



Analogical Reasoning

A major problem-solving strategy:
Using a familiar situation to make
sense of a novel one.

Schemas and problem-solving (Cont.)

Solving a problem requires **access and retrieval** of relevant schema(s).

Schema's **connectivity** improves **accessibility**.

Chunks retrieval reduces **Cognitive Load** and helps coping with complex situations.

Schema model explains **Novice-Expert differences** in problem solving.

(Marshall, 1995; Paas et al., 2003; Rumelhart, 1989; Sweller, 1988)

Students difficulties in Analogical Reasoning

- / Don't know how to get started,
- / Don't see resemblance between problems,
- / Mislead by surface features in a problem's statement,
- / Cumbersome, inefficient solutions.

Analogical Reasoning phases:

1. Identifying relevant schemas in memory;
2. Mapping similarities between the current problem and a schema (or previous example);
3. Making inferences;
4. Adapting the schema to fit the new problem. (Gentner & Holyoak, 1997)

Why patterns?

Reuse of algorithmic & design solutions to similar problems at various situations is a central theme in CS, and the major driving force behind the definition of patterns.

Pattern-Oriented Instruction (POI)

Algorithmic Patterns - examples

- Counting
- Conditional accumulation
- Extreme value computation
- Search for an element in a sequence
- Do all elements satisfy a condition?
- Integer to digits decomposition.

(~ 30 patterns)

Algorithmic Patterns – Solutions to recurring alg. problems

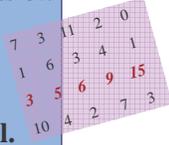
- ▽ Classify problems by goal (rather than by programming constructs);
- ▽ Building blocks of algorithm development;
- ▽ Encapsulate “algorithmic ideas”;
- ▽ Several patterns may be combined at different manners to form a solution.

Utilizing Algorithmic Patterns in a problem solution

Given a matrix of integer values,
Check the existence of a row, whose elements form an increasingly ordered sequence.

An algorithmic solution consists of:

- Search pattern,
- Do all elements satisfy a condition?
- Adjacent elements traversal.



Name: *Maximum Value*

Initial state: collection of values.

Goal: maximal value in the collection

Algorithm:

Initialize Max to First_value

While there are more items do

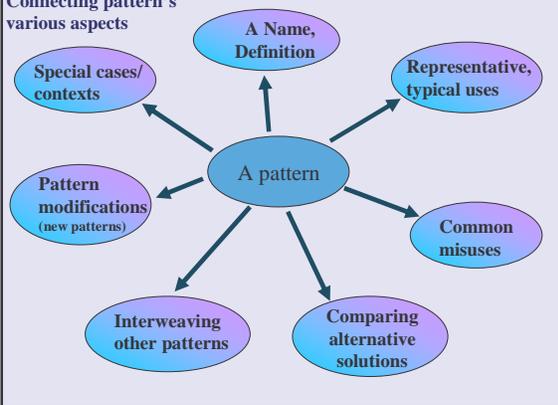
Assign next element to Next_Element

If Next_Element > Max then

Assign Next_Element to Max

Remarks: Highlights concerning the pattern, its use and related patterns.

Connecting pattern's various aspects



Pattern-Oriented-Instruction Guidelines

- ü Shifting emphasis from programming to problem-solving;
- ü Organizing problems around types of algorithmic tasks (and not around programming features);
- ü Illuminating various aspects of a pattern and its use;
- ü Discussing links between patterns, distinguish between similar patterns.

“Hard Copy” Patterns

↓
assimilation

Cognitive Schemas
(knowledge construction)

POI Guidelines (Cont.)

- ü Elaborating on the idea behind a solution (“Algorithmic idea”);
- ü Gradual increasing of difficulty level - Criteria involve pattern-related considerations.
- ü Abstracting a pattern from various examples.
- ü Integration with programming instruction – in a spiral way: patterns are revisited when adding a new programming feature;

Research Goal

Evaluating the effectiveness of
Pattern Oriented Instruction on
algorithmic problem-solving skills

What is “pattern assimilation”?

- Noticing similarities,
- Abstracting commonalities,
- Recognizing patterns’ applicability,
- Awareness of common mistakes,
- Correct modifications,
- Efficiency considerations,
- Identifying patterns in a given solution,
- Distinguishing between similar patterns.

Research Groups

<i>Experimental Group</i>	<i>Control Group A</i>	<i>Control Group B</i>
<ul style="list-style-type: none"> • Algorithmic-Patterns study materials, • POI approach 	<ul style="list-style-type: none"> • Same problems - organized by programming constructs, • No pattern definitions 	<i>(No intervention)</i>
Written Questionnaire Categorization Assignment – an interview		
Observations		

Research Methodology

Comparison research; A field setting;
 Experimental and two control groups.

Research sample:

High-school students (~100 each group),
 20 teachers (classes) in 15 schools,
 180 hours CS1 course.

Research Tools

- ∨ Questionnaire - algorithmic problems
- ∨ Categorization Assignment - interviews
- ∨ **Additional data collection:**
 - Teachers’ interviews; Class observations;
 - Teachers’ POI workshops;
 - Teachers’ instruction materials: exams, lab assignments, websites;
 - Students’ notebooks.

Research Stages

- ü Instruction materials development,
- ü Teacher workshops,
- ü Two-years pilot of POI,
- ü Patterns’ materials revised,
- ü Pilot comparison test,
- ü Main data collection;
- ⊕ Data analysis – in progress.

Categorization Assignment's Goals

Get insight of student's early stage of problem analysis:

- Employing analogical reasoning;
- Grasping the essence of a problem;
- Formulation of an idea for a solution;
- Making links to other problems;

Seeking POI impact.

Categorization Assignment

Assignment description:

Categorize eight algorithmic problems according to criteria chosen by the student.

- Semi-structured individual interview – thinking aloud;
- ~ 35 minutes;
- Probing student's reasoning, plans for solutions, clarifications, reflection on performance,...

Preliminary Observations (cont.)

- ∅ More elegant solutions.
- ∅ Better recognition of differences between similar problems.
- ∅ Faster characterization of a problem.
- ∅ Common distraction by surface similarities but shorter recovery time by POI.

Data Analysis - Preliminary Observations

Teachers: Powerful instructional tool for -

- ∅ Reviewing a large variety of examples,
- ∅ Evaluating & composing assignments.

Students:

- ∅ Exchange of ideas in POI group is more precise, abstract and fluent.
- ∅ Better awareness of solution's efficiency, more than one solution are compared.

★ Thank You



Preliminary Observations (cont.)

- ∅ Better realization of sub-tasks composition.
- ∅ High correlation between quality of categorization and performance in written questionnaire.
- ∅ Preference of pattern's names which are closer to programmed implementation.
- ∅ Patterns are retrieved from memory; Retrieval from hard-copy materials is rare!