Focus of research: Algorithmic Problem-Solving

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

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.

Cognitive Theories

Pedagogical Implications

In Practice:
Pattern-Oriented-Instruction (POI)

POI Evaluation:
Research Methodology
Data Analysis
Preliminary observations

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.

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

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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.

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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)

Pattern-Oriented Instruction (POI)

- 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.

Pattern-Oriented-Instruction Guidelines

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

“Hard Copy” Patterns

assimilation

Cognitive Schemas (knowledge construction)

POI Guidelines (Cont.)

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

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 Groups

<table>
<thead>
<tr>
<th>Experimental Group</th>
<th>Control Group A</th>
<th>Control Group B</th>
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<tbody>
<tr>
<td>• Algorithmic-Patterns study materials,</td>
<td>• Same problems - organized by programming constructs,</td>
<td>(No intervention)</td>
</tr>
<tr>
<td>• POI approach</td>
<td>• No pattern definitions</td>
<td></td>
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</tbody>
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Written Questionnaire
Categorization Assignment – an interview
Observations

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

Research Stages
Instruction materials development,
Teacher workshops,
Two-years pilot of POI,
Patterns’ materials revised,
Pilot comparison test,
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,…

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.

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.

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!

Thank You