



**Adapting Classic Computer Science
Problems for Elementary Students: Case
Study of the Four Color Map Problem**
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4 Color Map Problem

- Unsolved for over 100 years
- Computer aided proof (Appel & Haken, 1977)
- Nature of proof presents philosophical implications

Computer Science Education

- MIT - LOGO (Papert, 1980), Scratch (Resnick, 2006) - constructivist, constructionist, focused on programming
- Computers Unplugged (Fellows, 1991), focuses on computer science, also constructivist, constructionist
- Vocational

Other Frameworks

*4 levels of mathematical proof (Varghese, 2011) - naive empiricism, critical examples, generic example, thought experiment)

*Conceptual models in math and science (Confrey, 1990)

*Diagramming of conceptual model development (Clement, 2008)

Methodology

- Case study of adult expert, student expert, and student novices (2 of each)
- Dialogue and artifacts preserved
- Analyze drawing progressions and examples

Lesson Structure

- Problem setup
- Constrained 2 color problem
- Simple 3 and 4 color examples - must REQUIRE 3 or 4 colors
- Attempt to produce 5 color map
- 3D extension

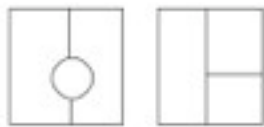
Lesson - Constrained
Map



Typical Incorrect 3 Color



Common 3 Color Maps



Common 4 Color Maps



5 Color Map Attempts



3D Extension



Results - Improvements

- 5 color setup should differ by age
- Visualization of informal 2 color constrained map proof desirable
- Co-teachers need to understand lesson process objectives before lesson

Results - Group Differences

- Speed of working through the problem primary difference
- Adult and students experts did not fundamentally approach the problem differently or differ in their results
- Experts sometimes could articulate general principles and were more attuned to fundamental issues in the problem (less extraneous lines)

Movie



Results - Conceptual Models

- 2 subjects articulated a general principle about 5 color maps
- One group started creating graphs (see movie)
- Drawings provided insight into thinking
- Full dialogue may be needed to more fully understand conceptual development

Results - Teacher Moves

- Process identified of setup, experience with scaffolding as needed, group discussion, repeat
- Minimally invasive teaching (closest to PBL)
- Some teacher explanation as needed

Results - Interest and Motivation

- High motivation - direct observation, unsolicited homework, not wanting to stop
- Periods of frustration
- Is difficulty a key part of high motivation?
- Possible reasons: open-ended, difficult, creative, visual, hands-on, social, unusual but familiar

Results - Standards

+High correlation with process standards (for example, make sense of problems and persevere in solving them)

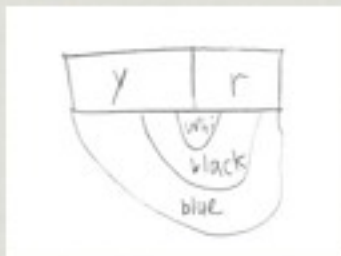
+High correlation with guiding principle 1: "Mathematical ideas should be explored in ways that stimulate curiosity, create enjoyment of mathematics, and develop depth of understanding"

+Content may not correlate well with traditional sequences (Massachusetts Department of Elementary and Secondary Education, 2011)

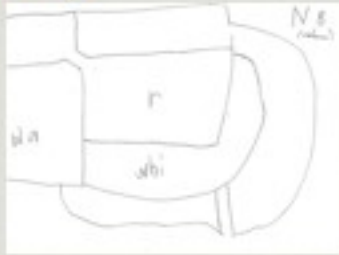
Results - Progression of Drawings



Early 5 Color Attempt



Intermediate 5 Color Attempt

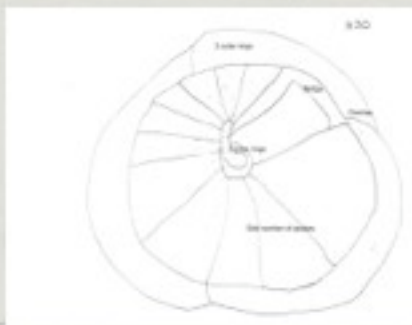


Intermediate (2)

S4 - Spoked Wheel/Outer Rings



Final 5 Color Attempt



Summary

- Adapted CS problems a rich and motivating affordance for mathematical processes and content
- Further research: relationship between frustration and motivation, more in-depth analysis of concept development and strategies

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