Perceptual Learning in Mathematics Education

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Introduction

What is Perceptual Learning?

Research in cognitive science suggests that successful learning and expertise are characterized by changes in the way information is picked up and classified through experience. This kind of learning—perceptual learning (PL)—has been relatively neglected both in theories of learning and educational practice.

Recent work indicates that PL is not typically advanced by explicit instruction but can be accelerated by computer-based learning technology. Perceptual learning grows through exposure to many short episodes and feedback. Incorporating systematic variation in instances across many simple problem solving episodes allows learners to extract invariant structures. These and other features are embodied in a series of software-based Perceptual Learning Modules (PLMs) being developed under this project.

Key Study Concepts:

This project aims to improve learning in the domains of measurement and fractions through the development of instructional software based on principles of perceptual learning.

The following ideas guide our research:

1) Some perennial difficulties in learning and instruction derive from an incomplete model of learning, specifically a neglect of perceptual learning.
2) Changes in information extraction, including discovery of abstract structure and growth of fluency, can be systematically produced by new instructional methods that target PL.
3) Using learning technology to integrate PL with modes of instruction that typically focus more on declarative and procedural knowledge offers great potential to improve learning.
4) Improving students’ understanding of units of linear measurement, unit structure, and fractional partitions of units as represented on rulers.
5) Strengthening students’ intuitions about the relationship between ruler problems and addition and subtraction operations, especially with fractions (e.g., the number sentence 12 ½ - 10 ½ = 7 can be modeled on a ruler as starting at 12 ½ and moving a distance of 10 ½ units to the left).

Learning Difficulties in Measurement and Fractions:

Many students struggle to achieve a meaningful understanding of and proficiency with concepts and skills related to measurement and fractions. Important conceptual and operational connections between measurement and fraction concepts are inadequately developed in the K-8 curriculum.

Measurement yields continuous (as opposed to discrete) quantities, and fractions are typically needed to create and represent measured quantities with accuracy. However, students show persistent confusion between discrete counting and measuring. They typically have an incomplete understanding of the properties of units of measure and the use of measurement scales and tools.

The item shown below, which is a released item from the 2003 NAEP Math Study, illustrates some of the conceptual difficulties students face for linear measurement.

Learning Goals:

1) Understanding that any start point can be seen as zero on a scale.
2) Distinguishing between position and distance on a scale.
3) Measuring distances accurately and flexibly on a ruler, including fractional distances.
4) Improving students’ understanding of units of linear measurement, unit structure, and fractional partitioning of units as represented on rulers.
5) Strengthening students’ intuitions about the relationship between ruler problems and addition and subtraction operations, especially with fractions (e.g., the number sentence 12 $\frac{1}{2}$ - 10 $\frac{1}{2}$ = 7 can be modeled on a ruler as starting at 12 $\frac{1}{2}$ and moving a distance of 10 $\frac{1}{2}$ units to the left).

PLM Structure:

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Problem Variables:

1) Trial Types: Find Distance, Find Endpoint
2) Input Formats: Drag a marker, Type numerical response
3) Numerical Types: Integer problems, Fractions/Mixed Number problems
4) Other Variables: - Rulers may be partially or completely labeled.
   - Rulers may be economically partitioned or overpartitioned.

Acknowledgments

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Method and Results:

Participants:

Participants were 63 6th graders who participated in the PLM instructional intervention plus 49 7th graders and 29 8th graders who served as un instructed control participants. 81% of the students at the school receive free or reduced lunches. A large percentage of children in each grade scored at the Basic and Below-Basic levels on statewide standardized math tests.

Procedure & Materials:

The study used 44-point pencil and paper assessments, with items distributed across a number of subscales. Subscales assessed the following abilities:

- Using a partitioned number line to express the length of a line segment in generic units
- Using both conventional and broken rulers to measure lengths in inches and centimeters
- Using conventional and broken rulers to construct extents of varying lengths
- Solving addition and subtraction problems with fractions
- Solving open-ended word problems involving linear measurements

6th Grade Intervention Group
- Pretest
- Short teacher-led introduction (10 minutes)
- Work individually with PLM software for approximately 6 sessions or until they meet mastery criteria for all item categories
- Brief teacher-led instruction session after 3rd PLM session (30 minutes)
- Immediate Posttest at end of instruction
- Delayed Posttest 4 months later

7th and 8th Grade Control Group
- Control group students were tested once, with no instruction or PLM training.

By the end of 7th grade, all curriculum units in the school’s regular curriculum (Math in Context) that are relevant to the math content of this study have been completed. Curriculum thereafter (including Algebra) assumes mastery of these concepts.

Results:

Prior to instruction, the 6th graders and the 7th and 8th grade control groups score similarly on the assessment, with no evidence of improvement through the end of middle school.

Conclusions:

The study results indicate that instructional methods based on perceptual learning can help students succeed in areas of the math curriculum known to be problematic. The robust and durable learning gains demonstrated for the 6th grade intervention group suggest that the Start to End PLM advances students’ structural insight and fluency in ways that the normal mathematics curriculum does not achieve. The software—which is able to track each student’s individual progress, to customize itself to the student’s rate of learning, and to certify mastery—provides a set of practical tools for differentiating instruction in classrooms.

Some perennial difficulties in learning and instruction derive from an incomplete model of learning, specifically a neglect of perceptual learning. Changes in information extraction, including discovery of abstract structure and growth of fluency, can be systematically produced by new instructional methods that target PL. Using learning technology to integrate PL with modes of instruction that typically focus more on declarative and procedural knowledge offers great potential to improve learning. Improving students’ understanding of units of linear measurement, unit structure, and fractional partitions of units as represented on rulers. Strengthening students’ intuitions about the relationship between ruler problems and addition and subtraction operations, especially with fractions (e.g., the number sentence 12 $\frac{1}{2}$ - 10 $\frac{1}{2}$ = 7 can be modeled on a ruler as starting at 12 $\frac{1}{2}$ and moving a distance of 10 $\frac{1}{2}$ units to the left).