Transfer of learning from traditional optics to wavefront aberrometry

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Outline

- Introduction and Motivation
- Wavefront Aberrometry
- Methodology
- Description of the Study
- Analysis and Results
- Concluding Remarks

Introduction and Motivation

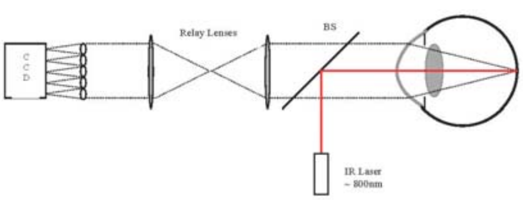
- Part of Modern Miracle Medical Machines
  - Study contemporary medical procedures
    - Physics relates to every-day medical devices
  - Transfer of learning[1]
    - Knowledge can be used in new contexts
  - Develop learning materials
    - Helping students apply their knowledge
- Wavefront Aberrometry

1. Rebello *et al.* (2005)

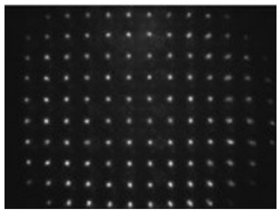
Physics of Wavefront Aberrometry

- A low-power laser beam is shone into the eye and focused on the retina.
- The light is reflected back through the eye.
  - It passes through the media, lens, and cornea, so it picks up those aberrations.
- Light exits the eye through an array of tiny lenses.

Physics of Wavefront Aberrometry, cont'd



Wavefront Aberrometry- Hartmanogram



- At this point, the Hartmanogram is formed.
- An eye that was free of all aberrations would have a "perfect" grid pattern

Modeling the Aberrometer

Research Questions

- What resources do introductory-level students use to understand light and optics, and what variations exist between students' understanding?
- To what extent can students apply their knowledge of light and optics to construct an understanding of wavefront aberrometry, and what scaffolding activities can be utilize to aide their knowledge construction?

Foundation: Constructivism[2]

- Individuals must construct knowledge
  - Based on individual interactions and experiences
- Learning is the (re)construction of knowledge
  - Requires new experiences/interactions
- Contained within Zone of Proximal Development[3]
  - Difference between what you can learn by yourself and with the help of more knowledgeable others

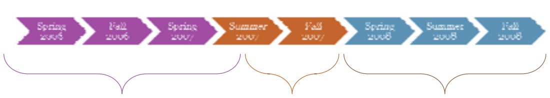
2. Piaget (1964) 3. Vygotsky (1978)

Research Design

- Mixed-methodology study
- Grounded Theory[4]
  - Cast a wide net – create a theory from the data
  - Bracket preconceived notions
- Phenomenographic Approach[5]
  - Understand from the learner's perspective
  - Elicit variations between participants

4. Strauss & Corbin (1994) 5. Marton (1986)

Study Timeline

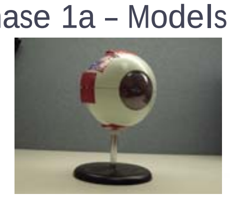


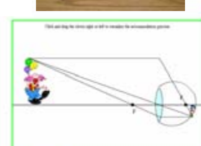
Phase 1 – Human Eye
- Clinical Interviews
- Grounded Theory
  - How do students understand the eye and vision?

Phase 2 – Aberrometry
- Two-part T/L Interviews
  - Phenomenographic
- How do students' construct and understanding of human eye, vision and aberrometry?

Phase 3&4 – Post-Instruction
- Post Instruction T/L Interviews
  - Phenomenographic
- Implementation - traditional lab
  - Phenomenographic

Phase 1a – Models of the Human Eye





Phase 1b and 1c

- Phase 1b – Qualitative Survey
  - Q1 and Q2 - Does the lens change to see objects at varying distances? How?
  - Question 3 – Can the lens change shape?
  - Question 4 – Irregular eye – corrective lens?
- Phase 1c – Clinical Interviews
  - Introduced Aberrometry questions
  - Used accommodating eye model

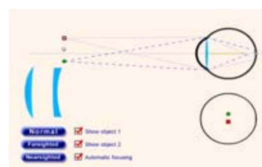
Phase 2 – Eye and Aberrometry

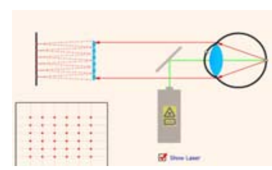
- Two part interviews
  - First interview – Human Eye and Vision
  - Second interview – Wavefront aberrometry
- Hands-on experiments and computer simulations
- What information could students transfer?

Phases 3 & 4 – Post-Instruction/ Implementation

- Post-instruction students
  - Only aberrometry component necessary
  - Same protocol as before
  - Groups and Individuals
- Included computer simulation of aberrometry
- Implementation
  - Identical protocol used in large-lab setting
  - Worksheet format

Computer Simulations





Resource Analysis

- Phenomenological Primitives (p-prims)[6]
  - Smallest pieces of knowledge
  - Learned when very young – small children know them
  - Useful in many circumstances and contexts
    - Not context specific
- Resources[7]
  - Larger grain-size (but can include p-prims)
  - Can be activated appropriately or not
  - Obtained from a variety of experiences
- Facets[8]
  - Concrete instead of abstract
    - Mapping of p-prims onto real world[9]

6. diSessa (1998) 7. Hammer (2000) 8. Minstrell (1992) 9. Redish (2003)

Sample Results – P-prims

- *Closer is bigger, closer is brighter*
  - The shape (length) of the eye changes the image
- *Changing inputs changes outputs – cause-effect*
  - If the incoming light changes, the image changes.
- *More input means more output*
  - The bigger the aberration, the more distorted the grid

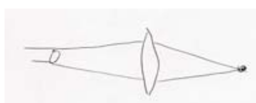
Sample Results – General Resources

- Shape of the Eye and Image Focus
  - " You're looking at changing the distance, as far as the back of the eye … it just goes hand-in-hand with the length of the eye. So if you move [the retina] back here, you're going to have to move [the screen] either backward or forward, I just don't remember which."
- Shape of the Eye and Image Size
  - "[The retina] is further away, so [the focal point] has to be closer, so [the dots] are going to be smaller but brighter points, and when [the retina] is up here, they are going to be bigger fuzzier points."

Sample Results – Light and Lenses

- Lenses dividing up the light
  - "The [eye] lens focuses the light onto the area of the array, and then the [array] lenses are breaking up the light … and focusing it to their own point."
- Light through Lenses
  - "[because of the aberration] light wouldn't shine through the lens as clearly. It would be reflected in all different directions … so now that you have a bending of the light, the focus [of the grid pattern] is just kind of messed up."

Sample Sketches – Light and Lenses



Sample Results - Aberrations

- Aberrations affect light
  - "Well the bottom ones [dots] don't' really change as much as the top ones. Like, if you push on the top [of the lens], the top ones [dots] kind of have a tendency of coming down farther because the light angle changed. But the bottom ones don't seem to have that much of a change because they're getting the direct light from the lens."

Sample Results – Implementation

- Same basic trends in the data
  - Same resources used by students in all phases
- Data was less 'rich'
  - Worksheets – no follow-up or probing possible
- Prediction Phases
  - Lack of convincing predictions
    - Stated in past-tense
  - Lack of explanation/reconciliation
    - 'our prediction was right/wrong'

Comparison of Phases

Phases 1 & 2 – Pre-Instruction	Phase 3 – Post-Instruction
• Basic knowledge about vision	• Basic knowledge about vision
• Fewer resources about lenses ▫ Experiential knowledge	• More resources about lenses ▫ Text-book knowledge
• Hesitant with aberrometer ▫ No prior-knowledge	• Less hesitant with aberrometer ▫ No prior knowledge
• Able to construct understanding of aberrometer ▫ More scaffolding needed	• Able to construct understanding of aberrometer ▫ Less scaffolding needed

Concluding Remarks – Research Q1

What resources do introductory-level students use to understand light and optics, and what variations exist between their models?

- Students have a large body of resources
  - Light, lenses, vision, and basic p-prims
  - Some appropriate, some less appropriate
- Pre- and post-instruction students differ greatly
  - Affects their willingness to create new knowledge

Concluding Remarks – Research Q2

To what extent can students apply their knowledge of light and optics to construct an understanding of wavefront aberrometry, and what scaffolding activities can be utilize to aide their knowledge construction?

- Students are able to construct an understanding
- Scaffolding activities are necessary
  - How light moves through lenses
  - How aberrations affect the light
  - How the grid pattern can be interpreted

Broader Impact of this Project

- Student understanding of human eye and vision
- Created learning materials on this topic

But more importantly …

- Example of how students construct knowledge
- Transfer of Learning
  - From basic physics to new contexts and situations
    - Useful beyond the concept of aberrometry, even optics

THANK YOU!

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