Perspectives on Transfer of Learning & Implications for Instruction

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EXPLORATION: Some background

- Eye Tracking
  - Measures eye fixation times in different areas (zones) on screen.

- Assumption:
  - Length of time in zone is proportional to information gathered from zone.

EXPLORATION: Representations

- Eye Fixation Data

EXPLORATION: Participants & Problems

- 3 Problems: One in each content area
  - Biology, Chemistry, Physics

- 3 Participants: One each majoring in:
  - Biology, Chemistry, Physics

EXPLORATION: YOUR TASK

- For the zone graphs provided
  - What are the similarities?
  - What are the differences?
  - What patterns, if any do you observe?

Talk to your neighbor 😊
## Problem Solving & Transfer

- All problem solving involves transfer of learning.
- Ability to use what you have learned in one situation in a different situation.

E.g. McKeough, Lupart & Marini (1995)

## Views of Transfer

- Identical elements must exist between situations.
- Knowledge must be encoded in a coherent model.
- Researcher can pre-decide what must transfer.
- Static one-shot assessment e.g. tests and exams.
- Focus mainly on students’ internal knowledge.
- Transfer is rare.

**Are these views applicable when we examine students’ sense making?**

E.g. Gick & Holyoak (1980); Reed & Ernst (1974); Thordike (1906)

## Other Views of Transfer

- (Re)construct knowledge in new context.
- Knowledge can transfer in pieces.
- Researcher must examine ‘anything’ that transfers.
- Dynamic, real-time assessment e.g. interviews
- Focus also on variety of mediating factors.
- Transfer is ubiquitous.


## Model of Transfer

**Static View**

- WORKING MEMORY
- WORKBENCH
- PRIOR KNOWLEDGE
- OUTPUT

**Dynamic View**

- Epistemic state, motivation, emotion and other variables
- EXECUTIVE CONTROLLER
- Controlling Factors

Transfer is the creation of associations between information read out by the learner & prior knowledge

The association is controlled by other factors e.g. learners’ epistemology, motivation etc.

Redish (2004)
Two Kinds of Associations

- Assigning new information to a knowledge element.
  - e.g. The electric field in region is 2 V/m

- Associations between two different knowledge elements.
  - e.g. Integral of Electric field is the Electric potential.

Two Kinds of Transfer

- ‘Horizontal’
  - Activating and mapping a pre-constructed knowledge structure to a new situation.
  - Associations between read-out information of a situation & elements of knowledge structure.

- ‘Vertical’
  - Constructing a new knowledge structure to make sense of a situation.
  - Association between knowledge elements to create knowledge structure.

Theoretical Framework

- ‘Vertical’ Transfer
  - Creating a new model to make sense of new information
  - Activation & Mapping of new information onto existing model

- ‘Horizontal’ Transfer
  - Existing model

Alignment with Others’ Views

<table>
<thead>
<tr>
<th>‘Horizontal’</th>
<th>‘Vertical’</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Low Road” Transfer</td>
<td>“High Road” Transfer</td>
</tr>
<tr>
<td>“Class C” Transfer</td>
<td>“Class A” Transfer</td>
</tr>
<tr>
<td>‘Assimilation’ of new experiences</td>
<td>‘Accommodation’ of new experiences</td>
</tr>
<tr>
<td>Involves Deductive reasoning: ‘Model Deployment’</td>
<td>Involves Inductive reasoning: ‘Model Development’</td>
</tr>
<tr>
<td>Uses ‘Applicative’ knowledge</td>
<td>Uses ‘Interpretive’ knowledge</td>
</tr>
<tr>
<td>Focus on ‘Efficiency’</td>
<td>Focus on ‘Innovation’</td>
</tr>
<tr>
<td>‘Prepared Problem Solving’</td>
<td>‘Preparation for Future Learning’</td>
</tr>
<tr>
<td>Structured, traditional problems</td>
<td>Ill-structured, non-traditional problems</td>
</tr>
<tr>
<td>Single/few internal representations activated repeatedly</td>
<td>Choosing, using and constructing multiple internal representations</td>
</tr>
</tbody>
</table>

‘Horizontal’ or ‘Vertical’?

- What type of transfer do these problems entail?

You are helping your friend prepare for her next skate board exhibition. She takes a running start jumps onto her skateboard that will glide along level track, then a sloped wall. To win she must reach at least 10 feet above where she started. She knows you have taken physics, so she wants you to determine if she can carry out her program as planned.

Cart A, moving at 3 m/s, has an inelastic collision with Cart B, initially at rest. After the collision, the carts move together up an inclined plane. Neglecting friction, determine the vertical height of the carts before they reverse direction.

Some Other Points

- ‘Horizontal’ & ‘Vertical’ Transfer...
  - are not mutually exclusive.
  - A given thinking process might involve elements of both ‘horizontal’ and ‘vertical’ transfer.
  - cannot be universally labeled.
  - What is perceived as ‘vertical’ transfer by a novice may be perceived as ‘horizontal’ transfer by an expert.
  - Experts may disagree about the type of transfer that has occurred in a given situation.
Back to Exploration

In what way, if any are the patterns you noticed consistent with our framework?

Talk to your neighbor 😊

Research Questions

- How do students engage in...
  - ‘horizontal’ transfer
  - ‘vertical’ transfer?
- In what conditions do they engage in each?
- Is there a preferred sequence?

...and several others....

‘Calculus to Physics’ Study

Research Question

To what extent do students retain and transfer their calculus knowledge while problem solving in introductory calculus-based physics?

Cui et. al. (2005)

‘Calculus to Physics’ Study

Research Participants

- **Students** (N = 28)
  - Enrolled in 2nd semester, calculus-based physics
  - After covering relevant topics in electricity and magnetism
- **Teachers**: Faculty, Instructors and TAs
  - Physics (N = 6)
  - Mathematics (N = 4)

‘Calculus to Physics’ Study

Research Plan

Semi-structured Interviews

- ‘Horizontal’ Transfer
  - Textbook-like Problems
- ‘Vertical’ Transfer
  - ‘Contrasting Cases’
  - ‘Jeopardy’ Problems


‘Calculus to Physics’ Study

‘Contrasting Cases’

Continuous vs. Discrete

When do you use integration in a problem?
Construct a physical situation that is described by the following expression:

\[ 2 \times \left( \frac{6.99 \times 10^8 \, \text{N} \cdot \text{m}^2}{\text{C}^2} \right) (2 \times 10^{-18} \, \text{C} / \text{m}) (5 \times 10^{-2} \, \text{m}) \cos \theta \, d \theta \]

Our goal is not to find out whether they get these problems right, rather the process they use to attempt the problems.

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Focus on underlying concepts.
Do more 'Word' problems.

Constructivism

Jean Piaget (1896 - 1980)

Learning due to
- Interaction with environment.

Stages of Development
- Sensorimotor (0-2 years)
- Pre-operational (2-7 years)
- Concrete Operational (7-11 years)
- Formal Operational (> 11 years)

From students' perspective perhaps this was vertical transfer??

How do we address these issues?
Could some of our what we have learned elsewhere give us some clues?
(Looks like we researchers have a hard time transferring too!! 😱)
Learning / Modeling

- MODEL DEVELOPMENT
- EXPLORATION
- CONCEPT CONSTRUCTION
- MODEL DEPLOY
  - Horizontal Transfer
  - Vertical Transfer
- APPLICATION

- Hands-on.
- Make predictions.
- Activate prior knowledge.
- Leads to cognitive conflict.
- Apply newly knowledge in different contexts.
- Hands-on design tasks.

Constructivism (continued)

- Lev Vygotsky (1896 – 1934)
  - Critical for Learning:
    - Language: “egocentric speech”
  - Stages of Development
    - Stage I: Learning by Self
    - Stage III: Automatized & Fossilized
    - Stage IV: De-Automatized

Vygotsky: Through another Lens

- Balance ‘horizontal’ and ‘vertical’ transfer
- Follow an ‘Optimal Adaptability Corridor’
- Adapt proven pedagogy:
  - First Model Development then Model Deployment
  - Use cognitive dissonance to promote model development
  - Scaffolding within Zone of Proximal Development
- Emphasize multiple models
  - Sensitivity to activate appropriate model

Characteristics of Instructional Strategies

- Balance ‘horizontal’ and ‘vertical’ transfer
- Follow an ‘Optimal Adaptability Corridor’
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In other words…

- What we currently try to do...
- ZPD: Points of Cognitive Dissonance

Also Applies to…

- Teachers:
  - Deploy their instructional schema
  - Develop new instructional schema within their ‘comfort zone’
- Researchers:
  - Deploy existing model how students learn to design instruction
  - Develop new models of how students learn.
Multi-Tier Teaching Experiment

Modeling cycles in the Multi-Tier Teaching experiment contain iterative stages of ‘vertical’ and ‘horizontal’ transfer for students, teachers & researchers.

Lesh & Kelly (2000)

BUT...

WHERE IS THE EVIDENCE THAT THIS MIGHT WORK?

‘Microscopic Friction’ Study

Students’ Initial Model of Microscopic Friction

- Friction is due to mechanical interactions
  - meshing up of bumps and valleys
  - rubbing of atoms

Corpuz et al. (2004)

‘Microscopic Friction’ Study

Edgar’s Project

GOAL

Design instructional experiences to help students construct a desired model of microscopic friction?

What model?

- Friction is due to electrical interactions.
- Friction varies with roughness as shown:

Roughness of Both Surfaces

Sequence of Activities

Model Deployment

Model Development

Model Development

Feeling & Sketching of surfaces

Final Model

Wooden Block Sandpaper Activity

Increasing

Roughness

Metal Blocks & Paper Transparency Activity

Increasing

Smoothness

??COGNITIVE DISSONANCE??

Can’t explain observations with metal blocks using present model
Microscopic Friction’ Study

SUMMARY FINDINGS

BEFORE

Increasing Friction

Increasing Roughness

AFTER

Increasing Smoothness

Increasing Roughness

APPLICATION

Can we apply the same instructional strategy to help students understand when calculus is applicable in going from one situation to another?

Talk to your neighbor 😊

HOW DO WE DESIGN INSTRUCTION THAT ‘WORKS’?

Instructional Design

Alternative Methodology

Carefully examine students’ model construction process, the effect of scaffolding and other mediating factors.

Teaching Interviews

Clinical Interviews

Curriculum Design & Development

Pilot- & Field-Testing

Steffe (1983); Steffe & Thompson (2000)

What is a Teaching Interview?

‘Mock’ instruction:
- Attempts to change student knowledge.
- Rich setting for students to express themselves.
- Variety of instructional strategies.
- Involve groups of up to three students.

Researcher’s Role:
- Observer.
- Instructor.

Benefits of Teaching Interviews

Provide insights about ...
- Dynamics of ‘horizontal’ and ‘vertical’ transfer.
- Effectiveness of materials & strategies.
- Student interactions with...
  - instructional materials,
  - peers, and
  - instructor.

Teaching Interviews (TIs) are a useful paradigm for research & development of instructional strategies.
In Terms of Our Framework…

- TIs help us explore the OAC: Find the...
  - Zones of Proximal Development.
  - Points of Cognitive Dissonance.
  - Strategies for Formative Assessment.

- Different trajectories
  - Spectrum of models

What other factors determine these trajectories?
Go back to Model of Transfer.

CONCLUSIONS

- Transfer is a complex process and must be considered from perspectives of ‘horizontal’ and ‘vertical’ transfer.
- Instruction typically focuses on ‘horizontal’ transfer and does not prepare students for ‘vertical’ transfer.
- To create adaptive learners, we must balance both as we navigate an ‘Optimal Adaptability Corridor.’
- This can done through carefully designed sequences of steps of both ‘vertical’ and ‘horizontal’ transfer.
- Teaching Experiments help us determine the optimal trajectory along the ‘Optimal Adaptability Corridor.’
- The notions of ‘horizontal’ and ‘vertical’ transfer are applicable to students, teachers and researchers in a multi-tier teaching experiment.
THANK YOU