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Making the invisible visible

The role of undergraduate textbooks in the teaching and learning of physics and chemistry

John Airey  Susanne Wikman  Emelie Patron
Overview

The wider study
Development of specialized semiotic resources
Disciplinary and pedagogical affordance
Unpacking
Semiotic audit
An example
Future directions
Four-year Swedish Research Council project.

Interested in the ways undergraduate students come to understand invisible phenomena through the specialized resources used in their disciplines.
Two areas of interest:

• Electromagnetic fields
• Chemical bonding
In these two areas:

1. What discipline-specific semiotic resources are made available to students?

2. How might these be unpacked for students?
Goodwin (1994) explains the development of professional vision—coming to see things in a particular, disciplinary way.

We frame the development of professional vision in terms of coming to understand how to interpret and use disciplinary-specific resources.

Airey (2006, 2009)
Tracking the development

An example of the development of specialized disciplinary meaning-making:

Building on O’Halloran (2007)
• **Slide 9:** Drawing Newton’s discovery of colour refraction (Newton and assistant present)

• **Slide 10:** 3D sketch by Newton (no people, much less detail)

• **Slide 11:** 2D presentation to Royal Society (standardized left to right, but many more rays than we would draw today)

• **Slide 12:** 2D presentation today (single rays, but addition of colour)
The curse of knowledge

- There are a number of reasons why students don’t understand disciplinary-specific resources
  - **Omission**
    Experts leave things out
  - **Overloading**
    Experts give too much information
  - **History**
    Disciplinary resources are idiosyncratic
  - **Expectations**
    Students’ everyday misconceptions

Airey & Eriksson (2019)
What has happened?

Removed information that is "irrelevant" for the discipline.

Higher Disciplinary Affordance

BUT:

Lower Pedagogical Affordance

Airey (2015)
Airey & Eriksson (2019)
Waves of affordance

Disciplinary representation

Unpacked representation

Time

High DA
Low PA

Low DA
High PA

UNPACKING

REPACKING

Patron (2022)
Semiotic audit

Semiotic audit—what is it?

Audit of semiotic resources made available to students and their affordances

Airey & Eriksson (2019)
Visual resources in chemistry

• Mathematical formulas
• Chemical formulas
• Tables
• Diagrams
• Photos
• Graphs
• Physical objects
• Animations
• Simulations
Frequency – chapter in chemistry book

1. Diagrams – 64%

2. Chemical formulas – 20%

3. Mathematical formulas – 6%

4. Photos – 5%

5. Tables – 3%
Examples of diagrams

Conclusion - Frequency

Large number of diagrams
High disciplinary affordance
Low pedagogical affordance
Need to be unpacked for students
Why chemical bonding?

Only 94 naturally occurring elements

How do these 94 elements combine to make everything around us?

Chemical bonding
Why chemical bonding?

Simplest chemical bonding

Two hydrogen atoms join to form a hydrogen molecule

Important model (Molecular Orbital Diagram)

Models nature, but it is only a model
Molecular Orbital Diagram

\[ H + H \rightarrow H_2 \]

How is the diagram introduced in the textbook?
Why chemical bonding?
Interpreting the diagram

Semiotic aspects students need to notice

It’s an energy diagram

Energy increases “up the page”

Diagram is read from the outside inwards
Interpreting the diagram

Chemistry aspects students need to understand

- Bonding depends on sharing electrons
- Change in energy
- Lowest energy "preferred"
Bonding depends on sharing electrons
Bonding depends on sharing electrons

$H_2$
Bonding depends on sharing electrons

How is this shown in the diagram?
Bonding depends on change in energy
Lower Energy

Bonding

H \quad H_2 \quad H
Lower Energy

Energy

Antibonding

Bonding

H  H₂  H
What’s wrong with this picture?
Going forward

How do students experience disciplinary-specific resources across a range of settings

Analyse the disciplinary-specific resources presented in lectures

Multimodal orchestration

Interview lecturers and students about what they “see”
Unpacking and repacking strategies

Removing "unnecessary" information

Possibility that transduction across resources is needed for disciplinary learning
Airey, J. (2006). *Physics students' experiences of the disciplinary discourse encountered in lectures in English and Swedish* (Licentiate dissertation, Department of Physics, Uppsala University).


