Challenging student intuition with item design

MICER III Zoomposium, 18.06.2020, Prof. Nicole Graulich

#nik_kola82 Graulich CER Group: www.uni-giessen.de/dc
How do people make decisions and what does this mean for item design in CER?
Roadmap

1. Intuitive reasoning impacts students’ decision-making processes

2. An exploratory study to challenge student surface reliance – approaches and struggles (pre-reading)

3. Where to go from there? - Ideas for continuing research

Pre-reading:
How do people make decisions?


System I Thinking
- fast
- intuitive
- effortlessly
- unconcious

System II Thinking
- analytical
- slow
- not effortlessly
Which of these two cities is larger?


Knowing less can, depending on the question, be more effective than knowing more.
Which person would you consider more friendly?


We tend to substitute a difficult (or even impossible) question by a simpler one.

*attribute substitution effect*
Which are the appropriate reagents for this reaction?

*Attribute substitution effect*


Hanna: “I would go with d.) There are two chlorines in the product, so with Cl₂ and CH₂Cl₂, I guess, you have enough chlorines to make it.”
“Students often apply rules memorized from particular examples to new questions which they deem to be similar based upon surface features of the molecules. [...], which lead them to incorrect answers.”

“Students are engaged in rote memorization of what features are related to nucleophilic and electrophilic behavior, rather than try to more deeply comprehend the relationships between those features and functionality.”

„The student focused most of the attention on those explicit structural cues that differentiated the three chemical compounds, implicitly discarding (i.e., benzene ring) or explicitly eliminating (i.e., –OH group) features that were actually relevant for the successful prediction of acid strength.”

students’ success in OC depends on the ability to:

(1) establish connections between the chemical properties and the structural representation
(2) consider implicit properties of molecules
(3) determine which implicit property is relevant in a problem context, despite explicit cues.

What type of items would capture this *relational conceptual understanding*?

Item Design Background

Inspired by:

- Variation theory of learning
  (Bussey, T. J. et al. 2012)

- Learning through contrasts
  (Schwartz, D. L. et al. 2011)

Explicit versus implicit similarity
Item Design Background

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Poll #2
A: A and B
B: B and C
C: C and A

Which two food items contain more sugar?

Explicit versus implicit similarity

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Which two nucleophiles would react similar with this bromalkane in a substitution reaction?

![Chemical structures](image-url)
Item Design ($S_N1/S_N2$ reactions)

**General Prompt:** Indicate the two structures that would react similar in a substitution reaction.

**nucleophilicity**

- A
- O$^-$
- Br
- B
- C$≡N$
- C

**solvent effects**

- Cl
- C$≡N$
- ?
- CCl$_4$
- C

**hyperconjugative effects**

- Br
- Br
- Br
- A
- B
- C

**leaving group**

- Br
- OCH$_3$
- Cl
- A
- B
- C

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LEADING QUESTION
How do students judge a comparable reactivity in items that are explicitly distracting?

How does students’ level of elaboration, when asked to provide a reason for their choice, relate to their performance?

Quantitative study, 156 students (chemistry majors / student teachers), 1st year OC

Paper-Pencil:
• Part 1 – Multiple Choice
• Part 2 – Multiple Choice and elaboration
• Instrument: substitution reactions, 68 items in total
• Concepts: Leaving group, hyperconjugative effects, solvent effects, nucleophilicity

Analysis
• statistical analysis
• rubric for the coding student elaboration
How to categorize students' elaboration?

Indicate the two structures that would react similar in a substitution reaction.

Students’ answers for choosing A and C:

A Both are secondary halogen alkanes
B Both react similar as both are good leaving groups
C Halogens are able to better stabilize a negative charge when leaving the molecule
D A and B have a high electronegativity.
### Rubric for students’ elaboration

**Deductive coding**

<table>
<thead>
<tr>
<th>Descriptive</th>
<th>Explicit</th>
<th>Implicit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both are secondary halogen alkanes</td>
<td>Both halogens are able to better stabilize a negative charge when leaving the molecule</td>
<td>A and B have a high electronegativity</td>
</tr>
<tr>
<td><strong>E1</strong></td>
<td><strong>E2</strong></td>
<td><strong>E3</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Functional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both react similar as both are good leaving groups</td>
</tr>
<tr>
<td><strong>E4</strong></td>
</tr>
</tbody>
</table>

**Student Examples:**

a. *Both are secondary halogen alkanes*
b. *Both react similar as both are good leaving groups*
c. *Halogens are able to better stabilize a negative charge when leaving the molecule*
d. *A and B have a high electronegativity.*
Results

This is what we got from a first analysis!

These items were not all answered in the same way.
Results

Reorganization of items

**leaving group**

- Br
- OCH₃
- Cl

**nucleophilicity**

- A
- Br
- ?
- B
- C=\(\text{N}\)
- C
- O\(\text{O}^-\)

*Item type 1 - supporting*

Explicit features support item solution

*Item type 2 - distracting*

Explicit features do *not* support item solution
Results

Box Plots after reorganization

- Large effect size for the item types (Cohen’s $d=1.4$)
- Small effect size for the elaboration prompt in both item types (type 2: $d=0.31$, $p=0.0001$ and type 1: $d=0.26$, $p=0.009$)
Students’ elaboration

- Students, who elaborate on the lower levels have a higher chance of solving the item of type 2 incorrectly.
Where to go from here?

- Assessing students’ understanding can be misleading, when the correct solution is possible based on surface features.

- Combining assessment with students’ deeper reasoning, e.g. two-tiers MCQs (Treagust, D. F. 1988).

- Supporting students to activate deep conceptual reasoning does not come deliberately and already starts during instruction.

THINK

What are you doing while teaching to support students to become more reflective about their intuitive approaches?
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BREAKOUT  Get to know each other and exchange your experiences.

CHAT  Decide which idea/question you want to share as a group via the chat box.
Making the unconscious conscious

metacognitive „loop“

- How can I determine changes, what can be taken as evidences?
- Do changes last? How I can observe this?
- How are learned abilities used in other contexts?

PROMPT

Revision of 1st attempt

Students’ 1st attempt to a prompt

Prompt to reflect on possible erroneous solutions (e.g. Talanquer, 2017)

Learning with material (e.g. conflicting animations, Kelly et al., 2017)

Analyzing worked-example, expert- or peer-solutions (e.g. work by E. Yuriev; Finkenstaedt-Quinn et al., 2019)

....
Huge Thanks to!

... Michael & Aishling for just being fabulous

... an open and respectful CER community

... every one of you for being here today!

... a fantastic CER research group in Gießen

Reach out to us!!
Resources


Online resources:

- Intuitive concept inventory: [https://www.surveygizmo.com/s3/4364595/ICI](https://www.surveygizmo.com/s3/4364595/ICI)
- Stacey Bretz Webinar: [https://www.youtube.com/watch?v=WfSh4r3wtR0](https://www.youtube.com/watch?v=WfSh4r3wtR0)