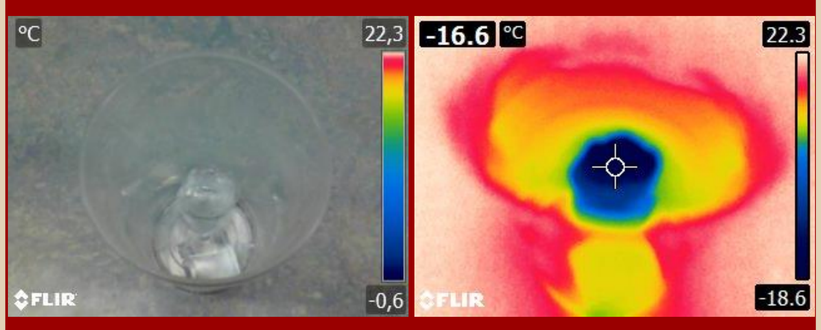
Adding salt to ice: Exploring students' cognitive resources

Christopher Robin Samuelsson,
PhD student in Physics Education Research,
Department of Physics and Astronomy,
Robin.samuelsson@physics.uu.se

Co-authors:
Jesper Haglund, Karlstad University
Maja Elmgren, Uppsala University

1. JUDGEMENT & REASONING

When **table salt is poured on ice**, the ice starts to melt and the temperature decreases.



Over the years, we have collected multiple data sets asking students to **Predict-Observe-Explain** (White & Gunstone, 1992) what happens to the ice and temperature when adding salt to ice.

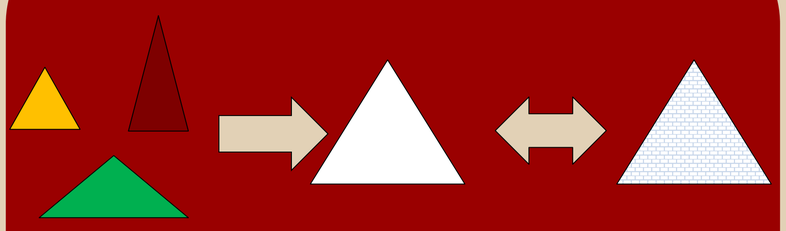
Students' reasoning in thermodynamics tends to be of the type "**linear causal reasoning**" (Rozier & Viennot, 1990)

Availability heuristic: Some cognitive resources are processed faster than others (Tversky & Kahneman, 1973)

Examples of cognitive resources processed fast through recognition include phenomenological primitives, a.k.a. **p-prims** (diSessa, 1993; Redish, 2004), **exemplars** and **protypes** (e.g. Nosofsky, 2010).

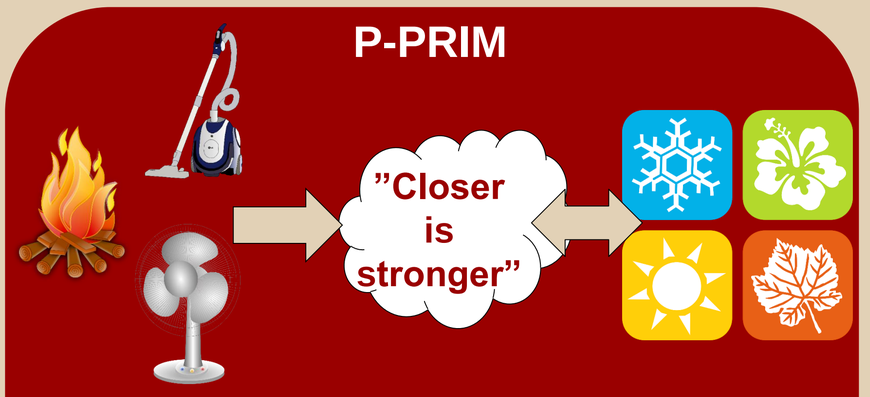
2. COGNITIVE RESOURCES

PROTOTYPE



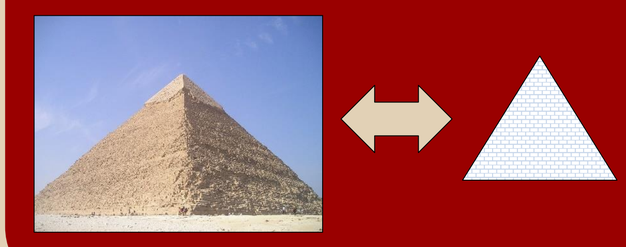
A **prototype** is an abstraction or average of the members of a certain category, based on the attributes deemed important to the category (Rosch, 1973). For example, the prototype for birds has the shape of a robin but it does not need to be a robin in terms of color, etc. (Gärdenfors, 2004)

P-PRIM



P-prims were proposed by diSessa (1993) to describe "irreducible" cognitive resources used to reason about a phenomenon. They could be described as "abstractions of patterns of behavior" (Talanquer, 2014, p. 1093) based on experience of similar events. We propose that p-prims are prototypes of phenomena.

EXEMPLAR



In contrast to prototypes, **exemplars** are specific instances of events that may form the basis of judgement in a reasoning process (Nosofsky, 2010).

3. CONTEXT & ANALYSIS

- Data collected in connection to/within the students' ordinary education in **thermal physics/thermodynamics**.
- **Videodata** transcribed before analysis.
- **12 groups** of students (2-5 participants per group, adding up to a total of 34 students) are included in the data.
- **Study programmes** included in the data: Chemical engineering, Engineering physics, Physics, Science Teacher (Upper Secondary School), Primary School Teacher
- The students have, in line with White & Gunstone (1992), been asked to first **predict** the outcome of the phenomenon (What happens to the ice and what happens to the temperature?), then **observe** it with infrared cameras and finally **explain** their observations, potentially modifying their predictions.
- An initial analysis of the **prediction phase** has been made for this presentation.

4. PRELIMINARY RESULTS

IDENTIFIED EXEMPLARS & P-PRIMS*

What happens to the ice?

No p-prims and most exemplars were used for the prediction.

8 of 12 groups used *"Salt on roads"* as basis for reasoning about the phase transition out of which 7 groups concluded that the ice would melt.

3 of those 7 groups used the intermediate step *"freezing-point depression"*.

The 4 of 12 groups, that didn't use "Salt on roads", predicted that the ice would melt, through "freezing-point depression" (**2 groups**), "entropy increase" and "unspec. experience"

What happens to the temperature?

Two potential p-prims were identified and one exemplar.

6 of 12 groups predicted an increase in T. This was based either on "Melting increases T", "Chemical bonds breaking releases energy" or "Chemical reactions increases T".

2 groups of 12 predicted that T would not change due to nothing reacting in the phenomenon.

2 of 12 groups predicted that T would decrease (and that the ice would melt). **1 based** it on "Melting requires energy" and the other on "Cooling beverages".

*the groups left out from the compilation, just guessed without motivating their guesses (like "nothing happens with T") or based their prediction on the name of their current project group.

IDENTIFIED EXEMPLARS & P-PRIMS

The following exemplars and p-prims were found in the students' predictions:

Exemplars: "Salt on roads", "Salt on ski slopes", "type-lab", "T in ocean", "Cooling beverages" and "Boiling water"

P-prims:
Macro: "Melting requires heating"
"Heating leads to a temperature increase"
Micro: "Breaking/reacting is releasing energy"

CONFLICTING RESOURCES

Exemplars: "Salt on roads" & "Salt on ski slopes"
Conflict: "[...] hang on...you also add salt to ski slopes to turn it into ice...oh my god"
Solution: "[..] you melt it first to make it freeze later"

Exemplars: "Salt on roads" & "Cooling beverages"
Conflict: "But it does not feel logical that it gets colder and then melts."
Solution: "[...]the cold is removed and finds the beverages and the ice melts"

5. CONCLUSION

Potential explanation for "Breaking/reacting is releasing": "**Energy as substance**" (e.g. Heron, Michelini & Stefanel, 2002)

The macro p-prims were **not productive** for prediction but would be **productive** in the explanation phase after an observation of T decreasing (which is shown in the rest of the data).

REFERENCES

diSessa, A. A. (1993). Toward an Epistemology of Physics. *Cognition and Instruction*, *10*(2), 105–225.

Gärdenfors, P. (2004). Conceptual Spaces as a framework for knowledge representation. *Mind and Matter*, *2*(2), 9–27.

Nosofsky, R. M. (2010). The generalized context model : an exemplar model of classification, 18–39.

Redish, E. F. (2004). A theoretical framework for physics education research: Modeling student thinking. *Proceedings of the International School of Physics "Enrico Fermi" Course CLVI: Research on Physics Education*, 1–56.

Rozier, S., & Viennot, L. (1990). Students ' reasoning in thermodynamics. *Tijdschrift Voor Didactiek Der B-Wetenschappen*, *8*(1), 3–18.

Talanquer, V. (2014). Chemistry education: Ten heuristics to tame. *Journal of Chemical Education*, *91*(8), 1091–1097.

Tversky, A., & Kahneman, D. (1973). Availability: A Heureistic for Judging Frequency and Probability. *Cognitive Psychology*, *232*, 207–232.

White, R. & Gunstone, R. (1992). Probing Understanding - The nature of understanding. London, UK: Falmer Press.