Understanding Matter
A Review of Research on Students' Conceptions of Matter

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Introduction

- Amongst all scientific concepts the concept of matter plays one of the most central roles for scientific literacy (Harrison & Treagust, 2002).
- Recently, learning progressions have been suggested as a means to foster students' understanding of scientific core concepts.
- The core of a learning progression is formed by a set of *big ideas* and *levels of understanding* (Krajcik et al., 2012).
- A first set of big ideas for the concept of matter was provided by Andersson (1990) which was expanded by Liu & Lesniak (2005) to the following: *structure and composition, physical properties and change, chemical reactions* and *conservation.*
- In the past, a variety of levels of understanding have been suggested focusing on different aspects of matter (see Duit, 2011).
- This study aims to identify common patterns across studies on students' understanding with respect to the four big ideas of matter from the last decade, working towards a more elaborate view on how students progress in understanding matter.

Methods

Design

- Systematic literature Review (see Bennett et al., 2005).

Selection criteria for articles

- Articles with a focus on students' conceptions of matter published in peer-reviewed, widely distributed journals with a high impact (impact factor 2012 > 1.0) from 2003 to 2012.

Sample

- 82 articles from: *Journal of Research in Science Teaching, International Journal of Science Education, Science Education, Studies in Science Education, Research in Science Education.*

Study	Number of Participants	Grade band / age	Aspects of Matter			
			SaC	Phy	Che	Con
Löfgren and Helldén (2009)	23	age 7 – 17	X	X	X	X
Krnel et al. (2005)	84	age 3 – 13	X	X		
Talanquer (2009)	(review)	K – 12	X	X	X	
Kermen and Méheut (2011)	144	grade 12	X	X	X	
Salta and Tzougraki (2011)	624 / 499	grade 7 & 9	X	X	X	X
Cokelez (2012)	76 / 50	grade 6 & 7	X			

SaC: Structure and Composition, Phy: Physical Properties and Change, Che: Chemical Reactions, Con: Conservation

Tab. 1: Excerpt of the included studies in this review(for full table see supplemental information)

Findings

- Studies that follow students over a broad span of time show strong commonalities in the way students' progress in understanding matter is described (Fig. 1).
- Starting from an understanding that is deeply connected to everyday observations students are supposed to progress towards an understanding of the particulate structure of matter and its relation to macroscopic properties along five levels.
- These levels can be considered as an overarching set of levels that are applicable within each of the four big ideas, which leads to a model to describe students' progress in understanding of matter as a core concept (Fig. 2).

- *Level 1:* Students seem to start with a naïve view of matter characterized by their daily life experience, explaining phenomena as they were observed.
- *Level 2:* Perceiving the existence of particles, students struggle to apply new terminology in a scientific correct way, for example they might perceive that particles are embedded in substances.
- *Level 3:* Perceiving that matter is built by particles and being able to apply a simple particle model in order to explain phenomena, students are not familiar with this new explanatory scope and are typically found to hold specific misconceptions like attributing macroscopic properties to the particles.
- *Level 4:* Understanding the nature of these particles, that is, that these particles are actually made of particles themselves, students are able to apply a differentiated particle model for explaining a variety of phenomena in a scientifically correct way.
- *Level 5:* Students are able to draw on their elaborate understanding of how properties of particles and of particles systems contribute to the macroscopic observable properties of a substance.

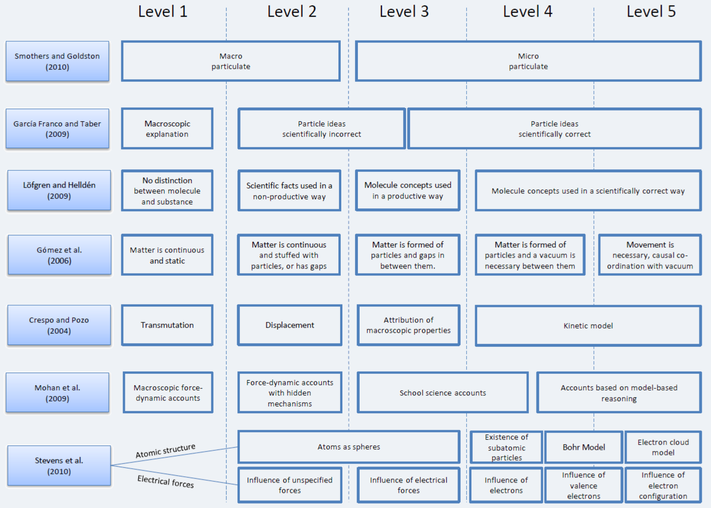

Fig. 1: Empirical studies upon our five levels of understanding are based.

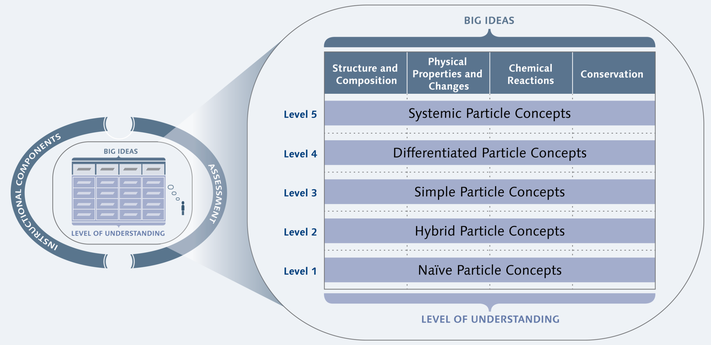

Fig. 2: Students' understanding of the four big ideas can be described in terms of the five levels of understanding.

Discussion

- Within the study presented here, a set of levels of understanding for the matter concept was derived from a sound literature base.
- These levels of understanding were found to be suitable to describe students' progression in understanding the concept of matter over time (Hadenfeldt et al., 2013).
- There is empirical evidence that an understanding of the four big ideas used in this study can be considered highly interrelated, but distinct (Hadenfeldt et al., under review).
- Given the number of articles included in this review, these levels may be considered "the main trend".
- Although the underlying set of four big ideas was followed by many researchers, other ways of defining big ideas can be found (eg. Smith et al., 2006; Stevens et al., 2010; NGSS, 2013).
- Overall, the model presented in this study might be considered a sound starting point for supporting current and future research on fostering students' progression in understanding matter.

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Supplemental Information:

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