European Association for Research on Learning and Instruction

11th International Conference on Conceptual Change. Epistemic Cognition and Conceptual Change

29. August – 1. September 2018
Klagenfurt, Austria

BOOK OF EXTENDED SUMMARIES
Dear colleagues,

Each of us exerts much thought and effort into our submissions to conferences answering the call for abstracts. Those summaries we submit for review are generally never shared with the community, only the accepted abstracts are made public.

For this conference, we asked all submitters whether they want to share their more extensive submission with their peers. This is the result. Please bear in mind, that there was - as usual - no required submission format but a strict word limitation. This leads to a wide variety of submission forms: While some opt to back their claims with an extensive list of references, others use the limited place to provide more argument, and trust that the reader will know whom they are referring to. Others creatively used the upload function we installed to allow the submission of figures and tables to add references they could not fit in the word limit.

Whatever form the final submission took, we thank the authors for their willingness to share their work, and wish you interesting insights while reading the extended summaries.

Gertraud Benke
(local conference chair)
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Studying initial conceptions of the autonomous car as the groundwork for designing road safety training

Emeline Ah-tchine & Erica de Vries (University Grenoble Alpes)

Keywords: Conceptual-change preconceptions; road safety education

Introduction
With the aim to develop relevant educational material in road safety, we report a study on initial conceptions of a particular innovative object, the autonomous car. How to behave with autonomous cars? Today, autonomous cars already exist but are not part of everyday life yet. With a similarity to traditional cars, the effective communication with the driver is not valid anymore (Guéguen, Meineri, & Eyssartier, 2015). People will have to first learn about and learn how to behave with autonomous cars. The identification of different initial conceptions of such a contemporary object is therefore relevant with a view to developing educational material, for instance in designing road safety instructions. In fact, a conceptual change might be necessary in order to adopt appropriate road safety behavior with autonomous cars.

Much is known about preconceptions of physical, chemical and biological phenomena and their influence in learning scientifically accepted theories and models. According to Chi, Slotta, and De Leeuw (1994) and Chi (2005), an important barrier in learning about an organism, object or phenomenon is its incorrect categorization within an ontological tree, such as wrongly categorizing a whale as a fish. Innovative technology may well span different possible frontiers between ontological categories, such as for example humanlike versus machinelike. The behaviour of drivers, passengers, and pedestrians may in turn depend on their particular view of the object as compared to normal cars.

In the current study, we expect to find two different profiles: autonomous cars might be seen as more safe (technology-controlled) or more unsafe (lack of controlling human). The first profile would correspond to viewing the autonomous car as a safe engine mounted with trustful and reliable technologies capable of recognizing and obeying traffic signs. The second profile would relate to a view of the autonomous car as an unsafe machine unfit to be integrated in a human traffic system and still more or less requiring a driver for control.

Methodology
An open-ended questionnaire was submitted to 180 French undergraduate students. The sample was composed of 14% of male, with a mean age of 20 years old and a standard deviation of 3.2. Among the participants, 83.3% indicated to have passed the theoretical part of the driving license exam, and 74.4% indicated to own a driving license. The questionnaire contained questions about the level of interest in and knowledge of the autonomous car. It then invited participants to write down a description of the autonomous car for a friend using their own words. Finally, it included demographic questions.

Results
Concerning their level of interest, 11.1% of the participants indicated never having heard of the autonomous car, 59.4% having a vague idea of it, 25.6% knowing what it is about and 3.9% having a great interest in it. One participant indicated to have been a passenger.
Regarding their description, we coded the answers following Chi’s methodology (1997). We obtained 13 exclusive categories (Table 1). We conducted a hierarchical cluster analysis (Yim & Ramdeen, 2015). Three categories with too few subjects (< 4%) were excluded.

<table>
<thead>
<tr>
<th>Table 1. Percentage of participants in each cluster by categories.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster 1</td>
</tr>
<tr>
<td>Self-driving</td>
</tr>
<tr>
<td>Autonomous</td>
</tr>
<tr>
<td>Useless driver</td>
</tr>
<tr>
<td>Useful driver</td>
</tr>
<tr>
<td>Executes a task</td>
</tr>
<tr>
<td>Settings necessary</td>
</tr>
<tr>
<td>Safe</td>
</tr>
<tr>
<td>Connected/smart</td>
</tr>
<tr>
<td>Sensors</td>
</tr>
</tbody>
</table>

Five clusters were identified using the Ward linkage method (Table 1). The category “Self-driving” did not discriminate between clusters. We characterized the clusters with a profile label by taking into account the categories scoring more than 19% in each cluster (in bold in table 1). In the largest cluster, 30% of the participants perceive autonomous cars as safe. The second cluster seems to be a simply semantic with no “flavor” as to a particular conception. The third cluster stresses functionality; with appropriate settings the car executes tasks by itself. The fourth cluster comprises a smart and connected car which is environmentally friendly. The last cluster reflects the least confidence in technology, but without mentioning “unsafe” as an explicit property: an autonomous car with sensors but still requiring a driver.

**Discussion**

This study shows that indeed profiles of initial conceptions with various emphases can be identified. We found one cluster with a “safe” conception representing 30% of the sample. However, only one out of five clusters, representing 13% of the sample, expresses doubts as to the safety of autonomous cars. Consequently, there is a need for the design of road safety instructions to create awareness of the specificity of the autonomous car and to teach about safety implications. In order to induce appropriate behavior, it should be clear to passive users, such as pedestrians, cyclists or other drivers, what an autonomous car can and cannot accomplish. Future research should address the actual behavior of pedestrians with different profiles and the effects of road safety instructions and/or visualizations of the state of autonomous cars.

**References**


Student’s conceptions of causes and processes forming eskers and erratics.
Mattias Arrhenius & Cecilia Lundholm (Department of Humanities and Social Science Education, Stockholm University)

Keywords: conceptions; geoscience education

Previous research
In geoscience education, research has mainly been conducted on student’s conceptions on topics such as the earth structure, plate tectonics, rocks and minerals (Cheek, 2010), but very few studies on students’ understanding of glaciers (Francek, 2013). Research on students’ understandings of glaciers (Felzmann, 2014; Happs, 1982; Reinfried & Hug, 2008) conclude on various learning difficulties such as for example relating glaciers to the aggregated states of water, understanding the dynamic nature of glaciers (seeing them as static objects), or using conceptual metaphors of glaciers in ways scientists do.

However, research on students’ conceptions on glacial/glaciofluvial landforms in geoscience education is still lacking, such as research on understanding of erratics and eskers, and in particular research that focuses on students’ alternative and scientific conceptions concerning causes and processes involved in the formation of these landforms.

Research aims
The aim of this study is to investigate students’ conceptions of causes and processes concerning the formation of eskers and erratics.

Theoretical framework
In conceptual change research there are many terms for describing students’ “incorrect ideas” such as misconceptions, naive beliefs, pre-conceptions and everyday ideas. However, some of these terms have been used inconsistently or without a clear definition in science education. Alternative conceptions is a similar term and can be described as conceptions which differ from what is accepted by science (Sexton, 2012, p. 168) and means that learners use their experience to construct explanations of natural phenomena in order to make them intelligible. In this sense alternative conceptions both encompass misconceptions and everyday ideas, but also convey an intellectual respect to the learners who holds these ideas (Thorn et al. 2016, p. 2).

Methods
Data consists of 135 written responses on a written assignment in the Swedish national test in geography for students aged 12-13 years. Answers were sampled randomised and subsequently analysed by using a qualitative content analysis (Elo & Kyngäs, 2007) and focussing explicit or latent meanings in students’ writings concerning causes and processes, the latter in terms of extraction, transportation and deposition of material. The assignment included the following question; “Why are eskers and erratics found in the Nordic region and how are they formed?” In order to gain a richer understanding of students’ conceptions, focus group interviews were conducted in three different schools with the same age group.

Results
The results show that even though the majority of students in the national test described glaciers/ice-sheets as the main cause for the formation of eskers and erratics, more than a third of the students hold alternative conceptions concerning these causes; some of these causes were
natural causes such as landslides and meteor impacts, while other were related to human activity, for instance remains of old Viking defence structures or material from modern road constructions. Further, the students who relate these landforms to causes described in geoscience (glaciers/ice sheets) hold alternative, partial or scientific conceptions concerning the processes involved in formation. The majority of these students hold partial scientific or scientific conceptions on the processes related to erratics, and alternative conceptions on the processes related to eskers. Very few students described the formation of eskers as the result of glaciofluvial processes. Finally, the results from the focus group interviews mirror results from the national test in terms of how students understand the processes involved in formation of these landforms.

Conclusion
From an empirical perspective, the results are important as they contribute with findings on 12-13-year-old students’ conceptions of the causes for, and processes involved in, formation of eskers and erratics. Additionally, while this study builds on previous work on students’ alternative conceptions on causes and processes in geoscience, it also expands the framework on students’ alternative conceptions. From an instructional perspective, the results are of importance for teachers as they provide new insights into students’ understanding of causes, and in particular processes, forming eskers and erratics by concluding on a wide range of alternative conceptions.

References


Students’ epistemic beliefs profiles across secondary school in Germany
Andrea Bernholt, Maria Lindfors & Nele Kampa (IPN - Institute for Science and Mathematics Education Kiel)

Keywords: epistemic beliefs; profiles; classroom environment

Theoretical background and research aim
Individual’s beliefs about the nature of knowing and knowledge have been investigated under the label of epistemic beliefs. Although research in this area is still growing, only a few studies deal with (young) school children and there is still less empirical research focusing on the development of epistemic beliefs over several school years. With regard to well-known measurement problems, a valuable approach might be to classify students in more homogeneous groups according to their beliefs in order to overcome the idea of (just) comparing means of individuals’ views about knowledge and knowing as an indicator for developmental trajectories. This person-centered approach as it is used e.g. in Latent Profile Analyses could be a way to detect similarities and differences in several groups and/or at several time points.

Research with this approach was done for our knowledge in three studies until now (Dai & Cromley, 2014; Trevors et al., 2017, Kampa et al., 2016) showing that it is possible to identify different groups of students according to their belief patterns. A limitation can be seen in the sample selection as all three studies focusing on one age group/grade level. Therefore, we ask 1) what kind of science-related epistemic profiles, if any, exist across grade 5 to 12 and how can these profiles be characterized and 2) how do students differ, if so, with regard to cognitive outcomes, motivational variables, and their perceptions of classroom variables?

Method
A cross-sectional survey was administered to students from grades 5-12 in secondary schools in Germany. The students were asked to answer a science test as well as a questionnaire regarding their science self-concept, interest in science, attributional style, background variables, and their perceptions of science lessons. Epistemic beliefs were measured with 22 items assessing science related beliefs about the certainty, source, justification, and development of knowledge (based on Conley et al, 2004). Overall, a sample of 3088 students remained for analyses. The students were aged from 9 to 19 years (M = 14 years, SD = 2.5) with 52% being female. Confirmatory factor analysis revealed suitable fit statistics ($\chi^2 = 263.620(69)$, RMSEA = .044, SRMR = .036, TLI = .919, CFI = .935) for all four epistemic beliefs constructs.
Table 1. Correlations between epistemic beliefs dimension, mean statistics, standard deviation and Cronbach’s α.

<table>
<thead>
<tr>
<th>Source</th>
<th>Certainty</th>
<th>Development</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Certainty&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.56**</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Development&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-.17**</td>
<td>-.22**</td>
<td>-</td>
</tr>
<tr>
<td>Justification&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-.01</td>
<td>.01</td>
<td>.47**</td>
</tr>
</tbody>
</table>

| M (SD) | 2.54 (0.79) | 2.54 (0.80) | 3.84 (0.69) | 3.83 (0.69) |
| α    | .73 | .61 | .64 | .60 |
| n    | 2821 | 2822 | 2803 | 2782 |

**p (two-tailed) < .001

Note: Likert scale with 1 = totally disagree to 5 totally agree. <sup>a</sup> higher values meaning more sophisticated beliefs, <sup>b</sup> higher values meaning more naïve beliefs.

We ran LPAs by grouping students in three different grade levels as an indicator for their school experiences in science (grades 5 & 6: almost no experiences in Chemistry/Physics but in Biology; grades 7-9 lower secondary school with lessons in Chemistry, Physics and Biology for all students; grades 10 – 12 upper secondary school with students choice of having a science or non-science profile). In the second step, we introduced the covariates (as auxiliaries(e)) into the LPA.

Results

Results revealed three different groups of epistemic profiles both in grades 5 and 6 as well as in grades 7-9. Interestingly, four different profiles can be distinguished in grades 10-12. To describe the different patterns of epistemic beliefs, Table 2 shows the mean statistics and sample sizes for each profile over the three groups. Profile 2 is characterized by sophisticated beliefs in all four dimensions. In contrast to this homogenous pattern, students in Profile 1 (called ‘evidence-based/dynamic’) show naïve beliefs regarding the certainty and source of knowledge. Moreover, they also believe that justifying knowledge with different evidences is important and that present knowledge is dynamic and changing. Profile 3 is characterized by the opposite pattern of Profile 1. Students in this group report sophisticated beliefs in the source and certainty dimension at the same time as they show slightly naïve beliefs (below scale average) for the justification and development perspectives (‘multiplistic’). We found a fourth profile in grades 10-12, which showed highly sophisticated beliefs over all four epistemic dimensions.
Table 2. Mean statistics for the epistemic beliefs dimensions according to the profiles.

<table>
<thead>
<tr>
<th>Grade 5 and 6</th>
<th>evidence-based/dynamic</th>
<th>sophisticated</th>
<th>multiplistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>3.33</td>
<td>2.00</td>
<td>2.49</td>
</tr>
<tr>
<td>Certainty</td>
<td>3.44</td>
<td>2.43</td>
<td>2.62</td>
</tr>
<tr>
<td>Justification</td>
<td>3.97</td>
<td>4.23</td>
<td>3.08</td>
</tr>
<tr>
<td>Development</td>
<td>3.77</td>
<td>4.23</td>
<td>2.98</td>
</tr>
<tr>
<td>n (%)</td>
<td>384 (44%)</td>
<td>270 (31%)</td>
<td>222 (25%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grade 7 - 9</th>
<th>evidence-based/dynamic</th>
<th>sophisticated</th>
<th>multiplistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>3.12</td>
<td>2.14</td>
<td>2.44</td>
</tr>
<tr>
<td>Certainty</td>
<td>3.09</td>
<td>2.02</td>
<td>2.51</td>
</tr>
<tr>
<td>Justification</td>
<td>3.91</td>
<td>4.08</td>
<td>3.01</td>
</tr>
<tr>
<td>Development</td>
<td>3.71</td>
<td>4.28</td>
<td>2.97</td>
</tr>
<tr>
<td>n (%)</td>
<td>453 (40%)</td>
<td>493 (44%)</td>
<td>181 (16%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grade 10 - 12</th>
<th>evidence-based/dynamic</th>
<th>sophisticated</th>
<th>multiplistic</th>
<th>highly sophisticated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>3.11</td>
<td>2.67</td>
<td>2.10</td>
<td>1.77</td>
</tr>
<tr>
<td>Certainty</td>
<td>2.99</td>
<td>2.32</td>
<td>2.07</td>
<td>1.68</td>
</tr>
<tr>
<td>Justification</td>
<td>3.51</td>
<td>4.10</td>
<td>3.40</td>
<td>4.08</td>
</tr>
<tr>
<td>Development</td>
<td>3.37</td>
<td>4.24</td>
<td>3.49</td>
<td>4.47</td>
</tr>
<tr>
<td>n (%)</td>
<td>183 (19%)</td>
<td>258 (29%)</td>
<td>245 (25%)</td>
<td>266 (27%)</td>
</tr>
</tbody>
</table>

Note: Likert scale with 1 = totally disagree to 5 totally agree. * higher values meaning more sophisticated beliefs, b higher values meaning more naïve beliefs.

According to our second question, we analyzed differences in students’ cognitive outcomes and motivational characteristics as well as their classroom perceptions between the profiles by introducing them as covariates (see Table 3).
Table 3. *Class profiles: Differences cognitive outcomes, motivational variables and perceived classroom characteristics between profiles across the three grade level*

<table>
<thead>
<tr>
<th></th>
<th>grade level</th>
<th>evidence-based/dynamic</th>
<th>sophisticated</th>
<th>multiplist</th>
<th>highly sophisticated</th>
</tr>
</thead>
<tbody>
<tr>
<td>**</td>
<td>5/6</td>
<td>-0.61&lt;sup&gt;2&lt;/sup&gt;</td>
<td>-0.45&lt;sup&gt;1,3&lt;/sup&gt;</td>
<td>-0.65&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7-9</td>
<td>0.02&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.33&lt;sup&gt;1,3&lt;/sup&gt;</td>
<td>-0.08&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10-12</td>
<td>0.38&lt;sup&gt;2,3,4&lt;/sup&gt;</td>
<td>0.66&lt;sup&gt;1,3&lt;/sup&gt;</td>
<td>0.52&lt;sup&gt;1,2,4&lt;/sup&gt;</td>
<td>0.69&lt;sup&gt;1,3&lt;/sup&gt;</td>
</tr>
<tr>
<td>grade chemistry</td>
<td>5/6</td>
<td>1.51</td>
<td>1.92</td>
<td>2.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7-9</td>
<td>2.58&lt;sup&gt;2&lt;/sup&gt;</td>
<td>2.35&lt;sup&gt;1,3&lt;/sup&gt;</td>
<td>2.76&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10-12</td>
<td>2.78&lt;sup&gt;4&lt;/sup&gt;</td>
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<td>3.53&lt;sup&gt;3&lt;/sup&gt;</td>
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As shown in Table 3, there are several significant differences between the beliefs profiles over grade level. By focusing on cognitive outcomes, we found that students – over all grades - in the ‘sophisticated’ (and also in the highly ‘sophisticated’) showed higher achievement test scores and had better grades in chemistry as well as in physics and biology compared to the other profiles. Moreover, with regard to motivational variables it seems that students in the ‘multiplist’ profile report inconvenient patterns compared to the other profiles like lower self-concept, lower science interest, an obstructive attributional style of failure and were less involved in classroom activities (cooperation, participation) as well as they felt to a lower extent supported by the teacher.

**Conclusions**

In sum, the results indicate that it is possible to identify distinctive groups of students with homogenous science-related epistemic belief patterns across grades 5 to 12. Moreover, the qualitative pattern seems to be comparable over different grade level, with the interesting result of an additional fourth profile in upper secondary which might be a hint for developmental processes. Furthermore, the results show that there are differences in motivational as well as cognitive outcomes between the profiles as well as differences in the way students perceive their classroom environment and teacher support, which will be discussed in more detail at the conference.

**References**


<table>
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<td>2.69(^2)</td>
<td>2.30(^{1,2})</td>
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<td>3.01(^3)</td>
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<td>10-12</td>
<td>3.43(^{2,4})</td>
<td>3.96(^{2,4})</td>
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\(^*\) p (two-tailed) < .05
\(^**\) p (two-tailed) < .001
\(^1\) = best to 6 = worst

As shown in Table 3, there are several significant differences between the beliefs profiles over grade level. By focusing on cognitive outcomes, we found that students – over all grades - in the ‘sophisticated’ (and also in the highly ‘sophisticated’) showed higher achievement test scores and had better grades in chemistry as well as in physics and biology compared to the other profiles. Moreover, with regard to motivational variables it seems that students in the ‘multiplist’ profile report inconvenient patterns compared to the other profiles like lower self-concept, lower science interest, an obstructive attributional style of failure and were less involved in classroom activities (cooperation, participation) as well as they felt to a lower extent supported by the teacher.


Analysing children’s and adolescents’ conceptions about the functioning of solar cells: a case study in an informal context.

Romain Boissonnade (University of Neuchâtel & University of Teacher Education BEJUNE)

Keywords: Conceptions; solar cells; technology; informal learning

Introduction
Since the 80’s, children’s conceptions about electricity prior to any formal instruction has received considerable attention (e.g. Lee, 2007; Osborne, 1981; Shipstone et al., 1988; Tiberghien & Delacôte, 1976). A few studies investigated children’s knowledge about solar panels, probably because it is a recent technology. Some researchers have tried to describe high school and undergraduate students’ conceptions of photovoltaic cells or photoelectric effects (De Leone & Oberem, 2004; Ing, Huang, LaCombe, Martinez, & Haberer, 2011; Kishore & Kisiel, 2013; Taslidere, 2016).

According to a constructivist perspective, prior knowledge and everyday experiences greatly influences the way concepts are acquired from elementary school to college level. In particular, there has been a persistent body of researchers who have explained how children’s conceptions is influenced by informal and out-of-school experiences.

This qualitative study is part of a larger project investigating children’s experiences occurring in a “solar toy” informal context and the influences in design, technology, engineering and science knowledge. We needed to describe the participants’ conceptions about the functioning of solar cells. For the purpose of this paper, we expected: a) to observe well-known preconceptions about light, energy and electricity; b) to find original conceptual frameworks which illustrating the situatedness of children’s conceptions.

Method
A holiday play scheme was organised in Switzerland and called “solar toys”. This out-of-school context enabled children and young adolescents to build a personal solar toy powered with a small photovoltaic panel. The study was carried out in this context with 26 French-speaking participants aged 7 to 13 (9 girls, 17 boys; Age mean = 10,1; SD = 1,7). They were interviewed individually, initially and after the session. Three main questions were asked: ‘What is the sun?’, ‘What is solar energy?’ and ‘What is a solar panel?’. Exploratory observations and field notes were also undertaken during the building activities and helped to characterise the conceptions and experiences. Qualitative analyses of this data enabled one to characterise a range of conceptual frameworks about the functioning of a solar panel.

Results
Analysis of the children’s responses supported past findings about children’s understanding of light, electricity and energy. Unlike previous research, many participants showed a lack of differentiation between energy and electricity.

Six conceptions were distinguished about the relationship between the Sun and the solar panel:

- the relationship can be neglected or ignored (past findings proved that children often ignore that light is an entity travelling into space);
- the sunlight may be thought as an external condition without any interaction with the device either because it is a living thing effective at daytime or it has to be co-present with the Sun;
- a direct path is necessary from the sun to the panel without any obstacles;
- the panel must be fed with the Sun either actively (the panel captures/sucks/takes something) or passively (the panel receives something).

Several naïve conceptual frameworks were hypothesised about the functioning of the solar panel: the panel can be thought as something which animates things, or like a property of objects that are animated as a whole, or as a cause for a physical phenomenon. In this latter case, different ontologies of the solar panel can be inferred: it is considered either as a switcher, or as a trap, or as a pipe, or as a converter.

**Conclusion**

The study offers a new confirmation of children’s conceptions of batteries and electric circuits. It also gives some insights about the way they acknowledge the functioning of solar panels. These preconceptions children bring to school are useful to better understand pupils’ difficulties and to foster a deep learning.

Comparing children’s conceptions about solar cells before and after their participation to the investigated workshop would be a worthwhile undertaking. Our preliminary interpretations suggest that children’s tinkering activities to build solar toys in this collective informal setting, could support their technological knowledge about solar panels, and also lead them to question the functioning of solar technologies. In this context, the development of analogies (Amin, 2015) may be an essential tool for a conceptual change at the interplay between engineering practices and physics concepts.

**References**


Changes in Aims, Ideals, and Reliable Processes During Epistemic Growth in Explanation
Clark Chinn (Rutgers University)

Keywords: explanation reasoning epistemic

In this paper, I will apply the AIR model of epistemic cognition to analyze how epistemic practices may change as people gain skill in explanatory reasoning individually and in groups and communities. The analysis provides one lens into epistemic conceptual change (Sinatra & Chinn, 2012)—that is, changes in the concepts that undergird reasoning.

The AIR model postulates that epistemic cognition comprises three components: people’s epistemic aims, their epistemic ideals (or standards) for evaluating epistemic products, and the reliable epistemic processes they use to achieve their epistemic aims. I will examine how aims, ideals, and reliable processes may change as learners’ advance epistemically within two different domains: science and history. To keep the analysis manageable, I will focus on one particular epistemic aim relevant to both science and history: explanation.

Changes in Explanatory Aims
Studies of scientists and historians alike have shown that scholars in both fields adopt a diversity of explanatory aims for various purposes (Godfrey-Smith, 2003; Tucker, 2011). For example, in science some explanations appeal to general laws that subsume particular instances; others present causal accounts; and others articulate systems that simultaneously meet multiple constraints. In both science and history, causal explanations may be general (e.g., explaining speciation, or why civilizations decline) or specific (e.g., explaining the emergence of a particular species, or why a particular war was fought). Another distinct historical aim is simply to develop historical narratives; the sense of explanation comes from seeing how all the parts fit together in a coherent whole.

Based on this analysis, one likely epistemic challenge for students learning science and history is to develop an appreciation of the sheer diversity of explanatory aims. In addition, students may see explanation as primarily causal, which may pose challenges for understanding other forms of explanation that are not simply causal. They will need to learn alternative conceptions of what explanations can be.

Changes in Ideals to Evaluate Explanations
Brewer, Chinn, and Samarapungavan (1998) argued for similarities in the ideals used by children and scientists to evaluate explanations. For example, Samarapungavan (1992) showed that children—like scientists—adopt explanatory ideals such as preferring explanations with broader evidential scope and better fit with other established knowledge. However, children are unlikely to adopt ideals such as fruitfulness of an explanation or high precision of mathematical fit of explanations with data.

While explanatory fit also matters to historians, they also adopt ideals such as contextualization (forming a narrative “tapestry” that integrates chronological, social, cultural, and personal contexts surrounding events) and corroboration (accounts should be supported by multiple sources). Research on historical document integration has suggested that most students do not use either of these criteria to evaluate information sources (Wineburg, 2001). In both fields, learning these ideals will involve qualitatively new understandings of what makes an explanation good. For example, mathematical fit is likely to be an entirely new concept that children must learn to apply to evaluate explanations in science.
Changes in Reliable Epistemic Processes

Finally, many of the processes used by scientists and historians to construct, evaluate, and revise explanations will be conceptually unfamiliar to novices. For example, scientists view observation as a potentially theory-laden process that must be conducted in ways that minimize potential biases; it is also inexact, so that multiple observations of the same thing will yield a range of results due to error in measurement and other factors. Such ideas are not part of students’ conceptions of observation ways (Eberbach & Crowley, 2009). In history, historians develop historical accounts through processes such as empathy (Breisach, 2007) and the development of sophisticated counterfactual scenarios (Weinryb, 2011). The psychological evidence, in contrast, indicates that these are not part of novices’ strategic repertoires; for example, children adults alike often simply project their own perspective as that of (Gehlbach, 2004). For students to learn such processes, they will need to develop new ways of conceptualizing the processes of explanation construction in science and history.

Conclusion

The three components of the AIR model provide a useful lens for analyzing both (a) the ways in which novices’ reasoning differs from experts and (b) how the developmental tracks in different domains differ because the expert “end points” differ. Using explanation as an illustrative reasoning practice, I argue that novices and experts in both science and history are likely to have different conceptualizations of the aims of explanation, of the ideals by which explanations are evaluated, and of the processes used reliably to produce explanations. The AIR model accordingly provides a lens for analyzing these conceptual differences, which is a first step toward designing better instruction.

References


Natural Number Bias in understanding variables in algebra – the role of mathematics textbooks

Stella Dimitrakopoulou (National and Kapodistrian University of Athens, Greece) & Konstantinos Christou (University of Western Macedonia, Greece)

Keywords: textbooks, variables, natural numbers bias

Introduction

Variable is a significant concept for understanding algebra but it’s multiple representations as a specific number, parameter, label or generalized number discommode student’s performance and lead them to misconceptions and diverse errors. Notwithstanding, students face multiple difficulties in understanding that variables are literal symbols to stand for any real number. Initially, they struggle to accept literal symbols as standing for numbers and after accepting this, they tend to think that they represent only natural numbers (Christou, 2017). Students’ tendency to think of variables as symbols of natural numbers rather than symbols of any real number, could be due to a natural number bias phenomenon. As natural number bias (NNB), it is characterized students’ tendency to apply their prior knowledge and experience about natural numbers in cases of reasoning about fractions and decimal numbers (Ni & Zhou, 2005).

Textbooks have a leading role in the providing systematic knowledge to the students, and thus it could contribute significantly to the ways variables are understood. Dogbey and Kersaint (2012) have investigated the treatment of variables in twelve mathematics textbooks, during four eras of mathematics education in the United States. They classified the ways variables appear in the textbooks, in seven main categories which are also used in this study and are presented below.

In this study, it is investigated the treatment of variables in Greek mathematics textbooks of 7th, 8th and 9th grade. More specifically it is tested whether variables are used as label, constant, specific unknown, generalized number or varying quantities using the previously mentioned categories. In addition, it is tested whether the numbers that the variables represent are natural or non-natural numbers. It was expected, according to previous research, that variables would appear mostly as a specific number and label. However, for variables’ number values no previous studies existed to compare the results with.

Method

Materials- Procedure

The mathematics textbooks of 7th, 8th and 9th grade, are the only certified for teaching, in Greek Junior High schools, by the Ministry of Education. All variables that appeared in exercises, worked examples, assignments, activities and definitions were placed in five majoring categories: a) label, when variables represent algebraic or geometrical quantities, which can have a numerical value, i.e., variables to name the angles of a triangle (see Figure-1a), b) constant, when variables represent a fix value like π=3.14159 (see Figure-1b), c) specific unknown, when variable takes one or two known or unknown values (see Figure-1c), d) generalized number, when variable takes more than two known or unknown values, or represented patterns or sequences (see Figure-1d) and e) varying quantities, when variables denote the functional relationship between two or more variables, as in linear systems (see Figure-1e).
Results - Discussion
The results, presented in Table 1, showed that the variables are mostly used in the Greek textbooks in all three grades as generalized numbers-33% and less as label-23%, specific number and varying quantities-20% or as constants-4%. However, there were statistically significant differences between the three grades and more specifically between 7th-8th grade [$\chi^2(4)=129, p<.001$] and 8th-9th grade [$\chi^2(4)=210, p<.001$] which were due to the domination of label and varying quantities in 8th grades’ textbooks.

Table 1: Categories of variables as they appear in the 7th to 9th grade in the Greek mathematics textbooks

<table>
<thead>
<tr>
<th>Category</th>
<th>7th grade</th>
<th>8th grade</th>
<th>9th grade</th>
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<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Label</td>
<td>71</td>
<td>24</td>
<td>180</td>
<td>33</td>
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<tr>
<td>Constant</td>
<td>--</td>
<td>--</td>
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<tr>
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<td>83</td>
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</tr>
<tr>
<td>Total per Grade</td>
<td>297</td>
<td>100</td>
<td>550</td>
<td>100</td>
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These results were different from Dogbey & Kersaint’s results where the main category was specific unknown. In that way the Greek mathematics textbooks present variables in a more sophisticated way than the American ones of the same grades.
Considering the second research question, which referred to the kind of numbers, natural or non-natural, that are attributed to variables, the results, presented in Table 2, showed that in 7th grade the non-natural numbers appeared in 32% which percentage increased in 9th grade to 58%. There were statistically significant differences between the three grades \( \chi^2(2)=34.6, p<.001 \), which are due to the low appearance of non-natural numbers in 7th compared to 8th grade \( \chi^2(1)=27.3, p<.001 \) and 9th grade \( \chi^2(1)=30, p<.001 \).

![Table 2: Presence of natural vs non-natural numbers in the Greek mathematics textbooks](image)

The results of this study showed that although variables predominated in the textbooks as generalized numbers, they were almost equally substituted with non-natural numbers and natural numbers. Thus, it can be argued, that NNB phenomenon which prevents students from mastering a rational number understanding (Christou, 2017) is reproduced through mathematics textbooks, reinforcing this way students’ tendency to think literal symbols as symbols that represent mostly natural numbers and not any real number. Taking into consideration, that non-natural numbers include fractions and decimal numbers which are introduced from the 3rd grade, and negative numbers which are introduced from the 7th grade, the presence of non-natural numbers is relatively low and could be much higher.

It is often argued that learning with learning revision, in this case is to transcend the barriers of NNB by revising the initial conception of number which is organized around natural numbers, is a difficult and time-consuming process and should be supported by specifically designed educational material (Vosniadou et al 2001). The results of this study bring to light empirical results that support that there is a lot to be done in this direction.

References


Can explicit modeling of dynamical systems in physics change students’ beliefs concerning the nature of scientific knowledge?
Elisabeth Dumont (ZHAW) & Hans U. Fuchs (Center for Narrative in Science)

Keywords: Physics, modeling, epistemology, conceptual change, narrative

In courses on modeling of dynamical physical and chemical systems and processes for industrial engineering students, we deal with a particular epistemic issue—the belief that concepts, laws, theories of physics are to be taken literally. This belief, a form of naïve realism, severely impedes students’ progress in learning about conceptual structures in the field they are studying. Here, we shall discuss how explicit instruction in modeling of dynamical systems can question students’ certainty that (conceptual) truth is “out there” rather than “in here,” i.e., in our minds.

Let us first describe the challenge we are facing. In traditional high school physics courses, students are exposed to ideas concerning the reality of the physical world and the nature of knowledge of this reality that is best described as naïve realism. School physics is rife with pop science that has little to do with the realities of nature, physics, or the human mind but rather creates a less than useful image of the role and nature of knowledge. Chief among modern fundamental beliefs are the world is made of matter and energy and reality is to be found in the motion of little particles.

Such certainties stand in the way of students learning how to become successful modelers of complex dynamical systems, both in science and in social science. The reason for this impediment is to be found in an aspect of epistemology that develops in parallel with our chief ontological beliefs concerning how the world really is; it is the assumption that physical concepts, laws, or theories, are to be taken literally—objectivist epistemology reflects naïve realism.

It is well known what this means for learning a science such as physics: since “truth is out there,” a learner cannot possibly get to the laws of physics herself, and she certainly cannot be creative in constructing models of how parts of the world work. In other words, she must be given the equations (that were found a long time ago by wise men—and a very few women) she is to apply uncritically to sterile situations that populate school physics.

In our course, however, we try to build students’ confidence in their ability to come up—spontaneously and creatively—with explanatory narratives for physical processes. Such narratives contain the seeds of conceptual structures needed for creating mathematical computer models of the systems that undergo physical, physico-chemical, or biochemical processes.

We have developed what we consider to be two important components of this approach that feed back upon epistemology and conceptualization. First, we choose some simple but ill-defined examples from social science for systems modeling and then let students apply the same model structures to examples of physical systems that are unknown from traditional physics instruction. As a consequence, students learn that they are the creators of ideas for formal relations that go into successful mathematical models (Fuchs and Dumont, 2013-17; Fuchs, 2010). Second, students learn that modeling and deploying models for simulations is a narrative process, also in physics (Morgan, 2001, 2012; Wise, 2011; Fuchs, 2015). This should let them see the nature of scientific knowledge in a new light—conceptual structure in physics is metaphoric (Amin, 2009; Fuchs, 2006) and framed by narrative (Fuchs, 2015; Fuchs, Corni, Dumont, 2016; Corni et al., 2017; Fuchs et al., 2018).

In an attempt to answer the question in the title, we shall now briefly outline an introductory sequence of our course where students are exposed to dynamical modeling for the first time. The
example from social science asks students to imagine a situation where a company absorbs an engineering department from another firm and merges it with their own group of engineers. Since employees have been paid different wages in the two companies for the same work, students are asked to describe, and then model and simulate, a process where wages in the two groups are equalized over the course of a certain period, first without increasing total payroll.

After successfully working on this assignment—where they need encouragement with conceptualization and help with the transfer of ideas into a software environment—students experiment with a hydraulic system where water levels in two communicating tanks equilibrate. Then they produce narrative descriptions and explanations of what is going on. Subsequent computer modeling happens with barely any help—students realize that the hydraulic model is analogous to what they create in the business case. Importantly, they do not have to be taught a law for the flow of liquid through the pipe—a relation between level difference and flow that is analogous to Ohm’s law in electricity. They have created a similar idea for the rate of transfer of payroll from one group of engineers to the other in order to achieve a form of equilibration of wages that is similar to what can be observed in the adjustment of levels of a liquid in two communicating tanks.

This modeling sequence changes students’ attitude with respect to the source of “laws” that describe behavior. They become more willing—and able—to construct models of novel situations on their own.

While students’ progress in the course is impressive, course feedback indicates that most of them are still far from revising their beliefs concerning scientific knowledge. Typically, when they start working on chemical dynamical systems, they still want to know “how things really work,” meaning how little particles behave, when the proper and successful form of modeling is derived from macroscopic physical science.

We suggest that substantial epistemological transformation in our students will take much longer than the time spent on a single first course. In order to see if apparent change is sustained over longer time and possibly into the professional carriers of our students, we would have to investigate their attitudes over the course of several years.

References


Conceptual Notions of p-values in Educational Research
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Keywords: Concepts of p-values, metascience

Background
When using statistics, conceptual change researchers typically rely on p-values to inform about the adequacy of hypotheses and their predictions. It might therefore be assumed that researchers have appropriate concepts and know about the adequate uses and interpretations of this tool. Recent studies however have shown that researchers tend to fall victim to a number of misinterpretations of p-values (Nieuwenhuis, Forstman, & Wagenmakers, 2011; Kline, 2013).

Two common misinterpretations are related to p-values higher than the cut-off for statistical significance, in the majority of cases p > .05. One misinterpretation is that p > .05 indicates no effect. While this is possible, given the low power of studies, a type II error (i.e. missing an existing effect) is often more likely. Thus, p > .05 really leaves inconclusive evidence (Altman, 1995). The second misinterpretation is that if one effect is significant (p < .05) and another one is not (p > .05), it implies that the two effects differ. The appropriate way to test this is an interaction test, which researchers often fail to conduct (Gelman & Stern, 2006).

The present study therefore wants to explore the following research questions:

- What is the prevalence of two misinterpretations (p > .05 = evidence for absence of effect, p < .05 vs. p > .05 implies difference in effects) of p-values in recent articles of three educational journals?
- What are typical theoretical, practical, and policy implications that conceptual change researchers draw based on these misinterpretations?

Method/Approach
An in-depth review was conducted on ten randomly selected articles from each of the following educational journals:

1. German Journal of Educational Psychology (impact factor according to Thomas Reuters Journal Citation Reports: 0.72; 21 empirical articles in 2016).
2. Instructional Science (IF: 1.69; 29 empirical articles in 2016).

In these overall 30 articles, focal hypotheses and statistical tests which yielded p-values > .05 were identified. Then, the authors’ statistical inferences, and theoretical, practical, and policy implications based on these p-values were noted.

Results
Out of 238 p-values, 95 yielded p > .05. Regarding the first misinterpretation, all of those were statistically misinterpreted as implying evidence for the absence of an effect. Regarding the second misinterpretation, 58 times researchers interpreted a difference between an effect with p > .05 and another one with p < .05 without conducting an appropriate test. These results differed between the three journals, but the overall picture was consistent.

Regarding the second research question, there was a great variety of implications that conceptual change researchers inferred based on these misinterpretations. A common practice was that in the
case of $p > .05$, researchers discussed reasons for the absence of an effect. Regarding erroneous conclusions about implications, the second misinterpretation beard more weight than the first one: In various cases researchers pointed out the remarkableness of one significant effect over another which did not reach the p-values below the cut-off, without however testing appropriately whether the two effects really differed from each other.

In some articles, authors raised the assumption that $p > .05$ might stem from small sample sizes. While sample size is linked to the frequency of a type II error, in none of the articles a potential type II error was explicitly discussed. In some articles, effects with $p > .05$ were fully neglected and not discussed at all.

Conclusions and Implications
The results indicate that misinterpretations of p-values exist in educational psychology, with a high frequency in the reviewed journals. In conceptual change research, misinterpretations of p-values frequently lead to unfounded theoretical conclusions, and practical and policy implications.

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How much politics is there? Exploring students’ experiences and views of values and objectivity in political science from an epistemic cognition perspective

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Keywords: political science, epistemological beliefs, values

Research aims
In a review of research on teaching and learning political science, Craig (2014) calls for a more genuine intersection of political science and learning, and a stronger focus on learning processes. Studies of other disciplinary fields have pointed to the fact that epistemic beliefs are an important aspect of students’ learning processes (Maggioni, Fox & Alexander, 2010), and in this paper we focus in particular on students’ epistemic beliefs in political science.

Students’ epistemic beliefs are difficult to grasp and analyse “head on”. In the study, students’ epistemological beliefs were analysed through students’ experiences of values and impartiality in teaching and classroom dialogues (c.f. Hofer & Pintrich 1997).

Theoretical framework
The research field on epistemic beliefs takes an interest in students’ beliefs about knowledge and the nature of the discipline they are taught. Focus is on “how individuals come to know, the theories and beliefs they hold about knowing, and the manner in which such epistemological premises are a part of and an influence on the cognitive processes of thinking and reasoning” (Hofer 2000: 378). Hence, students’ understandings of what knowledge is, and how knowledge is produced, are of interest. These two aspects have been operationalized into four dimensions (certainty of knowledge, simplicity of knowledge, source of knowledge and justification of knowledge (Hofer 2000: 380) that aim to capture ‘the nature of the discipline’ (Mason 2016).

These dimensions might shed light on potential disciplinary differences when it comes to for example university students’ beliefs about the certainty of knowledge (c.f. Hofer 2000). They may also add to our understanding of students’ learning in the academic discipline of political science (c.f. Craig 2014; Maggioni et al. 2010). By investigating student experiences within a framework of epistemic cognition in a social science discipline, we hope to contribute to current discussions concerning epistemic beliefs being domain general or specific (Muis et al 2006). As of yet, studies have been conducted in psychology (Peter et al 2015) and history (VanSledright & Maggioni 2016), but to our knowledge not in other social science disciplines.

Methodology
We conducted 13 interviews with students after one semester of studies. The interviews were open-ended and conversational (Kvale 1996: 19) and transcribed and analysed using abductive thematic analysis (c.f. Fereday et al. 2006). This hybrid process of inductive and deductive thematic analysis is a methodological approach that aims to integrate data-driven coding with theory-driven coding. The four dimensions - certainty of knowledge, simplicity of knowledge, source of knowledge and justification of knowledge (Hofer 2000: 380) - were theory-driven codes.

Results
Results show that the students are uncertain about the epistemology of political science. For example, students oscillate between different ways of making sense of the existence of values.
Values are seen both as something that constitute a threat toward objective knowledge, and at the same time, as a natural part of the discipline. In regard to certainty of knowledge, students are unsure of whether certain knowledge is possible or not in the discipline.

Students suggest the use of different but equally unproductive strategies to handle the existence of values; they wish for teachers to promote values that students themselves sympathize with, and for teachers to promote values in a hidden way. This can be seen as justifying the production of knowledge in the classroom. The production of “biased knowledge” on behalf of the teachers is accepted if it students themselves sympathize with this knowledge, or, if it is introduced in the classroom in a subtle way.

Interestingly, the results relate to epistemological tensions in political science. The epistemology – or theory of knowledge – of the discipline may not be totally fixed (Marsh & Stoker 2010), which can complicate students’ efforts to understand what constitutes knowledge in the discipline. While these results can be regarded as discipline specific epistemic beliefs, we believe that disciplines with multiple, or dominant but existing multiple epistemologies, can potentially bring about similar challenges.

**Conclusion**

From a theoretical perspective, this paper contributes to current discussions concerning epistemic beliefs being domain general or specific (Hofer 2000; Muis et al 2006). From an empirical perspective, the results contribute to our understanding of subject discipline epistemological beliefs, and to our understanding of teaching and learning processes in political science.

**References**


How do children aged between 4-11 years learn science, and what can this tell us about the efficacy of the science curriculum in England?

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Keywords: cognitive development, conceptual change, science education

Curricular design is an activity that rests on some fundamental assumptions about the organisation of knowledge and development of understanding. Presently the National Curriculum for England is organised in a manner that assumes sequential learning of scientific concepts so that generalised understanding can be developed on the basis of earlier concepts. However there is a distinct lack of any systematic literature on the processes behind conceptual development, which has often shown children’s learning to be piecemeal and unlikely to progress in such a straight-forward and linear fashion, contrary to earlier theorising. Other work also highlights the fact that general cognitive abilities can be highly influential in learning about numeracy and literacy concepts (Gathercole et al., 2003; 2004) however, little is known about the exact effects of general cognitive abilities on science learning. More recently, there are some indications that working memory and executive functions might well be implicated in science learning in preschool (Nayfield, Fuccillo & Greenfield, 2013), but little work has been carried out within the primary school age-range, therefore questions into how the mind and cognitive schemata are organised cannot be fully understood without first exploring the potential processes behind conceptual change and above all the ways in which related concepts are coordinated and interlinked; something which has rarely been the focus of psychological investigation.

This study aims to explore children’s conceptual development in science and the influences that general cognitive abilities may have on children’s understanding about scientific phenomena.

A total of 138 children were recruited for this study which consisted of three cohorts of children: 4-5 year olds, 6-7 year olds, and 9-10 year olds, thus covering the whole primary school age range. All children were investigated on their knowledge of four areas of biology currently included in the National Curriculum for England, which are: Inheritance, biodiversity, ecology and evolution.

Children’s knowledge of these concepts was investigated using a novel method that was developed and administered alongside measures of general cognitive abilities including working memory, inhibition and attention switching. Numeracy, receptive and expressive language. Other demographic measures were also collected. The same children were then followed-up one year later with the same testing procedures to track developmental progression of science knowledge and the long-term influences of general cognitive abilities.

Data were coded and analysed to look at the relationship between general cognitive abilities and biological knowledge and the possible route of progression of biological knowledge. Partial correlations revealed receptive language was significantly positively associated with all four biological concepts, closely followed by numerical knowledge. Meanwhile evolutionary concepts were the most significantly associated with general cognitive abilities, receptive language and number ability.

Two-stage hierarchical regressions were conducted to see what explained the most variance for each of the four biological areas of interest. All the regressions revealed highly significant models for biodiversity, ecology and evolution, but not for inheritance. Interestingly it was found that general cognitive abilities explained very little variance, but that the remaining biological concepts (except inheritance) significantly predicted variance, with age being a significant factor for biodiversity knowledge, and receptive language being a significant factor for ecological knowledge.
This suggests that scientific knowledge takes a piecemeal route of progression, with no one area contributing significantly to another. The findings also suggest that the development of biological understanding has very little to do with general cognitive ability. This is surprising given that past research in the domains of literacy and numeracy have demonstrated that the level of general cognitive abilities at a school-entry age can be predictive of later academic achievement (Gathercole et al, 2003).

The findings from this study also imply current curricular design may be flawed in its assumption of sequential learning where it is thought generalised understanding is developed on the basis of earlier concepts. Moreover, the influence of biologically specific language (both receptive and expressive) is what seems to drive the change toward more scientific understanding, which inevitably is route toward improving and enhancing academic achievement in science.
"This is Exhausting" - Finding the Skill, Will, and Thrill for Conceptual Change in the Digital Age

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Keywords: epistemic cognition, conceptual change, self-regulation

The rapid proliferation of information and information sources in the digital age has made even more salient the fundamental human challenges of determining who to trust, what to believe, and how to act based upon that trust and those beliefs (Greene, Sandoval, & Braten, 2016). Research has shown that all people, even millennials assumed to be “digital natives,” struggle to find, critique, and integrate multiple online information, particularly when there are conflicting sources about complex topics (Kendeou, Braasch, & Bråten, 2016; Rapp, 2016). Adaptively synthesizing such sources requires effective epistemic cognition, which is the process of acquiring, understanding, justifying, using, and creating knowledge (Barzilai & Chinn, in press; Greene, Sandoval, & Braten, 2016; Greene & Yu, 2016). Epistemic cognition is one component of intentional conceptual change (Sinatra & Pintrich, 2003), or the knowledge, ability, and desire to critically reconcile one's prior knowledge with new information. The likelihood of intentional conceptual change depends upon individual and contextual factors (Dole & Sinatra, 1998), which in turn predict the degree of engagement with new information. Those factors (e.g., cognition, metacognition, epistemic cognition, motivation, emotion, context, etc.) can, should, and indeed must be monitored and controlled in ways that help people achieve their goals; in other words, those factors must be self-regulated (Sinatra & Taasoobshirazi, 2018). However, knowing how to engage in intentional conceptual change, via epistemic cognition and self-regulation, is not enough. The very act of engaging in intentional conceptual change can be exhausting, particularly when people's foundational, deeply held knowledge and beliefs are threatened (Horrigan, 2016; Sinatra, Kienhues, & Hofer, 2014). There is a critical lack of theory and research on the cognitive and emotional toll exacted by the conceptual change and epistemic cognition challenges of the modern world.

The terms self-regulation, self-regulated learning, and metacognition have been used in interchangeable or contradictory ways, but self-regulation is the broadest term, encompassing the other two (Dinsmore, Alexander, & Loughlin, 2008; Greene, 2018). Self-regulation involves the ability to actively plan, monitor, adjust, and maintain optimal levels of cognitive, motivational, and emotional arousal to pursue desired goals, be they academic, social, or otherwise. Self-regulatory performance predicts a wide variety of desirable life outcomes, including physical and mental health, financial success, and academic achievement (Blair & Raver, 2015). However, models of self-regulation based around the idea of ego-depletion (i.e., Baumeister, Vohs, & Tice, 2007; Duckworth, Gendler, & Gross, 2014) posit people have a limited amount of resource for enacting self-regulation, and when that resource is depleted, people are more likely to resort to uncritical habits, instead of thoughtful action such as critically evaluating sources or challenging their deeply-held beliefs. There is a tremendous need to translate ego-depletion self-regulation model research into academic and learning context. In particular, there is a dearth of conceptualization regarding the role of ego depletion as a limiting factor in intentional conceptual change (Sinatra & Pintrich, 2003), or as an influence upon the epistemic cognition and self-regulation aspects of that model. Therefore, in this presentation, I will synthesize scholarly work on self-regulatory ego depletion with epistemic cognition (i.e., Barzilai & Chinn’s Apt-AIR model) and conceptual change theory and research (i.e., Sinatra and Pintrich's intentional conceptual change model) to identify productive directions for future research and practice on helping people manage the often-depleting challenges of the modern world. This conceptualization will help researchers begin to understand, and intervene upon,
the exhaustion that can prevent people from successfully self-regulating the myriad of sources and views they encounter in the modern, digital world, and engaging in intentional conceptual change.

References


Conceptual Change as Complex and Emergent
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Keywords: Emergence, Materialism, Grounded, Complexity, Epistemic

Theoretical Frame and Questions
Conceptual change research over the last 30 years has made considerable advances in understanding learning. However, its foundation within constructivist theory focuses research on mental models and capacities which have proved difficult to define. This paper draws on recent theoretical developments outside of conceptual change research to bring a new perspective to this issue. ‘New materialism’ (Coole & Frost, 2010) provides an ontological position which questions the separation of cognition from the material which makes up classrooms: brains, bodies, language, artefacts, technologies and the classroom environment. Linking this to complexity theory suggests that learning is emergent from the interplay of these materials (Hardman, 2015), and that this should be a focus of research.

To explore and develop this theoretical framework, we undertook empirical analysis of three consecutive lessons in which an experienced science teacher taught chromatography to a group of 13-14 year olds (n=27). Our primary research question was ‘how does learning emerge within the complexity of classrooms?’

Methods and Analysis
We observed the lessons and recorded video and audio from multiple positions. We then conducted verbal protocols, in which the teacher reviewed the video, pausing to comment at points he found significant (without prompting). This was also video recorded, as was a retrospective debrief in which the researchers discussed each lesson with the teacher.

An initial coding identified significant clips within the video data, which were then shown to a sample of six pupils from the class. The pupils were video-recorded whilst commenting upon what was taking place within the classroom, followed by a short period of debrief. By ”Asking students to respond to authentic dilemmas of justification” (Greene, Azevedo, & Torney-Purta, 2008, p. 157), we were able to investigate their epistemic and ontological beliefs around learning within the lessons. This was integrated within our analysis of what pupils were responding to, and learning from.

Coding of the video followed a grounded theory approach, framed within naturalistic enquiry (Corbin & Strauss, 2008). The two researchers and the teacher involved in the study separately coded the video pertaining to the first lesson (lesson, verbal protocols and debrief), using NVivo software. Comparison of the models generated from this phase allowed production of a common model for coding. Two further coding-comparisons were carried out during the remaining video coding, from which the final model was developed.

Findings and Significance
A significant finding was the epistemic belief, expressed by both teacher and pupils, that learning is achieved through pupils developing and applying models. This informed pedagogy and pupil learning strategies, which included the use of mini-whiteboards as a means of generating and adapting representations of chromatography through discussion. This can be related to the artefactual view of models (Gilbert & Justi, 2016) and views of representation as central to conceptual change (e.g. Tytler, 2013). However, the complex and materialist frame furthers this by recognising that models
within the classroom emerge not just from the ‘mental models’ of pupils (Vosniadou, 2008), but within the interplay of brains, bodies, available resources and environmental influences.

Our model suggests that the pupils and teacher engaged in creativity that was both enabled and directed by the material resources of a classroom, but also by their epistemic beliefs. For example, one pupil bent a mini-whiteboard to represent a curved surface. This action emerged from the interplay of resources (white-board), embodied gesture (use of arms) and verbal dialogue. This emergent episode took on meaning for the pupil, who referred to it in later reasoning.

Another emergent episode was the teacher telling a joke around colleagues having labelled a ‘stationary cupboard’ incorrectly, referring to the cupboard not moving (stationary) rather than pens, paper etc. (stationery). This took on meaning in relation to the stationary phase within chromatography, and the pupils reported this joke without prompting when relaying their understanding during verbal protocols. Such episodes suggest emergent processes within learning.

However, the teacher chose to amplify some aspects of what emerged, whilst restricting others – providing both positive and negative feedback. The verbal protocols revealed that these choices were informed by his (often implicit) epistemic beliefs around how pupils learn, but also by his strategic aims in relation to what he wanted to teach them. We thus theorised how pupils were constantly developing models through language, gesture and representation and how the teacher was dynamically encouraging and ‘directing’ the emergent processes within the classroom.

In the model developed from this study, learning can be seen as a process of meaning-making which is both enabled and directed by the material context of a classroom, but also by the epistemic beliefs and strategic aims of the teacher and the pupils. We find Floridi’s (2011) definition of ‘information’ as meaningful data to be useful in describing this: from all sensory data, both teachers and pupils respond to the information within classrooms. We propose that what is meaningful stems from previous learning, epistemic beliefs and strategic aims, and thus meaning is emergent within the material context of the classroom. This model provides a first step in recognising the detail of how learning emerges.

References


Delay or Deficit in Algebraic Acquisition
Judi Humberstone & Robert Reeve (University of Melbourne)

Keywords: Acquiring Algebraic Competence; Deficit and Delay

Many children struggle in their transition from arithmetic to algebra (Kieran, 1981, 1992; NMAP, 2008), and equal sign (=) misunderstanding is widely regarded as a key factor that contributes to their difficulties (e.g., Alibali, Knuth, Hattikudur, McNeil, & Stephens, 2007; Carpenter, Franke, & Levi, 2003; Knuth, Stephens, McNeil, & Alibali, 2006; Li, Ding, Capraro, & Capraro, 2008; McNeil & Alibali, 2005(a), 2005(b)). Interpreting the equal sign as a bi-directional symbol, indicating that the two sides of an equation are equal and interchangeable, is fundamental for algebraic problem-solving success (Kieran, 1981, 1992). Furthermore, conceptualising the equals sign correctly is of particular importance given that algebra has been described as a “gatekeeper” to future educational and employment opportunities (Moses & Cobb, 2001; National Research Council, 1998).

Previous research (Humberstone & Reeve, 2008; Humberstone & Reeve, submitted) has suggested that conceptual change is involved in the transition from an arithmetic (uni-directional) to an algebraic (bi-directional) interpretation of the equals sign and that distinct profiles characterising the development of algebraic reasoning ability based on individuals’ understanding of the equals sign can be identified. However, little research has investigated whether the different profiles identified prior to and during algebra instruction are homogeneous or heterogeneous groups of students. Specifically, the outcomes of prior studies have been silent on whether students in the less sophisticated groups were simply delayed in their acquisition of algebra, or whether they had a basic algebra deficit. In other words, within a single profile, are there different individuals representing both algebraic deficit and delayed algebraic progress?

The current study investigates the progressive acquisition of algebraic competence in 135 Year 7 (78 males, 57 females) (M = 13 years 3 months, SD = 3 month) in three phases over an eighteen-month period (the first phase being prior to formal algebra instruction).

In order to identify a developmental algebraic competence profile structure, separate Latent Gold cluster analyses of differential performance on canonical (e.g., 2x +3 = 15) and non-canonical arithmetic equations (e.g., 17 = 3c – 4) were conducted at each of three testing phases. In each case, a four-cluster solution was generated accounting for 79%, 66% and 63% of the variability in the data respectively (ratio of change in BIC < 0.01). The four groups in each testing phase were ordered according to overall equation problem-solving success; the numbers in the Phase 1 groups were: 20, 61, 34 and 20; for Phase 2 groups, the numbers were: 15, 46, 32, and 42 and for Phase 3, the numbers were: 11, 33, 25 and 66. Chi-square analyses were conducted to confirm that the clustering process was robust across phases, and the findings indicated that there was a significant (but not complete) overlap in group membership across the three testing sessions. What was of interest though in determining the heterogeneity of the groups was whether students classified in Cluster 1 (the least sophisticated group) in Phase 1 are also classified in Cluster 1 at Phase 3. An examination of progressive group membership across the phases revealed eight distinct across-phase groups: (1) students in Cluster 1 in all phases (referred to as Cluster 1) (n = 8); (2) students in Cluster 1 in Phase 1 who were classified into more sophisticated groups in subsequent phases (Cluster 1+) (n = 12); (3) students in Cluster 2 in all phases (Cluster 2) (n = 27); (4) students in Cluster 2 in Phase 1 who were classified into more sophisticated groups in subsequent phases (Cluster 2+) (n = 34); (5) students in Cluster 3 in all phases (Cluster 3) (n = 13); (6) students in Cluster 3 in Phase 1 who were classified into more sophisticated groups in subsequent phases (Cluster 3+) (n = 21); (7) students in Cluster 4 in
Phase 1 who were classified into less sophisticated groups in subsequent phases all phases (Cluster 4) (n = 4); (8) students in Cluster 4 in all phases (Cluster 4) (n = 16).

Although, it was apparent that the groups identified at each testing phase reflected a developmental sequence from arithmetic processing to algebraic understanding, the analyses also revealed that the groups were in fact not homogeneous. Students who exhibited improvement across the three testing phases sequentially followed a similar algebraic developmental pathway to that revealed in previous research (Humberstone & Reeve, 2008); however, within each of the competence profiles, there was a group of students who did not progress across time and who could reasonably be assumed to exhibit algebraic deficit. Of particular importance was the finding that the four deficit groups did not differ from each other at Phase 3 for algebraic problem-solving ability, despite being separately classified at Phase 1. This outcome represents a significant contribution to developmental research in algebra. Previous studies have implied that all students progress from a naïve to a more advanced state of interpretation of the equals sign (McNeil & Alibali, 2005a) in the same way. Moreover, algebra researchers have assumed that algebraic difficulties result from the different ways in which concepts are understood in the two domains (Kieran, 1992; Puig & Rojano, 2004). It was evident from the current study that a small group of students did not attain algebraic competence (at least in the short term), and, furthermore, the reason for the apparent algebraic deficit appeared to be inadequate entering arithmetic competence. No previous researchers have acknowledged that some students may lack sufficient arithmetic knowledge for attaining algebraic ability.

Overall, the research highlights the importance of the early identification of individual differences in understanding algebraic equivalence. Furthermore, the outcomes have important pedagogical implications for algebra instructional design (Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001). Challenging students’ entrenched arithmetic operational view of the equals symbol as a canonical (left-to-right) operator may facilitate the conceptual change to an algebraic bidirectional understanding in students who are simply delayed in algebraic acquisition. However, the subsequent mathematical consequences for the students exhibiting algebraic deficit highlight the importance of ensuring that all students have adequate arithmetic competence prior to the introduction of algebraic concepts.
Keywords: students, knowledge stability, climate change

The acceptance of climate change facts and information are crucial for environmental education and students’ personal epistemology has important consequences for learning when students try to understand complex scientific topics - such as climate change (Bråten, Strømsø and Vidal-Abarca, 2009). Learning outcomes and learning processes are recognised to be influenced by the individual’s epistemological beliefs in the sense that more sophisticated beliefs facilitate conceptual change (Andre and Windschitl, 2003). Epistemological beliefs have been structured into four dimensions of beliefs; knowledge stability, complexity, origin and beliefs about justification (Hofer, 2000; Schommer 1990). This study focuses on the dimension of knowledge stability, which suggests that a student’s strong belief in the certainty of knowledge, which implies scientific results to be stable, is considered to reflect a less productive impact on learning. Furthermore, Trautwein and Lüdtke, (2007) reported a relationship between upper secondary school students’ epistemological certainty beliefs and education. Business students showed the highest certainty scores in comparison with humanities/arts and social science students. Hence, a subject specific approach in relation to epistemological beliefs is of interest and the current study focuses on knowledge certainty in relation to business and economics students’ beliefs in anthropogenic climate change existence and various solutions, some being governmental initiatives (i.e. CO2 taxes).

Purpose
This study aims to explore changes in students’ beliefs regarding knowledge certainty and relations to beliefs regarding climate change. Two research questions guide the study;

1. Do students accept climate change facts and are there changes in acceptance and relations to certainty of knowledge over the time of one year of business and economics education in upper secondary school?

2. Are there changes in relationships between students’ beliefs of knowledge certainty and beliefs about efficient solutions to reduce climate change over the time of one year of business and economics education?

Methodology
Students followed a three-year program where 15% of the curriculum included courses in business economics. A survey was administered twice, first to 212 students (T1) aged 17, and then a year later (T2). All together 142 individuals were identified as participants at both times. It gathered information on students’ characteristics, acceptance of climate change and conceptions of solutions based on; market prices, education/information, tax and legislation measures (Ignell, Davies and Lundholm, submitted). Epistemological belief items measured knowledge certainty (Trautwein and Lüdtke, 2007) and participants responded to a 4-point Likert scale ranging from totally agree, to totally disagree, regarding seven items; ‘scientific theories can be proven at any time’, ‘scientific theories that we presently consider to be correct can be proven false in the future’, ‘even scientific knowledge must be revised time and again’, ‘at some stage scientist will be able to explain the whole world’, ‘scientific research shows that for most problems there is one clear-cut answer’, ‘scientific laws are universal truths and scientific knowledge is unimpeachable’. The internal consistency for the
scale was .54 while exploratory factor analysis identified three factors with eigenvalues higher than 1 and presented partly higher Cronbach’s alpha value; Science has clear cut answers = .63, Science can be revised = .62 and Science is universal truth = .42. These accounted for 64 % of variation in the data. Paired sample t-test analysed average changes in acceptance of and conceptions of solutions to climate change.

Preliminary results and conclusion
Almost all students (96 %) acknowledged the facts of global warming and results showed no significant change (p = .13). The overall levels of knowledge certainty were at T1 (M = 2.36, SD = 0.42) and at T2 (M = 2.35, SD = 0.38) and demonstrated fairly high scores of seeing knowledge as certain, no significant change was shown over time t(116)= .29, p = .77. We found at T2 a significant positive relationship between the knowledge certainty scale, of all seven items, and students’ acceptance of climate change facts (B = .33, p = .003).

Furthermore, preliminary results show few mediating relations between categories of knowledge certainty and efficient climate change solutions. At T1, one of three categories, science can be revised, predicts seeing taxes as efficient solution. Two solutions - education and information, and higher prices for goods - are predicted by the category science has clear-cut answers. At T2, none of the categories of science certainty predicts beliefs of effective solutions.

This explorative study suggests educational implications for environmental education. It shows that scepticism regarding climate change existence is a minor issue for educators to take into account in Swedish upper secondary business education. Furthermore, it indicates that beliefs about knowledge certainty influence acceptance of climate change facts. It also appears that beliefs in science as certain and unchanging influences the belief in education/information as an efficient way to solve climate change, possibly it is seen as an ‘information problem’. However, these findings show correlations and it is not clear what the causal mechanisms are, thus further enquiries are needed to understand why a certain epistemic belief predicts various climate change solutions, governmental or other.

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Epistemic (conceptual) change meets psychometrics – Exemplary application of measurement invariance analysis to capture the development of teacher students’ epistemic beliefs

Eric Klopp & Robin Stark (Saarland University)

Keywords: epistemic change, conceptual change, measurement invariance

Theoretical background

One of the major aims of teacher education is the competence to critically reflect teaching and learning processes. A major prerequisite for such a competence are advanced epistemic beliefs (e.g. Lunn-Brownlee, 2017). Thus, it is important to know the developmental trajectory of epistemic beliefs, especially to construe effective strategies to foster the development of sophisticated epistemic beliefs.

To understand the development of epistemic beliefs their so-called dual nature (Muis et al., 2006), i.e. epistemic beliefs are both domain-general and domain-specific, must be considered. Furthermore, the developmental trajectory of epistemic beliefs can manifests in a mean change of stable beliefs over time or in a change of the belief itself, i.e. epistemic conceptual change (Sinatra & Chinn, 2011). Thus, methods are required that allow us disentangle the developmental trajectory and can handle the dual nature of epistemic beliefs.

Latent variable models are frequently used to model epistemic beliefs. A possibility to characterize epistemic belief development is the notion of α-, β-, and γ-change (Chan, 1998). α-change refers to changes in the mean of a latent variable where the latent structure is constant over time and the measurement properties of its indicators remain invariant over time. In the case of β-change, the latent structure remains constant over time but the measurement properties of its indicators are not invariant. γ-change refers to a situation in which the latent construct changes over time. This characterization of change process matches the definition of levels of measurement invariance. α-change implies longitudinal scalar invariance whereas β-change indicates either longitudinal configural or metric invariance but not longitudinal scalar invariance. Lastly, γ-change indicates the absence of longitudinal configural invariance. Thus, epistemic conceptual change only takes place in the case of γ-change.

The purpose of this paper is an exemplary application to demonstrate how the notion of α-, β-, and γ-change can be applied to study the development of pre-service teachers epistemic beliefs taking the dual nature of epistemic beliefs into account.

Methods

204 teacher students (143 female, MAge=21.95 [sd=5.63]) participated i. We measured domain-general and domain-specific epistemic beliefs in equidistant intervals at the beginning, in the mid, and the end of the first semester and investigated longitudinal measurement invariance. In the case of longitudinal scalar invariance, i.e. α-change, we furthermore applied latent change score models (Newsom, 2015) to describe the development of latent means over time. For each measurement we calculated ω-reliability (Raykov, 2001).

Domain-general epistemic beliefs were measured with the scales Certainty of Knowledge (ωT1/T2/T2=.66/.69/.73), Omniscient Authority (ωT1/T2/T2=.51/.53/.51), and Reflective Nature of Knowledge (ωT1/T2/T2=.54/.73/.68) adapted from the German Epistemic Belief Questionnaire (Moschner & Gruber, 2017).
Domain-specific epistemic beliefs were measured using an adapted version of the Connotative Aspects of Epistemological Beliefs questionnaire (Stahl & Bromme, 2007). We used the scales Texture of Knowledge (ωT1/T2/T2=.71/.77/.77) and Variability of Knowledge (ωT1/T2/T2=.59/.67/.75).

Results
The results for the measurement invariance analyses are depicted in table 1. The results indicate scalar invariance, i.e. α-change, for Omniscient Authority and Texture of Knowledge. For Omniscient Authority, the latent change scores indicated no mean changes between the three measurements. Regarding Texture of Knowledge we found no mean change between the first and second measurement (D12=0.066, p=.278) but a significant increase between the second and third measurement (D23=0.147, p=.006). For Certainty of Knowledge and Variability of Knowledge the results indicate metric and configural invariance for Reflective Nature of Knowledge. Thus, for these scales the data suggest β-change. γ-change and thus epistemic conceptual change did not occur in this study.

Discussion
The results of this study can be seen from both a substantive and methodological perspective. From a substantive perspective, our study points to the importance to distinguish between possible development trajectories that may result in mean changes of a stable construct or in a conceptual change of the construct itself. From a methodological perspective this application of α-, β-, and γ-change demonstrates the power of the method to study epistemic (conceptual) change. Furthermore, the results points to the importance of investigating measurement invariance in longitudinal models. Neglecting the level of measurement invariance may yield danger of false conclusions about the development of epistemic beliefs. Lastly, we want to point out that the method is not limited to study the development of epistemic beliefs, it may also be applied to other areas of conceptual change research where latent variable models are applicable.

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Educational controversies, epistemological sensitization and critical thinking instructions – Effects of an intervention to foster pre-service teachers’ epistemic beliefs

Eric Klopp & Robin Stark (Saarland University)

Keywords: epistemic change, intervention, teacher education

Introduction
The critical reflection of teaching processes is a core competency of teachers and therefore an important goal for preservice teacher university training. A key prerequisite for this competency is sophisticated epistemic beliefs (Lee-Brownlee et al., 2017). The developmental approach to epistemic beliefs distinguishes three stages of epistemic development: absolutism, multiplicism and evaluativism, where evaluativism the most sophisticated stage of epistemic beliefs development (Hofer & Pintrich, 1997). Thus, there is a need for intervention strategies that foster sophisticated epistemic beliefs.

Drawing on Bendixen and Rule’s (2004) epistemic change model, Rosman et al. (2006) developed an intervention to foster evaluativism. The intervention prompts epistemic doubt through presentation of resolvable controversies and induces epistemic change through presentation of resolution strategies. The main idea of this intervention is that the mere existence of controversies is inconsistent with absolutism and multiplicism, which in turn should induce epistemic doubt. As the controversies are resolvable, the following presentation of strategies to resolve the controversies should induce epistemic change towards evaluativism. Thus, the intervention should reduce absolutism and multiplicism while at the same time promoting evaluativism. According to Klopp and Stark (2017) an epistemic sensitization (Porsch & Bromme, 2011), in which the possible reasons for scientific controversies are presented before the intervention, strengthens its effects.

Valanides and Angeli (2005) demonstrated that critical thinking instruction also fosters epistemic change. The infusion-approach, i.e. a guided reflection, is more effective in fostering epistemic beliefs than the general-approach, i.e. an unguided reflection. Thus, instructions drawing on the infusion-approach to reflect the controversies and resolution strategies should foster epistemic change towards evaluativism.

Following that line of reasoning, we developed an intervention to reduce absolutism and multiplicism and enhance evaluativism in pre-service teachers.

Methods
The invention consists in presenting resolvable, educational controversies followed by the presentation of resolution strategies. In a two-factorial design, we varied in a first between-factor critical thinking instruction (approach: infusion vs. general) and the presentation of an epistemic sensitization (sensitization: with vs. without) in a second between-factor.

In total, 106 preservice teachers participated (23 male, MAge=22.48 [SD=.429]). We measured epistemic beliefs by means of Barzilai and Weinstock’s (2015) scenario-based questionnaire before and after the intervention. This questionnaire allows separately assessing absolutism, multiplicism and evaluativism. Furthermore, we asked the participants to provide an essay about the scenario. We analyzed the essay regarding the level of epistemic beliefs using an adaptation from Mason and Scirica’ (2006) scheme and determined an essay score. To analyze epistemic change we calculated standardized residuals for epistemic beliefs and the easy score (Rosman et al. 2016).
Results

Descriptive results are shown in table 1 and 2. Regarding absolutism there was only a significant interaction (F[1,99]=8.19, p=.005, ηp2=.08). There was a simple main effect of the approach in the condition with sensitization (F[1,55]=4.45, p=.040, ηp2=.07). A simple main effect of sensitization in the general-approach condition indicated a reduction of absolutism in the combination epistemic sensitization and general-approach.

Regarding multiplicism, we found a main effect of sensitization (F[1,99]=5.66, p=.019, ηp2=.05). Multiplicism was only reduced in the condition without sensitization. There was a simple main effect of sensitization in the general-approach condition (F[1,49]=6.08, p=.017, ηp2=.11). Thus, multiplicism was only reduced without a sensitization and using the general-approach. In the condition with sensitization multiplicism even increased.

There were neither main nor interaction effects for evaluativism nor for the essay score. For the essay score, there was a simple main effect of approach in the sensitization condition (F[1,53]=6.08, p=.017, ηp2=.10). The essay score only increased if the infusion-approach was combined with the epistemic sensitization.

Discussion

Absolutism and multiplicism were only reduced using the general-approach, possibly resulting from a deeper elaboration of the resolution strategies in this condition. The increase of multiplicism in the sensitization condition can result from a backfire effect (cTrevors et al., 2016). The discussion of the reasons for scientific controversies seems to highlight the subjective nature of scientific knowledge and thus fosters multiplicism. The question why there are no effects for evaluativism and the essay score remains open. A cautious interpretation of the simple main effect of the essay score suggests that fostering evaluativism requires a sensitization measure combined with a structured and guided reflection of the resolution strategies. The results suggest tailored interventions to foster sophisticated epistemic beliefs.

References


Young Children’s Emerging Epistemology and Science Learning: Unraveling the relation between Theory of Mind, Personal Epistemology and Conceptual Change

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Keywords: ToM, Personal Epistemology, Science Learning

During science learning a reorganization of children’s initial cognitive structures and a replacement of their entrenched beliefs with a new explanatory framework is often needed (Vosniadou, 1994). However, it seems that an ontological change of children’s naive concepts is not the only thing needed. Vosniadou & Skopeliti (2014) argue that major epistemological and representational changes in naïve physics also take place. Children need to change their epistemological perspective, i.e. to understand that knowledge is constructible and not absolutely true or false.

Previous research (Kyriakopoulou & Vosniadou, 2004, 2008) has revealed the great difficulty children have to understand such an epistemological perspective. This might suggest that children must have acquired various epistemic and metacognitive abilities in order to understand our world, such as the ability to understand that our beliefs about the world are hypotheses that can be tested and falsified.

A number of researchers have proposed that the developmental origins of such epistemological understanding are identifiable in young children’s Theory of Mind (ToM) (Burr & Hofer 2002; Fagnant & Crahay 2011; Kuhn et al., 2000). In this paper we would like to take this argument a step further and argue that ToM understanding together with children’s developing Personal Epistemology (PE) may in turn be related to Science Learning (SL). Furthermore, it will be argued that the ability to think of beliefs as constructed by individuals, and therefore represent various perspectives, constitutes a common cognitive-epistemological component between ToM, PE and SL.

Three exploratory studies were conducted. In the first study we examined the impact of children’s emerging ToM on their epistemic beliefs. Sixty-six elementary school children (mean age: 10 years and 8 months) were administered a) a 2nd order false belief task – the Ice Cream Story (Perner & Wimmer, 1985), and a 3rd order false belief task – the Dubble Bluff by the Strange Stories (Happe, 1994) in order to measure their ability to attribute false beliefs to others and b) the Nature of Science Interview in order to measure their epistemic stance (Carey et al., 1989). A correlation analysis (Pearson r) on the mean scores of performance on ToM ability (M=2.02, StD=.70) and epistemic stance (M=1.14, StD=.20) was conducted. As expected, performance in ToM and PE correlated significantly with each other (r(63)=0.457;p<.001). A regression analysis, with performance on the epistemic task as dependent variable and ToM as predictor, showed that children’s ToM ability accounted for the 21% of the variance in the epistemic task (Carey at al., 1989) and appeared to be strong predictor for children’s ability to take into account different conceptions of the same situation in the world (Beta=.457; p≤0.001).

A second study tested the hypotheses that 1) there is a high correlation between children’s ToM ability, their PE and SL, and that 2) there is a developmental path in the direction ToM to PE and to SL. The participants were 46 elementary school students (mean age: 10 years and 7 months). All participants were administered a set of measures to test 1) ToM: a 2nd order false belief task and a 3rd order false belief task 2) PE: the Nature of Science Interview (Carey et al., 1989), and 3) SL: the Model-Based reasoning task (Kyriakopoulou & Vosniadou, 2011).
The results confirmed our first hypothesis and statistical significant correlations were found between children’s ToM ability and their performance on PE measures ($r_s=0.434, n=46, p<0.01$), between ToM measures and SL measure ($r_s=0.542, n=46, p<0.001$) and between performance on PE measures and performance on SL measure ($r_s=0.498, n=46, p<0.01$). In order to examine the hypothesis for a stepwise development a hierarchical regression analysis was conducted. In this analysis, with performance on SL measure as dependent variable, we first introduced into the equation as predictor the performance on ToM tasks and at a second step the variable performance on PE measure. The regression was statistically significant in both steps ($F(1,45)=14.726, p≤0.001$ and $F(2,45)=11.300, p≤0.001$ respectively). More specifically in Step 1, ToM ability contributes significantly to the prediction of performance on the SL measure ($R^2=.234; Beta=.501, p≤0.001$). In Step 2, the introduction of the variable PE increased the predicted performance ($R^2=.314; Beta=.327, p≤0.05$).

The results of this analysis indicate that a) ToM ability is a good predictor for children’s epistemic stance and b) both ToM and children’s PE were good predictors for their ability to reason on models of the physical world.

At a third study we examined the above relations through a developmental perspective. Thirty-eight 4th graders and 36 6th graders were administered similar measures from ToM and SL tradition. Statistical significant correlations were found between ToM and SL. Indeed, the correlations were higher for the 6th graders compared to the 4th graders ($r_s=0.439, n=36, p<0.01$ and $r_s=0.355, n=38, p<0.05$ respectively). The results also confirmed the hypothesis of a stepwise development. The hierarchical regression analysis conducted was statistically significant for the 6th graders but not for the 4th graders ($F(1,34)=11.160, p≤0.01$ and $F(1,36)=3.920; p=.055$ respectively). It seems that as older children acquire more mature aspects of ToM, become more capable of producing multiple representations of a same physical phenomenon at different levels of explicitness and detail.

The present research shows that there is a reason to believe in the existence of a common structure between ToM, PE and SL that refers to the continuous revision of the process of knowledge acquisition. As children revise their naive representations they become more aware of how these representations are linked to the world. This awareness is possible to facilitate scientific learning and help children to understand that knowledge develops in different levels of explicitness.
Unpacking students' epistemic cognition in a computer-simulated environment

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Keywords: epistemic cognition, computer simulation, problem solving

Introduction

Students' epistemic beliefs have received considerable attention in recent decades. Nevertheless, this field may be perceived as both vast and muddled due to methodological and conceptual issues. To move the research field forward, we claim there is a need to focus on how students' scientific epistemic beliefs (SEB) are brought to bear in different learning contexts. Therefore, the current study strives to unpack the processes that are in play and can be understood by students' actions in relation to a specific problem solving situation in science. We use the term epistemic cognition since we argue that there is a distinction between epistemic beliefs and epistemic cognition. Epistemic beliefs are generally stable over time and contribute to the scope of epistemic practices, and though epistemic cognition draws upon epistemic beliefs, it is more context sensitive and relates to context-specific knowledge and skills (Sinatra, 2016). The aim of the study was to deepen our understanding of students' epistemic cognition in a problem-solving situation by capturing students' epistemic practices and their sense making in the moment. The following research questions guided the present study:

1) What epistemic practices do students express during the science problem solving task?
2) How can processes of epistemic cognition be understood from students' epistemic practices in this specific context?

Theoretical Framework

To understand how students' behavior and actions in the problem solving situation (epistemic practice) can help us to characterize their epistemic cognition, we need to outline a framework that can be used for analysis of the information obtained from the students. First, we define more specifically scientific epistemic beliefs (SEB) and how these are identified, then epistemic practice and how its features emerge as students encounter the problem solving situation, and finally, what we understand by epistemic cognition, as derived from the epistemic practices that students express during problem solving.

Studies indicate that there are relationships between students' SEB and their achievement in science (Bråten, Ferguson, Anmarkrud, Strømsø & Brandmo, 2014). Moreover, how students' interact with the situation will in turn affect their ability to make decisions regarding their scientific strategies in a particular moment (Sinatra, 2016). Epistemic practice is how a person within a given context is approaching, justifying and evaluating knowledge. According to Russ (2014) may actions, rationales and decisions serve as clues about how a person determines the use of knowledge in learning. Muis and Gierus (2014) recommend a greater focus on behavioral indicators of epistemic cognition in different situations.

Research Methods

This study draws on findings from a previous study on students' SEB in computer-simulated problem solving. Three students were purposefully chosen based on their different behavior, to understand in more depth their epistemic practices and hence their epistemic cognition. Data collection was undertaken by video and screen recordings from the computer simulation and audio recordings from
a recall interview. Narratives for each student were constructed based on their SEB, behavioral responses to the simulation and answers in the interview. A problem-solving situation that included problems that could be solved in different ways, was the computer simulation software, Algodoo. The task was to bring a plain seesaw into balance in at least four different ways. Observations of the screen and video recordings focused on the students’ behavior and actions as these occurred and were triangulated with stimulated recall interviews. Data were transcribed and coded. Combining all data enabled us to determine what the narratives should include, which was problem solving strategies, conceptual understanding, and self-evaluation.

Results
Patterns of behavior for each student could be related to SEB as summarized in table 1. The observed actions constitute students’ epistemic practices.

Table 1
Summary of students’ background information and epistemic practices

<table>
<thead>
<tr>
<th>Student/Outcome</th>
<th>SEB profile</th>
<th>Problem solving strategies</th>
<th>Conceptual understanding</th>
<th>Self-evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nelly</td>
<td>Naïve.</td>
<td>Guess: -Trial and error</td>
<td>-Limited knowledge of</td>
<td>-Confident</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Acting out</td>
<td>concepts</td>
<td>-Motivated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Testing the environment</td>
<td></td>
<td>-Proud of attempts</td>
</tr>
<tr>
<td>Julian</td>
<td>Mixed naïve and sophisticated</td>
<td>Guess: -Trial-and-error</td>
<td>-Good knowledge of concepts but limited transfer to problem solving.</td>
<td>-Confident.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Think: -Using symmetry</td>
<td>-Reflects productively</td>
<td>-Proud and satisfied with attempts.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alex</td>
<td>Sophisticated</td>
<td>Guess: -Acting out</td>
<td>-Good knowledge -Effectively interprets, applies and integrates</td>
<td>-Confident</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Think: -Using symmetry</td>
<td></td>
<td>-Draws on previous experience</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Inquiry -Looking for patterns</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Using known skills</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discussion and Conclusion
In this study, we set out to further our understanding of the process of epistemic cognition through eliciting epistemic practices of students whilst they engaged in a science problem solving task using the simulation Algodoo. Through a detailed analysis of the epistemic practices of three students whilst problem-solving, who have different SEB, we have been able to represent the process of epistemic cognition for each student. For a student (Nelly) with naïve SEB and limited conceptual understanding, problem-solving is consistently trial and error. For a student with good conceptual knowledge but mixed SEB (Julian), higher level solutions are obtained only when encouragement to reflect on practice occurs. A student with more sophisticated SEB and good conceptual knowledge (Alex) demonstrates more innovative approaches – his SEB allow him to devise his own set of rules to determine strategies that result in high level solutions. We have found that revealing students’
thinking and behavior while engaging in specific contexts has enabled us to provide insights not only about the productiveness of SEB but also how SEB are adapted to a specific context.

References


Think you know it? Well, think again: Reappraising plausibility judgments to facilitate knowledge reconstruction in science

Doug Lombardi (Department of Teaching and Learning, Temple University)

Keywords: plausibility; evaluation; conceptual change

Along with my research team, I have been developing and testing instructional scaffolds to facilitate students’ scientific evaluations during knowledge reconstruction. Our research comparatively examined instructional scaffolds in classroom settings with the goal of gauging how students can reconstruct their knowledge through reappraising epistemic judgments (i.e., plausibility). We built our study on a theoretical perspective suggesting that students may construct scientifically accurate knowledge through a process of generating scientific evaluations and reappraisals of plausibility judgments (Lombardi et al., 2016a). Evaluations about an explanation’s plausibility are fundamentally linked to an individual’s knowledge, based on the presupposition that plausibility judgments are tentative and malleable (Lombardi et al., 2016a). Researchers have also implicated plausibility as an important factor in conceptual change (Dole & Sinatra, 1998). We examined two research questions:

1. What are the relations between evaluation, plausibility, and knowledge, and how do instructional scaffolds promoting evaluation of the connections between lines of evidence and alternative explanations facilitate plausibility reappraisal and knowledge reconstruction?
2. How do instructional scaffolds promoting evaluation of alternatives compare to those that do not, specifically in the shifting plausibility judgments and changing knowledge toward scientifically accurate understanding?

Methods

The project involved grade 9-12 students from a large urban district in the Southwest US and a medium-sized suburban district in the Northeast US. We tested four scaffolds—covering the topics of (a) causes of current climate change (b) fracking and earthquakes, (b) wetlands and land use, and (c) formation of Earth’s Moon—based on an activity called the Model-Evidence Link (MEL) diagram. Chinn and colleagues (2012) originally developed the MEL structure for biology topics. We adapted their MEL structure so that each topic had four lines of evidence and two alternative explanations about a phenomena (e.g., increase in moderate magnitude earthquakes in the US). Each MEL had short statements highlighting major lines of scientific evidence and two alternative, explanatory models (a scientifically accepted model and a plausible, but non-scientific, model). Participants drew arrows of four different types between each evidence statement and alternative model: (a) evidence supports the model, (b) evidence strongly supports the model, (c) evidence has nothing to do with the model, and (d) evidence contradicts the model.

We compared the MEL to two other scaffolds: the MET and Mono-MEL. The MET is similar to the MEL (i.e., two alternative models), but has a tabular format. The Mono-MEL incorporates the same figure design as the MEL, but only presents one model (scientifically accepted). Participants completed an “explanation task” by writing about the links they evaluated. We scored this tasks based on levels of evaluation expressed in participants’ written responses (Lombardi et al., 2016b). Participants recorded their plausibility judgments at pre and post instruction for each explanatory model using a 1–10 scale (1 = greatly implausible and 10 = highly plausible; Lombardi et al. 2013), and completed 5-item knowledge measures for each topic, making a 20-item knowledge instrument, at pre and post.
Results

For RQ1, we used structural equation modeling (SEM) and constructed the latent variables (evaluation; pre and post instructional plausibility; and pre and post instructional knowledge) combining scores for all four topics. Several fit and quality indices indicated excellent model fit and quality. The paths between evaluation and post plausibility, and post plausibility and knowledge were significant (Figure 1). However, the path between evaluation and post knowledge was not significant. This indicates that post plausibility mediated the relationship between evaluation and knowledge per Lombardi et al.’s (2016a) theoretical perspective.

![Figure 1](image)

*Figure 1.* Model of the relations between study variables. Solid lines indicate significant pathways and dashed lines indicated non-significant pathways.

For RQ2, we conducted repeated measures ANOVAs to compare different instructional treatments (MEL, MET, and Mono-MEL). There was a significant interaction between treatment and time for plausibility, $F(2,61) = 5.67$, $p = .006$, medium effect size ($\eta^2 = .157$). Simple effects analyses revealed that there was no significant difference between MEL, MET, and Mono-MEL pre plausibility scores (Figure 2). However, post plausibility MEL scores were significantly greater than post MET ($p = .032$) and Mono-MEL scores ($p < .001$). MEL and MET plausibility scores also significantly increased from pre to post (all $p$-values $\leq .030$). However, there was not a significant pre to post change in Mono-MET scores ($p = .42$). Another ANOVA revealed a significant interaction between treatment and time for knowledge, $F(2,61) = 3.67$, $p = .03$, medium effect size ($\eta^2 = .107$). Simple effects analysis showed no significant difference between MEL, MET, and Mono-MEL
knowledge scores at pre and post, and no significant change in Mono-MET scores from pre to post (Figure 3). However, there were significant increases in MEL and MET knowledge from pre to post (all *p*-values ≤ .030).

Figure 2. Average pre and post instructional plausibility scores by treatment activity. The possible score range was from -9 to +9. Bars on each column indicate ±1 standard error.

Figure 3. Pre and post instructional knowledge scores by treatment activity. The possible score range was from 20 to 100. Bars on each column indicate ±1 standard error.
Discussion
This research suggests that scaffolds can promote students to evaluate their own knowledge in light of scientific evidence and facilitate critique of alternative explanations. Scaffolds facilitating students’ evaluations of the connections between lines of evidence and alternative explanations helped students to reappraise plausibility judgments about scientific explanations and reconstruct their knowledge to be scientifically accurate. Our hope in conducting such research is to inform future instruction that will help equip a scientifically literate citizenry able to solve local, regional, and global problems.

References


Conceptual change and inhibition in chemistry: An fMRI study
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Keywords: Conceptual change; Chemistry; Inhibition

Chemistry educators often have to deal with their students’ alternative conceptions about many scientific concepts. Indeed, alternative conceptions are diverse, tenacious and resistant to traditional teaching strategies (Liu, 2001). Furthermore, teachers cannot simply disregard many of those alternative conceptions since students will sometimes use them to interpret new information. Effective methods to foster conceptual change are thus necessary, especially for counter-intuitive concepts such as vacuum in atoms (Taber, 2002).

Unfortunately, despite several attempts to model conceptual change, there is still no widely accepted model (Rusanen, 2014). Furthermore, many of these models differ on claims about the nature of alternative conceptions relating to normative scientific concepts (diSessa, 2008; Vosniadou & Skopeliti, 2014). Another source of disagreement comes from the definition of change that implicitly means that initial conceptions need to be modified in a successful conceptual change (Potvin, 2013). It could be a radical modification (e.g. Posner, Strike, Hewson, & Gertzog, 1982) or a more gradual evolution (e.g. diSessa, 1993). But in some cases, researchers argue that alternative conceptions are not replaced nor modified after a successful conceptual change and that they would rather coexist in experts’ minds (Mortimer, 1995; Potvin, 2013).

The use of functional magnetic resonance imaging (fMRI) to study conceptual change has also strengthened the coexistence claim (Brault Foisy, Potvin, Riopel, & Masson, 2015; Masson, Potvin, Riopel, & Brault Foisy, 2014). Indeed, those results showed that experts activated brain regions associated with inhibitory control significantly more than novices when correctly evaluating incongruent stimuli that required to overcome an alternative conception. However, it is still uncertain that inhibition is needed to learn and master chemistry.

Seventeen (9 women and 8 men) college (N=13) and university (N=4) chemistry teachers were recruited. The task used for this experiment was created using E-Prime 2.0. The task consists of 40 pairs of true-of-false statements. Each pair contains a statement congruent with a common alternative conception in chemistry while the other one is incongruent with the same alternative conception. 64 statements were presented in blocks composed of four random stimuli of the same condition. Each block was randomly presented and followed by a rest period.

Response accuracy and response times were recorded with E-Prime and analysed with SPSS. Functional brain images (T2*) were recorded with an fMRI scanner and preprocessed and analysed with SPM 8. The rationales behind the preprocessing protocol is explained extensively by Masson, Potvin, Riopel, Brault Foisy, & Lafortune (2012).

As expected, participants were more accurate when evaluating congruent stimuli (M = 96.29 %, SD = 3.44) than incongruent stimuli (M = 71.47 %, SD = 11.40). A significant difference was observed with a paired t-test, t(16) = 9.757; p < .001; d = 2.95. Response times between congruent (M = 3058 ms, SD = 1196) and incongruent (M = 3631 ms, SD = 1424) stimuli were also significantly different, z = 7.796; p < .001; r = .40. Furthermore, fMRI results showed a greater activation in the pre-SMA and ventrolateral prefrontal cortex/anterior insula when incongruent stimuli were correctly evaluated (incongruent > congruent, p < .001, uncorrected, min. 10 voxels, random effect analysis). These
regions are frequently activated in cognitive tasks that required inhibitory control (Laird et al., 2005; Nozari, Mirman, & Thompson-Schill, 2016; Simmonds, Pekar, & Mostofsky, 2008).

These results consolidate the hypothesis that alternative conceptions are not erased nor modified after a successful conceptual change. Several conceptual change models might need to be reconsidered to include the coexistence of conceptions. Teachers might also need to adapt to include different strategies that promote durability in learning (Potvin, 2013, 2017).

References


The relations between inhibition, spontaneous focusing on quantitative relations, and rational number knowledge
Jake McMullen, Erno Lehtinen & Minna Hannula-Sormunen (University of Turku)

Keywords: rational number, inhibition, SFOR

Rational number knowledge has been identified as a core component of mathematical development. In light of this, it is of serious concern that students face substantial problems in coming to understand rational numbers as having distinct features from natural numbers already when they start learning about the size of rational numbers (Stafylidou & Vosniadou, 2004). The over-reliance on natural number reasoning is slowly overcome through experience and training, yet vestiges still linger even in highly educated adults (Vamvakoussi, Van Dooren, & Verschaffel, 2012). It is thus assumed that individuals must often inhibit their natural number reasoning when confronted with rational numbers and therefore stronger inhibition may then support success with reasoning about rational numbers.

Successful development of rational number knowledge has also been found to be associated with a higher tendency of Spontaneous Focusing On quantitative Relations (SFOR; McMullen, Hannula-Sormunen, Laakkonen, & Lehtinen, 2016). SFOR tendency is defined as “the spontaneous, (i.e. unguided) focusing of attention on quantitative relations and the use of these relations in non-explicitly mathematical situations” (McMullen et al., 2016, pg. 858) It is hypothesized that a higher SFOR tendency leads to greater opportunities to deal with relational features of everyday situations, when often natural numbers are not sufficient and rational numbers are necessary for reasoning in or describing a situation. Since the foundations of the natural number bias may partially lay in experiences in the everyday world which privilege natural numbers (Andres, Di Luca, & Pesenti, 2008), those students with a higher SFOR tendency may also benefit from the extra practice in inhibiting their automatic use of natural number reasoning. It is therefore possible, that the relation between SFOR tendency and rational number knowledge may be mediated by inhibition.

Thus, the present study aims to answer the question: does inhibition explain the relation between SFOR tendency and rational number size knowledge?

In order to do so, 74 fifth-grade students, who have received instruction about the size of fractions and decimals for at least two school years in their regular classrooms, completed measures of SFOR tendency (Teleportation Task; McMullen et al., 2016), rational number size knowledge (Comparison and Ordering of Fractions or Decimals; Stafylidou & Vosniadou, 2004), and inhibition (Nepsy Inhibition sub-test). All tasks were completed one-on-one with a trained researcher as a part of a longitudinal study examining the development of pre-maturely born children (all participants in the present study were a part of the full-term comparison group). SFOR tasks were completed prior to any other explicitly mathematical tasks, so that the children were not aware of the mathematical nature of these tasks. Thus, when asked to describe how sets of objects had changed during a “teleportation” (obvious systematic changes included color, shape, content, and amount), if they described that the objects had undergone a change by a multiplicative relation (e.g. multiplied by three, half as much), or if they drew the correct number of that would appear based on the previous transformation, they could be said to have done so spontaneously.

Results revealed that only SFOR ($\beta=.32$, $p=.005$) was related to rational numbers size knowledge: $F(2, 71) = 6.10 \ p < .004$, $R^2 = .15$. These results suggest that the relation between SFOR tendency and rational number knowledge is not explained by better inhibition. The success with learning about
rational numbers demonstrated by those students with a higher SFOR tendency may be due to other advantages gained by increased practice with rational numbers in and out of the classroom rather than increased support for inhibitory processes.

There are a number of limitations in the present study that warrant consideration in follow-up studies. In particular, the measure of inhibition could be integrated into the measure of rational number knowledge by examining reaction times in judging rational number size. Previous studies have found that reaction time measures can capture the dual-processes that occur when reasoning about rational numbers (Vamvakoussi et al., 2012). As well, tasks which involve mathematical reasoning and other cognitive control measures may be more appropriate a measure of general inhibition. These issues will be explicitly addressed in a follow-up study to be presented at the conference.

References:


Beliefs about learning in the pedagogy of Dutch chemistry and physics
teacher educators.

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Keywords: teacher beliefs, learning theory principles, pedagogy

This master thesis study finds its origin in my daily practice as a teacher educator where I’m curious
to the role of learning theories as they are presented in every teachers education.

In literature on science pedagogy the majority of publications are grounded in conceptual change
theory (CCT); however, within Dutch teacher education CCT is hardly taught nor used in science
pedagogy. Park, Kim, Park, Jeong & Park, (2016) report that teachers, even when they know learning
theory principles explicitly, do not believe it adds value for practice. However, teacher educations are
supposed to have a more broad set of theories and models ready as they should lead new teachers
into a variety of pedagogy. This raises the question whether teacher educators do know the CCT
theory and, if so, why they do not include it in their curriculum. The main purpose of this research
was to investigate the relation between vision upon science pedagogy and learning theories and
(implicit) knowledge of CCT principles.

The assumption that orientations to learning shapes daily pedagogy was argued for by Magnusson
Krajcik en Borko (1999). The theoretical base for beliefs, holistic views and theories in the teacher’s
profession was build upon the work of Korthagen & Kessels (1999). State of the art in CCT was based
upon the Handbook of Research in Conceptual Change (Vosniadou, 2013) and the recent work by Lin,
Yen, Liang, Chiu & Guo (2016).

A survey containing 50 statements on CCT principles, formulated both more abstractly and with
reference to concrete educational settings, was designed and validated through review by CCT
experts. It was then put to all 60 Dutch teacher educators in chemistry and physics, of which 47 filled
out the survey. It was explicitly requested to indicate if they personally were convinced of the
statement on a three point scale (not - maybe/can be discussed - definitely) and if they opined
whether the statement/principle ought to be taught in science pedagogy. With open questions, we
tried to elicit their vision on science pedagogy and the role of learning theories therein. Results were
subsequently discussed with four participants in half open interviews. All results were analysed in a
mixed methods design.

The survey made clear that albeit teacher educators are generally quite supportive of the cognitive
and affective principles of CCT, only few of them are acquainted with the theory as a whole, and
those who do only have knowledge of the old cognitive basics from early 1980s. In subsequent
interviews, however, when results were presented and CCT was discussed more in detail, it seemed
that some participants did recognize the principles in their daily practice. This led some to adjust
their vision upon learning theories, while other teacher educators remained critical. This could be
sourced to a very critical, sometimes even cynical, view of the achievements of social sciences in
general. Such resistance obstructed them to make a more firm connection between theory and
practice.

Given the results that the CCT principles in this study were recognized widely, one can wonder how
CCT could become a more general accepted and embedded in teacher education.
References


Brain-Based Mechanisms Involved in Conceptual Change in Science: A Literature Review

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Keywords: Conceptual change; Neuroimaging; Brain-based mechanisms;

Context
Conceptual change has received a great amount of attention among researchers, but there is little consensus on what conceptual change is or on what “changes” in conceptual change (Lin et al., 2016). There is nevertheless agreement (e.g., Rusanen, 2014; Vosniadou, 2014) that a better understanding of conceptual change requires a more accurate and detailed description of the learning mechanisms underlying it. However, this remains a compelling challenge for the field to resolve (diSessa, 2017). The present literature review aims to contribute to a better understanding of these mechanisms by synthesizing studies that have used neuroimaging techniques to examine brain-based mechanisms involved in conceptual change. The rationale behind this choice is that there is a growing corpus of studies that have examined conceptual change in science using a neuroimaging approach, but this corpus has not yet been subjected to a rigorous review.

Methods
First, a database (e.g., ERIC, Google Scholar) search was conducted using a set of keywords related to conceptual change (e.g., “conceptual change”, “conceptual learning”), scientific disciplines (e.g., “physics”, “chemistry”), and neuroimaging techniques (e.g., “functional magnetic resonance imaging” [“fMRI”], “electroencephalography”). Articles’ titles and abstracts were screened, leading to a total of 24 a priori relevant studies. Because of the limited number of studies published in scientific journals, studies published in the form of peer-reviewed conference proceedings, doctoral dissertations or master’s theses were considered acceptable. Second, these 24 articles’ full texts were analyzed applying inclusion criteria – study had to explicitly involve a task related to conceptual change in science and use a neuroimaging technique to measure brain activity during the task – leading to inclusion of a final total of 9 relevant studies.

Results and Discussion
One of the main results drawn from synthesizing the nine studies is that completed conceptual changes are strongly associated with the brain-based mechanism of inhibitory control. For example, using fMRI, Brault Foisy et al. (2015) and Masson et al. (2014) compared the cerebral activity of experts (i.e., undergraduates in physics) and novices (i.e., undergraduates in humanities) in physics while they evaluated the correctness of visual stimuli depicting either common misconceptions or their corresponding scientific concepts. Experts, but not novices, systematically provided scientifically correct answers and were presumed to have successfully completed conceptual changes. In addition, experts’ brains, compared with novices’, showed greater activation in the ventrolateral prefrontal cortex (VLPC). This activation was attributed to the implementation of inhibitory control, a brain-based mechanism that consists of resisting and blocking the misconceptions that were still present in the experts’ neural networks and conflicted with their scientific knowledge. Another study using fMRI (Malenfant-Robichaud et al., 2017) found that this mechanism was still involved even with a higher degree of scientific expertise. This study focused on chemistry college professors and found that, to provide scientific answers to items underlying misconceptions in chemistry compared with items that did not, professors’ brains showed activation of the inhibitory control mechanism.
Using fMRI and a pre-post design, two other studies (Brault Foisy et al., 2017; Nenciovici et al., 2017) compared the cerebral activity of novices in physics (i.e., undergraduates in humanities) before and after being presented with the scientifically correct answers to a task. The task consisted of evaluating the correctness of visual stimuli depicting either common misconceptions or their corresponding scientific concepts. Before, novices systematically answered in accordance with their misconceptions. After, they systematically answered in accordance with the scientific concepts. Novices’ brains after, compared with before, showed greater activation in posterior parietal regions, but not in the VLPC. This activation was attributed to memory retrieval mechanisms, but not inhibitory control.

These findings suggest that, because inhibitory control is associated with completed conceptual changes, training novice learners to inhibit their misconceptions could foster conceptual change. This hypothesis would need to be tested by future empirical studies. Simply presenting novices with scientifically correct answers, a teaching technique sometimes used in classrooms, does not appear to foster conceptual change, because it does not lead to activation of inhibitory control.

A more complete summary of the review results will be presented at the SIG-3 Conference and discussed in relationship with possible pedagogical implications and future research leads.

References


Assessment of misconceptions in designing conclusive experiments
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Keywords: scientific reasoning, misconceptions, CVS

Designing, understanding and interpreting unconfounded experiments, as well as drawing valid conclusions in testing causal hypotheses are relevant abilities in the development of scientific reasoning. The Control of Variable Strategy (CVS) as a core skill of domain-independent experimentation skills plays a crucial role in the exploration of causality. Understanding and applying the CVS is crucial for the achievement of educational goals such as inquiry and critical thinking (Chen & Klahr, 1999).

When trying to plan unconfounded experiments, children differentiate between two classes of goals according to Schauble et al. (1991): science goals and engineering goals. Following science goals, children use experiments in order to find out something. Following engineering goals, children try to “engineer” a particular desirable outcome. For testing causal hypotheses using the CVS, children thus need to adopt science rather than engineering goals.

Even when children do adopt science goals, errors in planning conclusive experiments still occur due to incomplete or faulty conceptions. Children may not be able to apply the CVS correctly because they fail to understand the goal of the task, do not consider the variable level when testing for causality, misunderstand the need to compare and contrast variable values across conditions, or misunderstand that causal state of only one variable at a time can be investigated in an experiment. These failures lead to typical errors in applying the CVS, such as varying the wrong focal variable, varying multiple variables, ignoring confounds, varying all variables, or varying no variable at all (Siler & Klahr, 2012).

Prior assessment instruments could show that already primary school children can be successfully trained in understanding and applying the CVS (Schwichow et al., 2016). However, despite the seminal works by Schauble et al. (1991), and Siler and Klahr (2012), it is not yet clear which misconceptions primary school students typically hold and need to overcome during training.

The main goal of our project was to develop and evaluate an experimentation-skills test for primary school students. Special attention was given to the assessment of misconceptions, such as engineering goals (Schauble et al., 1991) and incomplete or faulty strategies of applying the CVS (Siler & Klahr, 2012). In addition, a training was developed to enhance student’s experimentation skills and to decrease the occurrence of prevalent misconceptions about experimentation.

Our test covers all subskills of CVS as defined by Chen and Klahr (1999). These subskills concern planning, understanding, identifying, and interpreting conclusive experiments. In addition, we assess typical errors based on misconceptions in understanding, interpreting and planning conclusive experiments. Overall, our test uses five different types of items, of which the following two are particularly relevant for identifying misconceptions: In misconception items, children are asked to evaluate a given experiment (either confounded or not) by selecting among a list of reasons why this is or is not a good experiment. While some answering options represent application of the CVS (e.g. “This is not a good experiment because they varied too many things at the same time”), others represent the adoption of “engineering goals” that preclude the application of the CVS (e.g. “This is not a good experiment because the fertilizer did not make the plant grow more tomatoes.”).
In planning items, children are presented with a brief story of another child confronted with a causal research question. They are further given a table of potential causal factors, and are asked to design an unconfounded comparison by selecting their experimental set-up in a multiple choice format. Based on children’s answering patterns, several of the misconceptions described by Siler and Klahr (2012) can be detected; in particular: varying the wrong focal variable, varying two or three variables, keeping everything constant, and varying everything.

A first wave of data collection (Spring/Summer 2017) with eight 5th grade classrooms (Mage = 10.3, n = 152 children) has already been concluded. The main wave of data collection (Winter 2017/2018) is currently on-going, encompassing around 30 additional classrooms and follow-up data from most classes.

In the classrooms from the first wave, we found a significant learning gain for both types of items (planning and misconception items) for the treatment group in contrast to an active control group. On the misconception items, the frequency with which students picked an “engineering focus” answering options decreased in the treatment but not the control group (Figure 1).

On the planning items, we found a reduction in the application of faulty or incomplete strategies in designing conclusive experiments for the treatment group but not the control group (Figure 2; “all” means that students varied all possible variable levels, “wrong focal” means that students varied another variable than the focal one, but applied CVS correctly, “none” means that students varied no variable, “focal plus” means that students varied more than one variable at a time).

Overall, the findings from the first wave of classrooms show that both types of items successfully assess typical errors and misconceptions in designing and interpreting conclusive experiments. Furthermore, our results allow to observe students’ conceptual change in planning and interpreting unconfounded experiments. Our results indicate that student’s prevalent misconceptions can be reduced by explicitly instructing and training of domain-independent experimentation skills, in particular the Control of Variable Strategy. This indicates that the development of incomplete or faulty conceptions can be reduced by training domain-independent experimentation skill such as applying the CVS while conducting an experiment based on science goals.

References


Preliminary analysis of the “Models of conceptual change” project: qualification of- and support given to- conceptual change models in five major science education research journals since the beginnings

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Keywords: Conceptual change; Model; Meta-synthesis

Context

Considering its possible importance and implication in the success of science teaching and learning, conceptual change as a phenomenon has been given considerable attention in the science education research literature (Duit & Treagust, 2012). For example, meta-syntheses have provided interesting accounts of the most important factors that seem to positively influence conceptual change (Lin, et al., 2016). However, what qualifies as a “conceptual change model” remains problematic. While some of the most iconic propositions have been easily labeled as conceptual change models (while sometimes without epistemologically securing this qualification), not all of them are considered as such, however, for the same reasons. For example, some of them concentrate on describing learning processes (DiSessa, 2002; Vosniadou, 2012), while others concentrate instead on the pedagogical sequences that favour them (Posner, Strike, Hewson, & Gertzog, 1982). While some focus almost exclusively on strong restructuring, others are more general and address learning in a more holistic way. Other qualification problems also emerge: can a mere set of recommendations be called a model? Can an epistemologically impeccable proposition that has been given support only by its proposer be worthy to be called a model? Etc.

This also brings us to the central question of this research: how much have each one of the conceptual model propositions been given attention throughout history of conceptual change research? What is the historical weight (more or less support) of each of them? Notwithstanding the problem of what counts as a model, an evaluation of such support could be obtained by merely counting the number of citations for each one. However, this approach would not spare us the problem of the objective value and meaning of each one of the available citations. Indeed, how many of them give a positive, neutral or negative appreciation (and what might be the strength of- or enthusiasm behind- these appreciations)? Are all of these citations “position statements”, by which authors reveal their preference? Which ones of them are empirically grounded? And finally: were these supports sustained over time or were they short-lived?

The present research project aims at bringing answer elements to most of these questions through a thorough and comprehensive review of literature (meta-synthesis) that goes back to the beginnings of published conceptual change research.

Methods

From an initial search in the ERIC and PsycInfo databases that was performed on January 1st, 2017 [for "conceptual change" AND (science* OR physics OR chemi* OR biolog*) in all fields], we initially pre-selected 1286 articles. We then restricted our analysis to the five journal with most occurrences (Sci. Ed; JRST; IJSE; Learning and Instruction and European JSE), for a total of 283 articles. Based on general relevancy criteria, 33 have been disqualified. Each one of the remaining article was then separately analysed by two trained reviewers using a previously elaborated analysis guide, which was then adjusted as the analysis of the first 20 articles unfolded. Afterwards, each pair of reviewers had
to agree about the elements of their individual analysis in order for them to be inserted into the database. 11 reviewers were involved in the effort.

The information they gathered was about (1) the identification of the article [year, first authors’ country, journal, discipline, school level, etc.]; (2) the used definitions of conceptual change and considered conceptual elements [preconceptions, p-prims, epistemic frameworks, intuitive rules, core intuitions, etc.]; (3) all available and recordable supports to each conceptual change model whether they were given by (a) clear or (b) indirect evocation, by (c) position statement (positive or negative); or by (d) empirical arguments. When empirical evidence was provided, we also recorded the research questions, participants (N), presence of a control group, methodology, data collection instruments or methods, and particular nature and strength of the provided evidence.

**Expected results and conclusion**

The end of the analysis of the entire corpus is scheduled for the autumn of 2018. Therefore, the complete results will not be available for the conference, but we will be able to provide a preliminary analysis of more than 80% of the corpus at EARLI SIG-3.

These results will present the complete methodology that has been used, the rationale and criteria behind methodological choices; including the selection and subselection algorithms, the criteria used for qualifying propositions as models, as well as the ones involved in qualifying a “support to a model” as such. We will also present the recorded existence and evolution of these supports (evocation; position statements; empirical) over time for each model in comprehensive graphs. We will then propose an interpretation of the recorded evolutions of supports to models since the first appearance of the concept of conceptual change model in the literature up to recently.

**References**


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Pre-service biology teachers' perceptions about critical thinking
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Keywords: critical thinking model, conceptual, everyday understanding

Theory
Scientific literacy and thus critical thinking are needed in order to tackle societal problems appropriately (Bybee, 1997). Critical thinking is accompanied by a complex interplay of various characteristics, which we illustrated in a literature-derived critical thinking model (see Figure 1). These characteristics, namely intellectual standards, knowledge, motivation, cognitive skills, and self-regulation, are interconnected, but do not necessarily build on one another. In our model, a thorough involvement with a subject, e.g. a problem or a claim, leads to an individual and alterable positioning. This involvement is controlled by intellectual standards providing autonomy, fairness, accuracy, breadth, depth, rationality, logicalness, relevance and significance (Paul & Elder, 2014). For the involvement, a critical thinker needs domain-specific knowledge (McPeck, 1981; Ennis, 1989) and training (Halpern, 2014) as well as cognitive skills (Facione, 1990; Halpern, 2014) in order to synthetise (e.g. search, collect, learn), determine (e.g. systematise, categorise, define), evaluate (e.g. judge, analyse, question), interpret (e.g. understand, explain), reflect (e.g. think, deepen) and discuss (e.g. argue, debate) certain aspects. He or she needs motivation for truth-oriented and reason-based problem solving as well as an aspiration for learning and expertise (Siegel, 1988; Facione, 1990; Ennis, 1997). Finally, a high level of self-regulation (Facione, 1990) affecting all other characteristics is crucial for changing perspective, but also realising something and, as a result, modifying thoughts or actions.

Objective
Critical thinking has been discussed as a fundamental educational goal for decades already, however, we hardly know anything about whether and how these ideas are put into practice. To provide a more thorough understanding of critical thinking and its meaning for biology teaching, we need to evaluate teachers perceptions first before focussing on teaching strategies and environments. Therefore, our research question was: How do pre-service biology teachers perceive a critical thinker?

We derived the hypothesis: Because pre-service biology teachers have an "everyday idea" of critical thinking they equate being critical with being sceptical or suspicious.

Methodology
Two groups of pre-service biology teachers (Spring 2017: n1=34, Autumn 2017: n2=23) were asked to participate in an associative writing activity. They spent 5 minutes on jotting down any characteristic they regard important to value a person a "critical thinker". Participants found themselves in the middle of their teacher training programme (6–8th semester). Handwritings were transcribed and analysed using the software MAXQDA. A deductive category system was developed and used to analyse the content qualitatively and quantitatively. Data analysis is still in progress.

Findings
Most of the participating students addressed a *subject* such as claims, opinions as well as unnamed sources, and quite some linked critical thinking to subjects in the domain of science. Almost all students named *intellectual standards*, especially breadth and autonomy, but also...
depth, fairness, accuracy, logicalness and rationality. A third of the students associated a critical thinker with "*positioning*" or "reaching or having an opinion". For most students a critical thinker "evaluates given knowledge and information", whereby *evaluation* is primarily characterised as "questioning". However, students do not specify how this should be done and only few students argued that domain-specific knowledge is needed to question something or recognise a potential problem. *Synthesis*, in terms of collecting, researching and learning something, is hardly addressed. Almost all students (81%) addressed attitudes or dispositions, primarily "scepticism, suspicion and not believing everything", but also "being against the mainstream or authorities" as well as "persuasiveness". About 60% of the students addressed features in the area of *self-regulation*, mainly "changing one's own perspective", and some also mentioned "awareness for changeable, limited and incomplete knowledge". Only a few students named modification, acceptance, realisation and being self-critical. The distribution of categories did not vary between the two groups.

Conclusions

Many of our students picture a critical thinker as being suspicious and sceptical. However, scepticism and suspicousness is not the same as being critical. Besides, being critical (in the Austrian cultural area) is not the same as critical thinking. We believe that being critical or thinking critically is part of most peoples’ self-concept, perhaps because it indicates intellectual independence. People may perceive themselves as being responsible citizens and thus critical thinkers. It is important to note that “much of the theoretical work and many of the pedagogical endeavours in this area are misdirected because they are based on faulty conceptions of critical thinking”, which relate to “mental processes and procedural moves that can be improved through practice” and transferred to different fields (Bailin et al., 1999, p. 269). These conceptions may hinder or misguide the domain-specific implementation of critical thinking in the classroom. We propose that it is essential to give teachers and policy makers a clear and understandable explanation of critical thinking and to evaluate their individual perceptions. If faulty conceptions of critical thinking are continuously promoted in the classroom, it may mislead students to equate suspiciousness with the intellectually more demanding process of critical thinking.

References


Understanding students’ explanations of geoscience phenomena
Sibylle Reinfried (University of Teacher Education Lucerne)

Keywords: Knowledge-in-Pieces, explanatory primitives, learning

Introduction
This study explores the nature of students’ geoscience knowledge structures. The study is based on the theory perspective of Knowledge in Pieces by diSessa (1993). Students were asked to explain the complex hydrological phenomenon of water springs, an integral part of the water cycle that is usually beyond direct perception. The topic is important in geoscience teaching and education for sustainable development.

According to the Knowledge in Pieces perspective, students’ explanations of the physical world are seen as spontaneous constructions. These constructions result from the activation of fundamental knowledge elements that diSessa (1993) has described as phenomenological primitives (p-prims). diSessa’s p-prims are understood to be intuitive fine-grained knowledge elements that are unconsciously activated by the learner in response to a particular situation. They result from the learner’s experience in the world, are the basis on which a learner makes sense of a situation and operate as implicit presuppositions of how the physical world works. Kapon & diSessa (2012, p. 266) have expanded this approach by developing the construct of explanatory primitives (e-prims). In their view, explanations are formed by reducing each phenomenon to a certain set of functional knowledge elements, the so-called e-prims. While p-prims relate to abstracted experiences of the physical world, e-prims are self-explanatory units and result from social interaction, language (metaphors) or explicit instruction. Kapon & diSessa (2012) suspect that every e-prim has a reliability priority, which is based on recurring confirmations of the e-prim in everyday life situations and reinforces or reverses the original cue. The higher the priority of an e-prim, the more readily it is activated in any given context and the lower the probability of it being rejected in subsequent context-related reasoning.

Kapon & diSessa (2012, p. 272f) have developed a set of criteria for identifying e-prims. They have also established criteria for determining the reliability priority of e-prims, thus demonstrating the degree of confidence an individual has in one or her e-prims (ibid, p. 274). We have used both these instruments in our study in order to identify p- and e-prims relating to water springs in the students’ explanations and assessing the priority of these knowledge elements. The goal of the research presented here was to examine students’ geoscience knowledge structures and to better understand the basics of their reasoning.

Research Questions
• Do the students’ employ p- and e-prims relating to water springs in their explanations and what do these primitives mean in terms of content?

• Do the e-prims have high priority for the students thus demonstrating a high confidence students have in these explanatory prims?

Methods
The analysis was exemplified by two case studies of two 12-year old students and made use of excerpts from interviews, drawings and brief written explanations provided by the two students. The differing data sources permitted a fine-grained analysis of the students’ thinking as well as facilitating triangulation. The data analysis was carried out by means of an iterative process involving several
runs, to identify the p-prims and e-prims in the students’ self-generated explanations conveyed in the interviews using the criteria developed by Kapon & diSessa (2012, p. 272f and 274f). The knowledge elements, which could be p-prims or e-prims, were compared with those already identified by diSessa (1993) and Kapon & diSessa (2012) and empirically confirmed by other researchers. We also expected to discover e-prims not previously defined.

Results
In the context of their explanations of what they mean by water springs, the boys created very different narratives, but the intuitive knowledge elements at the core of their reasoning were the same. The students’ explanations are based on a number of e-prims. However, two of them, the e-prims matter in motion has force and hard matter blocks, loose matter lets things through, have not yet been described in the research literature so far. Both e-prims fully conforms with the operationalised definition of an e-prim developed by Kapon and diSessa (2012, p. 272). Both e-prims cued by both students in the context of the water spring topic have a high priority.

Conclusions and Implications
With the help of the criteria developed by Kapon & diSessa (2012, p. 272) it was possible to investigate what cognitive resources the students draw upon when forming explanations which allows a deeper insight into the fundamentals of their knowledge construction and reasoning. The two e-prims identified in this study play a major role in intuitive thinking in the context of springs and ground water. They explain why the idea that springs and ground water must have something to do with large underground caves or channels is so widespread and difficult to change (Reinfried et al., 2012).

The findings of this study are of major importance for planning lessons and will help teachers hone their expertise in diagnosis. By allowing students to explain subject matter in their own words and illustrate it through drawings, the teacher will be able to identify intuitive knowledge elements and recognise how such knowledge elements affect students’ understanding. It can be used in teacher training to help trainee teachers understand student thought processes. The findings also contribute to the further development of theories in conceptual change research especially the „resources perspective“ (e.g. Brown & Hammer, 2013).

References
Discipline-specific epistemic beliefs across disciplines in higher education: Combining intra- and interindividual perspectives

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Keywords: epistemic beliefs, higher education, domain-specificity

Do students from the social sciences think differently about psychology than students from the natural sciences? Do they perceive psychological findings as less certain than biological findings? Since the 1970s, questions like these have been investigated under the umbrella term epistemic beliefs, which are defined as individual conceptions about knowledge and knowing, often regarding a specific domain (Hofer & Pintrich, 1997). Developmental models (Kuhn, 1991) distinguish three belief types: absolutism, multiplism, and evaluativism. Absolutists see knowledge as an accumulation of certain and absolute ‘truths’. Multiplists stress the subjectivity of knowledge and tend to perceive all viewpoints on a topic as equally legitimate. Finally, evaluativists see themselves as part of the process of knowledge by evaluating and weighing differing viewpoints.

Prominent methods in epistemic belief research are either between-subjects or within-subjects designs: In between-subjects studies, researchers adopt an interindividual perspective by investigating differences in the epistemic beliefs of two separate populations. For example, Rosman, Mayer, Kerwer, and Krampen (2017) contrasted psychology and computer science students regarding their (discipline-specific) epistemic beliefs. In contrast, within-subjects studies compare the epistemic beliefs of one population concerning at least two domains or topics. For example, undergraduate students’ beliefs about mathematics are contrasted with the same students’ beliefs about history (Buehl, Alexander, & Murphy, 2002). However, previous research has neglected the combination of these approaches, that is, investigating interactions between within- and between-subjects levels. This allows to investigate whether populations systematically differ in their beliefs regarding different domains. For example, students with a natural science background (STEM students) might perceive mathematics as more absolute and psychology as more multiplistic compared to students from non-STEM backgrounds (e.g., since they are socialized differently in terms of the criteria they employ to evaluate evidence).

In the present study, we investigated differences in psychology-specific epistemic beliefs by combining intraindividual (within-subjects) and interindividual (between-subjects) perspectives. Due to differing knowledge structures between psychology and biology (Muis, Bendixen, & Hearle, 2006), we expected that university students have lower absolute and higher multiplistic psychology-specific in contrast to biology-specific epistemic beliefs (intraindividual perspective, Hypothesis 1). Moreover, since STEM students are socialized to using ‘harder’ evidence (e.g., mathematical proofs; Muis et al., 2006), they might devaluate ‘softer’ evidence. Thus, we expected such students to have lower absolute and higher multiplistic psychology-specific beliefs than non-STEM students (interindividual perspective, Hypothesis 2). Finally, for the same reason, we expected that STEM students perceive an even stronger difference between psychology and biology than non-STEM students regarding both absolute and multiplistic beliefs (combination of inter- and intraindividual perspective; Hypothesis 3).

To test our hypotheses, we conducted a nationwide online study with N = 938 German undergraduate and graduate university students studying a multitude of different disciplines (the only inclusion criterion was ‘studying at a German university’) during summer to fall 2017. 290 participants (31%) had a STEM background (i.e., biology, chemistry, computer science, engineering/technology, geography, mathematics, pharmacy, physics). Epistemic beliefs were
measured by the EBI-AM (Peter, Rosman, Mayer, Leichner, & Krampen, 2016), a multiple-choice inventory that measures absolutism and multiplicism on separate scales. Domain-specificity was realized through the questionnaire’s instruction and by replacing the domain in the item wordings (sample item for multiplicism: In [psychology], only uncertainty appears to be certain). We collected data on psychology-specific and biology-specific epistemic beliefs as well as on epistemic beliefs regarding participants’ own discipline or educational research (not analyzed here), which is why participants took three test versions (randomized order). Scale reliabilities (Cronbach’s Alpha) ranged between $\alpha = .75$ and $\alpha = .88$.

Preliminary data analyses were conducted through one- and multifactorial analyses of variance (more elaborate analyses will be presented at the conference). In line with Hypothesis 1, our data revealed that psychology is perceived as less absolute ($F_{1,717} = 601.18; p < .001$) and more multiplicistic ($F_{1,717} = 632.30; p < .001$) than biology (psychology and biology students were excluded from these analyses). Regarding Hypothesis 2, STEM students had stronger psychology-specific multiplicistic beliefs than non-STEM students ($F_{1,794} = 5.85; p < .05$), but the groups did not differ significantly in their psychology-specific absolute beliefs (psychology students were excluded from these analyses). Finally, supporting Hypothesis 3, the difference between psychology- and biology-specific epistemic beliefs was higher for STEM students regarding both absolutism ($F_{1,704} = 4.03; p < .05$) and multiplicism ($F_{1,704} = 5.52; p < .05$; psychology and biology students excluded).

In sum, while all three hypotheses were supported (except Hypothesis 2 regarding absolutism), our data show that intraindividual differences in epistemic beliefs (Hypothesis 1) were considerably higher than interindivdual differences (Hypothesis 2) or a combination of both (Hypothesis 3). Our results provide clear evidence for the domain-specificity of epistemic beliefs and show that students recognize differences in knowledge structures between disciplines. Furthermore, they show that students with a STEM background seem to perceive such differences in an amplified way. Implications for research and practice as well as additional analyses will be presented at the conference.

References


Teaching for understanding social-ecological systems using Dynamic Learning and Thinking Journey

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Keywords: Dynamic learning, Thinking journey, Conceptual change

Background

The conceptual change process is often described as enabling students to change their relation to the learnt concept. Posner et al. (1982) described a dialogue with the learner where through cognitive conflict processes she would prefer the new understanding of the concept over the previous one she had held. The problem is that students tend to stick to their former ideas and not to change their perceptions according to the teachers’ persuasions (Dole & Sinatra, 1998). Furthermore, prominent scholars like Vosniadou (2007) and Carey (2009) emphasize the difficulties of going through a conceptual change process.

In the current study the approach towards conceptual change stemmed from enabling the students to connect between observation and understanding. The students visited three different social-ecological systems in Israel, where there are connections between social inequality and interesting ecological systems. Their learning was done based on the ideas of Dynamic Learning (Schur & Valanides, 2005) for learning about the specific systems and those of Thinking Journey (Schur, 2015; Stein et al., 2015) for developing the understanding through the use of multiple perspectives.

Methodology

Our research was done with 20 M.Ed. students learning in the environmental education program who learnt a course about social-ecological systems. Then they went to three field trips to observe and analyze different systems in real environments and learn about them in situ. They drew the systems and explained their drawings. Though the students had prior knowledge about social-ecological systems, they found it difficult to observe a real system and be able to connect the theory to the reality. Our findings suggest that the conceptual change processes of specific students related to their ability to use abstract thinking in connection with the real features of specific systems and get to higher order of understanding.

An analysis system was developed that enabled us to measure the understanding levels of the students in the different field trips. It contained 5 levels of understanding that were validated by the four authors of the research. The categories for levels of understanding are the following: 1. Pre-system understanding. 2. Partial understanding of the system. 3. Understanding the ingredients of the system. 4. Understanding the inter-relations between the different components of the system. 5. Understanding of the systematic structure of each social-ecological system.

Results

The three drawings of each one of the students were analyzed (altogether, 60 drawings of all the students) and the development of the conceptual understanding was determined for each one of them. According to our findings based on the analysis of students’ drawings each one of the students had a unique learning path in the three field trips. At the end of the course most of the students were able to understand the concept of social-ecological system at the level of 3 and above. There was an increase of the number of the students reaching the levels of understanding 4 and 5, from...
11% to 19%. In order to get to higher levels of understanding one needs to enable the students a higher level of mediation, which we have already done with good results in our new research.

Drawings 1 – 3 reflect the learning process that one of the students experienced. At the first field trip she understood the social-ecological system at level 3, being able to identify the different social and ecological components. At the second field trip she added the inter-relations between the different components of the system. At the third field trip the student was able to understand the system at level 5, meaning being able to perceive the system in relation to the relevant theories and in the process to disconnect herself from the immediate sensual impressions, while integrating the various component of the system unto a connected representation with a theoretical meaning. The evolution of the student’s understanding and the conceptual change she has experienced are presented in the following sequence of drawings:

**Drawing 1:** Understanding level 3 – “core cognition” observing the ingredients of the system

**Drawing 2:** Understanding level 4 – The drawing reflects understanding of the system and its inter-relations. The student connected with arrows the different ingredients of the system
Conclusions
The importance of this research is in the feasibility to observe real conceptual changes of each of the students in the learning process that related to the individual needs of the different students. The learning process based on the Dynamic Learning and Thinking Journey enabled 50% of the students to improve their understanding of the learnt concept and enabled them to observe in their unique fashion social-ecological systems in a variety of realities.

*Drawing 3: Understanding level 5* – The whole system is drawn as a connected system, looking like a big cabbage. The theoretical understanding is interpreted into a cohesive point of view of the specific system.
Uncertainty processes in the process of solving a challenging mathematical problem
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Keywords: Uncertainty processes, mathematical problem, learners’ types

Uncertainty processes in the process of solving a challenging mathematical problem

Background
This study deals with the involvement of emotions in the process of understanding. The uncertainty processes deal with the connections between emotions and their effects on the way that students learn. The learning process that involves changes in the conceptual understanding of students involves elements of uncertainty (Schur & Nevo, 2018). Emotional processes are important to learning processes (Pekrun et al, 2002). In order to examine the interrelations between understanding and emotions we examined the emotions involved in a challenging mathematical assignment (Schur, 2018).

Methodology
A qualitative research was done relating to the following research questions:

1. What were the emotions that 9th grade students expressed during a challenging mathematical problem?
2. Can one typify different types of ways for students to tackle a challenging assignment along the ways in which the students described their emotions and uncertainty processes?

8 students participated in the study. They were considered to be talented in mathematics learning. They were interviewed in details in the process of solving the problem, and they drew their emotions of the learning process they experienced.

Research Tools
1. The challenging mathematics problem: Imagine that you stand on a road that goes from left to right. In the left side of it there is a truck. In the side of one of its wheels there is a source of light that is projected towards you. All around you there is darkness. The truck drives from left to right and passes in front of you. So you see the movement of the source of light clearly. How will you see the movement of the source of light? What will be its trajectory? Please draw the trajectory of the source of light.
2. Students documents: This study focuses on the emotional processes the students went through. The students’ drawings of their emotions reflected their unique ways of tackling the challenging problem.

Finding
Seven of the eight students solved the problem and drew the answer. The eighth began the process but could not finish it. It took the students several pages of writing and drawings to go through the solution. Some of the students worked independently and others needed the constant mediation of the teacher.

The drawings of the emotions and uncertainty processes of the students enabled us to typify six types of learners along their ways of tackling the problem: independent, distance taker. Drowned, wondering, asking questions and fighter.
We will elaborate two of them here.

Drawing 1: Wondering

The learner drew himself with a big head and a question mark and two big eyes. In a way this drawing is reminiscent of The Cry of Munch. This is the way the learner explained his drawing: “The head is the main part, the body is negligible... the head does the job. The mouth opens, but words don’t go out. Because I understand and don’t understand at the same time... The mouth did not know what to say. In a question mark fashion. I don’t know what to say. I did not panic. I felt that I lack some tools”. But as time went by, the student connected to the problem that fascinated him and worked with passion. “It triggered me to tackle the problems that I faced. I totally devoted myself to the story of the problem”. He worked hard with deep considerations and offered some alternative solutions, until he reached a satisfying graphic representation of the movement of the source of light. He went through a meaningful learning process that stemmed from his initial wondering.

Distance taker

Two learners distanced themselves from the problem, telling themselves that their value will not diminish if they will not be able to solve the problem. The first one drew her emotions as a turning wheel. This is a philosophical point of view. Even if she will not succeed in solving this problem she will be able to do so in another one.

The second student described her personal attributes. She drew the process in the following way:

Drawing 2: The good looking girl that thinks about a mathematical problem

She drew herself thinking about the problem. “I drew myself with my hand on my chin, to show that I am thinking. The eyebrows signal that I think, pondering...and then the bubble show my thinking. I drew what I had in my imagination... The mouth here is a mouth of indecision. It is not a crooked mouth, it is a thinking mouth...I drew my eyes open, explaining that I watched but using my imagination”. She was the only one who drew her face, relating in details to its features, and showing the outside beauty. She also emphasized her ability to relate to the problem and to use her
imagination. Her abilities and outside features were not dependent on succeeding to solve the problem. She was at the same time inside the process and outside it. She was able to have an initial solution to the problem, and did not continue further.

Conclusions and possible implications
Tackling the same mathematical problem involved very different emotional processes from each of the students. Mathematical problems’ like any other challenging problem solving or learning involves uncertainty processes. Asking to draw emotions can be an important factor in enabling a teacher to focus her mediation on specific traits of learning of students.

Uncertainty processes can encourage and increase the motivation to tackle a challenging mathematical problem. At the same time they can create a feeling of discomfort and insecurity of not being able to solve the problem.

References


Thinking Journey as a means for individual conceptual changes in physics studies
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Keywords: conceptual changes, individual understanding, Thinking Journey

Thinking Journey as a means for individual conceptual changes in physics studies

Background
Classical articles like (Driver et al., 1994) or (Nussbaum, 1985) emphasize the generalization of the sequence of notions of each of the learnt concepts. In a former study, our findings suggest that a conceptual change of an Ethiopian new immigrant to Israel in her understanding of the Earth’s concept had unique characteristics, though the changes were compatible to those described by Nussbaum (Schur, 2012). In this study, we would like to further show the individual nature of the conceptual change process that students experienced in the classroom through the use of Thinking Journey pedagogy allowing the students to connect their knowledge with observations of environments created in the students’ minds.

The classroom teaching of the topic of refraction was done through the use of Thinking Journey (TJ) mode of instruction (Schur, 2015; Stein, Galili & Schur, 2015; Schur & Galili, 2009). TJ enables students to study through experiencing journeys in their minds that give multiple perspectives of the learnt concepts or topics. Attentive teaching in the classroom allows the students to go through individual paths of knowledge construction and conceptual understanding.

Methodology
The qualitative study examined the conceptual understanding process of 5 students who learnt in a class of 14 students in 10th grade who studied the topic of refraction. The students experienced four creative mediated interactions in the classroom that created Thinking Journey and were interviewed in the process of their learning.

The learning started and ended with the following task: You enter a drop of water that is on the lawn. Please draw the way that you see the environment.

In order to analyze the changes in the understanding of the students their final drawings were compared to the initial ones, while reflecting on the influence of the scientific knowledge of the principles of refraction on visualizing an environment.

Results
Though all the learners learnt in the same class, each one of them had a unique conceptual learning process.

Drawing 1: Ben’s initial view of the surrounding from within a drop of water.

Drawing 1. Ben’s initial view
Ben wrote: “I imagined a drop of dew on the lawn. I am on the bottom of the drop. I can see the lawn that I am on it. I can see its cells because I am so small. In addition, I can see some sorts of microbes inside the drop”. Ben had a general description of the environment around him from the point of view from within the drop of water. As the mediation enabled him to become small and enter a drop of water, he saw in his imagination small features around him.

The initial description of Ben and all the students was descriptive. The students did not use scientific explanation. Some of them saw small features around them, others described rural or urbanite views.

One can compare Ben’s final drawing with the initial one (Drawing 2: Ben’s view from within a drop of water at the end of the learning process):

After learning he used scientific explanation. Ben compared between the way that the environment was seen with naked eyes with the way it was seen within the drop of water. He claimed that the form within the drop of water was distorted,. It looked bigger and less sharp than the shape of the environment with naked eyes. He wrote that the sharpness of the vision changed and was distorted near the boundaries of the drop of water. He also wrote that the colors would change, and drew the scenery accordingly.

The other students’ drawings related also to scientific principles. Each one of them described a different point of view. Learning the refraction principles and the way they are affecting different contexts enabled the students to change their understanding of the concept of refraction and the way it affects their observation of reality.

Conclusions
The students experienced a process of conceptual change through the use of Thinking Journey (TJ) mode of instruction. Though all the students were given the same tasks in the classroom, each one of them constructed an individual path of conceptual learning. The students had to go out of their egocentric point of view and felt free to connect themselves to a different point of view of refraction. The change of the understanding of the students was examined through their ability to connect between their added knowledge of the principles of refraction with their representations of refraction scenery constructed in their minds. The classroom teaching related to the specific places of the students, allowing an attentive dialogue between the teacher and the students. The use of drawings enabled the teacher to focus her mediation on the specific learning path of each of the students, while teaching the same learning tasks to the whole class.

References


On the negative effect of inquiry learning activities on scientific reasoning skills
Martin Schwichow & Silke Mikelskis-Seifert (PH Freiburg)

Keywords: Inquiry based learning, scientific reasoning,

Science is not just a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge (NRC 2012). This twofold meaning of science is reflected in science curricula of various countries that aim to promote students’ knowledge of scientific concepts and their scientific reasoning skills (e.g., USA: NGSS Lead States 2013; Germany: KMK 2005).

Scientific reasoning is the intentional construction of knowledge via generating, testing, and revising hypotheses (Zimmerman 2007). Many relevant scientific reasoning skills are brought together under the term control-of-variables strategy (CVS). CVS enables students to design an experiment in a way that alternative causal effects or interactions can be excluded. Therefore, all variables except the one being investigated should ideally be held constant (or “controlled”) across experimental conditions (Woodward 2003). Procedurally, CVS includes the ability to recognize confounded and unconfounded experiments and the ability to design experiments in which conditions differ with respect to a single contrasting variable. It is also important to understand CVS conceptually, which involves the ability to make appropriate inferences from the results of controlled experiments (e.g., only inferences about the variable being tested are warranted), as well as an awareness of “the inherent indeterminacy of confounded experiments” (Chen and Klahr 1999, p. 1098).

Scientific reasoning skills such as CVS are crucial for generating new knowledge from scientific experiments and inquiries and thus are relevant for inquiry based learning. Inquiry based learning is an instructional approach in which students learn by actively using scientific methods to answer research questions (Bell et al., 2005). As inquiry based learning requires scientific reasoning, students’ scientific reasoning skills should improve with the amount of inquiry activities they have experienced. Furthermore, students’ declarative knowledge and conceptual understanding (content knowledge) of science is an important predictor of their ability to utilize scientific reasoning skills (Nehring et al. 2015). Content knowledge seems to scaffold students during scientific reasoning by supporting them to ask relevant research questions, to identify variables, and to interpret the outcome of experiments.

This study aims to investigate the dependency between students’ scientific reasoning skill, their experience with inquiry activities and their science content knowledge. The research questions of this study are (1): Does the amount of inquiry activities students have experienced predict their CVS skills? And (2) does the amount of inquiry activities still predict students’ CVS-skills when controlling for students’ content knowledge?

To investigate these questions, we conduct a correlative-study in a high-school in south Germany. All students (N = 216, 42% female, mean-age = 15.1 years) of four 8th, two 9th and four 10th grade physics classes answered two test instruments and one questionnaire. First, they took the 24 item CVS Inventory (CVSI) by Author (2016). The CVSI items ask students to choose controlled experiment for testing given hypothesis and to interpret the presented outcome of confounded and controlled experiments. All items of the CVSI are in the context of electricity and electromagnetism and heat and temperature. Second, students answered a 39 item content-knowledge-instrument about their declarative knowledge and conceptual understanding in these fields of physics. Finally, students got a
seven item questionnaire on inquiry-activities (e.g. How often do you plan your experiments?) in which they had to estimate the amount of inquiry activities in their physics classes on a five level Likert-scale (“never” to “every lesson”). We utilize multilevel linear modelling with random intercepts to analyze the data because students are nested within classes.

A one-way-ANOVA yields no significant effect of grade on students CVS skills F(2,212)=2.95, p=0.055. However, a one-way ANOVA with physics-class as between subject factor shows significant differences of students’ CVS skills between physics classes F(9,201)=2.65, p=0.006. Next, we analyzed if these differences can be explained by a different amount of inquiry activities. A linear random intercept model shows a significant negative effect of inquiry activities on students CVS skills (F(212)=4.58, p=0.0345, intercept=0.62; p<0.001 = b=-0.14; p=0.034). This effects persist when students content knowledge is added to the model (F(212)=6.42, p=0.01, intercept=0.45; p<0.001, b=0.16; p<0.001, bcontnet=0.35; p=0.01).

The results of this study are surprising as we found a negative effect of inquiry experience on students’ CVS-skills even when controlling for differences in content knowledge. A possible explanation is that inquiry activities not per se support the development of scientific reasoning but that cognitive activation and regulation are more crucial for developing and understanding scientific reasoning skills (Modrek et al. 2017). However, based on the available data it is not possible to exam the quality and classroom inquiry praxis in more detail. Our finding shows that policy, praxis and research should focus more on the cognitive effects of instruction and less on surface features like inquiry activities.

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Changing How We Think About Knowledge: Exploring The Relationships Between Epistemic Cognition And Conceptual Change

Gale Sinatra (University of Southern California)

Keywords: epistemic cognition, epistemic conceptual change

We are in unprecedented times. The rate of advances in scientific discovery is at an exponential level compared to just decades ago. And yet, at least in the USA, Americans are showing resistance to and in some cases outright denial of accepted scientific evidence (Sinatra & Hofer, 2016) on a wide range of topics from stem cell therapy (Ho, Brossard, & Scheufele, 2008), to the safety of genetically modified foods (Heddy, Danielson, Sinatra, & Graham, 2017), to vaccinations (Kata, 2012), to whether humans are contributing to climate change (Sinatra, Kardash, Taasoobshirazi, & Lombardi, 2012). It has been suggested that there is currently an attack on the very concept of truth. Today, individuals in the USA more frequently get their news from social media outlets than traditional news sources and the veracity of that information has become more difficult to ascertain. Separating “fake news” from news that conflicts with one’s worldview is fast becoming a sophisticated and demanding task. McIntyre (2015) warned “we have reached a watershed moment, when the enterprise of basing our beliefs on fact rather than intuition is truly in peril.”

The emerging field of epistemic cognition (EC) or “how people acquire, understand, justify, change, and use knowledge in formal and informal contexts” (Greene, Sandoval, & Bråten, 2016, p. 1) may have more to contribute to the current challenges facing conceptual change research than ever before in this nascent fields’ history. The justification of knowledge, for example, depends on the regulation of strategies for evaluating sources and evidence in an intentional and thoughtful manner. Sinatra and Pintrich argued that intentional conceptual change requires “the goal-directed and conscious initiation and regulation of cognitive, metacognitive, and motivational processes to bring about a change in knowledge,” (2003, p. 6). “I saw it on Facebook” does not provide the degree of informed justification needed to weigh the issues and arguments necessary to change one’s own or another’s conceptions about vaccine safety, or Russian interference in the USA’s 2016 presidential election. This is the context in which epistemic cognition can inform conceptual change (Sinatra, 2016). Reasoning, thinking, and problem solving in any discipline frequently entails a change in conceptions; both conceptions about content but also conceptions about knowledge itself, or “epistemic conceptual change,” (Sinatra & Chinn, 2012). This suggests there is a reciprocal relationship between epistemic cognition and conceptual change that will be explored in this session.

This invited symposium will highlight the contributions of advances in epistemic cognition for conceptual change research as well as the contributions of conceptual change research to our understanding of how individuals (or social groups) think and reason in this new “post-truth” era where individuals are struggling with the very notions of truth, fact, evidence, and rationality.

First, Gale Sinatra the session organizer, will present a brief introduction and overview of the session.

In the first presentation, Changes in Aims, Ideals, and Reliable Processes During Epistemic Growth in Explanation, Clark Chinn, Rutgers University, USA will demonstrate how the AIR model of epistemic cognition applies to epistemic conceptual change.

In the second presentation, Think you know it? Well, think again: Reappraising plausibility judgments to facilitate knowledge reconstruction in science, Doug Lombardi, Temple University, USA will present his work on instructional scaffolds he has designed to promote high school students’
evaluations of alternative explanations which promote explicit reappraisal of plausibility judgments and lead to conceptual change.

In the third presentation, “This is Exhausting” – Finding the Skill, Will, and Thrill for Conceptual Change in the Digital Age, Jeff Greene, University of North Carolina, USA will examine the toll taken on individuals who engage in the self-regulatory and epistemic cognition processes necessary to promote conceptual change.

In the fourth presentation, Moderating and Mediating Effects of Attitudes and Epistemic Beliefs on Conceptual Change, James Vivian and Krista Muis, McGill University, Canada will present their work on the role of attitudes and epistemic beliefs on misconceptions when reading refutation versus expository texts on vaccines.

In the final presentation, Towards Expertise in Historiography: Ontological and Epistemological Changes in the Concept of History Mikko Kainulainen and Marjaana Puurtinen, University of Turku, Finland will extend our discussion of epistemic cognition and conceptual change into the domain of history.

Finally, Panayiota Kendeou, University of Minnesota, USA will serve as our discussant.

References


Conceptual change and representational change: are they sides of the same coin?
Florence Mihaela Singer (UPG University of Ploiesti)

Keywords: representational change, structures, adaptive representations, abstraction

Introduction
The idea of conceptual change entered education as an analogy drawn from the history and philosophy of science that proved helpful in understanding the difficulties people experience in changing conceptions from one explanatory framework to another. Research on students’ pre-instructional conceptions has been embedded in various theoretical frames over the past decades. Starting from analogies with Kuhnian ideas of paradigmatic change of a theory within a scientific community, the classical conceptual-change view emphasizes an epistemological position that stress on discontinuities rather than continuity in learning. Thus, for example, in showing that some of the child’s concepts are incommensurable with those of adults, Carey (e.g. 1985) argued for strong knowledge restructuring during childhood. Subsequently, this view had a definite focus on the cognitive conflicts inevitable as far as students’ knowledge develops, and which students frequently resolve by generating misconceptions.

To bring more nuances to these approaches, Smith, diSessa, & Roschelle (1993) claim, among others: casting misconceptions as mistakes is a too narrow view of their role in learning; misconceptions are faulty extensions of productive prior knowledge; instruction that confronts misconceptions is misguided and unlikely to succeed. More than 20 years later, in a trial to conceive the variety of theories inside the conceptual-change paradigm in education, Brown (2014) proposes the complex-system perspective as a unifying tool. This perspective brings into attention the representations students embedded in their own knowledge.

A question
Although a focus on cognitive conflicts could challenge learning in various situations, there are many instances when such focus could undermine children’s natural propensities for effective learning. Moreover, gaps and spurts, anticipations of the new knowledge and simultaneities have been recorded in cognitive development by many researchers, new Piagetians included (e.g. Fischer & Rose, 2001). Therefore, a new question emerges: What about if, instead of focusing the learning process on discontinuities and incommensurabilities, teachers would stress on continuities, connections and a feed-forward approach? While the first part emphasizes conceptual change, the second deals with a representational-change view. The present paper is focused on this debate arguing that a representational-change approach is feasible for students of various ages because children have innate propensities that predispose them to learn new knowledge and their minds are endowed for recursive processes and spontaneous bridging.

Empirical explorations into the students’ procedures while solving challenging mathematics problems showed that they activate various types of cognitive structures and navigate among concurrent representations, ending by selecting the most adaptive for the task at hand (e.g. Singer, 2009; 2010). The chosen representation might be right or wrong, but what is important for the present discussion is the students’ vacillation between representations while solving or posing mathematics problems. This intuitive capacity to shift among representations in problem solving and posing (e.g. Singer, 2012) can also serve as prerequisite in favor of a representational change approach.
Some accounts for an empirical research

To test the effectiveness of using representational change in learning, a complex methodology should be put in place in classroom settings. Some steps towards such an integrated methodology have been done through the Dynamic Structural Learning (Singer, 2004; 2007) framework, under two principles:

1. Learning is more efficient when it is based on structuring innate predispositions, and already existing mechanisms of information processing.
2. Within an adequate context, dynamic attractors for new knowledge and understanding could be enhanced through appropriate training, after their initial emergence in real-time activities.

In the teaching practice, these result in some types of actions, which are mathematically-specific. First, representations and representation shifts are to be used systematically as powerful tools for learning. Second, abstract concepts should be conveyed very early in school in an informal way, in order to stimulate the children’s abstracting capacity and offer contexts to create and re-create representations. Third, periodically, previous representations should be integrated in more complex structures, allowing students to explore equivalences and differences. Prior empirical research has shown that parts of these are happening in the usual teaching, but they are to be practiced on a more systematic basis.

Implications for practice

Briefly, a representational-change approach in teaching may: offer deeper connections for making mathematics meaningful to learners, by drawing on children’s innate propensities and spontaneous ability for cognitive bridging; stress the continuity between old and new knowledge in students, through both valuing students’ adaptive representations and providing students with a variety of new representations that engender a dynamic view of knowledge; accommodate children with abstractions through gradual processes of understanding based on successive cycles of integrating complexity into subsequent levels of abstracting, which is typical for mathematics as a domain of human knowledge. In addition, the stimulation of the representational power of mind may develop more fluent thinkers so much needed today, when the pace of knowledge accumulation (and change) is more dynamic than ever before.

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The role of instructional analogies on understanding and persuading on the validity of counter-intuitive information

Irini Skopeliti (University of Patras) & Stella Vosniadou (Flinders University)

Keywords: science learning; text comprehension; analogical reasoning

The present study investigated the influence of an instructional analogy in the comprehension of counter-intuitive scientific explanation in expository text. The use of analogies to facilitate understanding of counter-intuitive information has been investigated by a number of researchers (Brown & Clement, 1989; Chiu & Lin, 2005). However, the results of the studies are mixed; some studies argue that analogies can be used as a scaffold to help children encode and process the scientific information and may facilitate the restructuring process (Gentner & Markman, 1994), while other studies raise concerns about the possibility that analogies can create additional misconceptions (Duit, Roth, Komorek, & Wilbers, 2001). In a review of the literature, Dagher (1994) came to the conclusion that the contribution of analogies to conceptual change is difficult to evaluate because “the contribution of instructional analogies to conceptual change may be tacit, leading to small but substantive shifts in students’ understanding of concepts, changes in the ‘normal’ rather than the ‘radical’ order” (p. 609). One of the aims of the study is to determine these small but substantial changes in students’ conceptions that the presence of an analogy fosters and how they relate to conceptual change processes.

The present research aimed at investigating the influence of analogy in the comprehension of counter-intuitive scientific explanation of the day/night cycle. We hypothesized that the no-analogy text would be difficult to understand because the scientific explanation would be in conflict with children’s prior knowledge. Contrary, the analogy text could help the understanding of the scientific information because it would present the new and unfamiliar explanation through a familiar domain.

In the first study 81 3rd graders and 68 5th graders were divided in two groups -one group read a no-analogy text which presented the scientific explanation for the day/night cycle, while the other group read an analogy-text which presented exactly the same scientific explanation and also used an analogy which mentioned explicitly that earth rotates around its axis just like gyros turns around on the vertical split while roasting. All children were asked to recall the texts immediately after they read them. Additionally, all the children received a pretest and a posttest, to determine their knowledge about the day/night cycle before and after reading one of the texts.

Children’s explanations in the pretest showed that there were no participants from both experimental groups who knew the scientific explanation of the day/night cycle. In the posttest, children from the analogy condition achieved significant changes in their original explanatory structures \( \chi^2(1)=.368; p=.544 \) and replaced their original explanations with a consistent alternative or scientific one. Contrary, children from the no-analogy condition who changed their original explanations mostly added the new information to their original structures, constructing mixed/fragmented models with no explanatory value.

Children’s recall protocols were parsed into clauses and the number of clauses recalled was subjected to an ANOVA [grade*text]. The results showed main effects for grade \( F(1,145)=4.605; p<.05; \eta^2=0.051 \) in favour of the 5th graders and for text type \( F(1,145)=12.404; p<.001; \eta^2=0.079 \) in favour of the analogy text. We then collected all the invalid inferences created and subjected them to a mixed ANOVA which showed statistically significant interaction between grade and text type \( F(1,145)=5.157; p<.05; \eta^2=0.055 \). Children from the no-analogy condition showed age differences in
the creation of invalid inferences, in favour of the 3rd, compared to children from both age in the analogy condition who created few invalid inferences.

The recalls of the analogy text were categorized in three categories of analogy understanding – no, partial, and complete understanding of the analogy. About half of the students showed evidence of complete understanding and only few children did not understand the analogy. Multiple regression analyses showed that children with more advanced prior knowledge were more likely to understand the analogy [Beta=.411; (x2(2)=7.821; p=.020)] and that analogy understanding would predict positive posttest explanation change [Beta=.513; (x2(4)=10.257; p=.036)]. However, a large number of the children with initial explanations at pretest achieved a complete or partial understanding of the analogy and some children who understood the analogy completely did not adopt a scientific explanation of the day/night cycle at posttest. For these inconsistencies we conducted an interview study to further investigate relations between prior knowledge, analogy understanding and the adoption of the scientific explanation.

Thirty-nine 3rd and 5th graders participated in the study. We used the same questionnaire and texts used in Study 1. Children were also asked to indicate whether they were aware of the differences between their own pretest explanation and the one given in the text, whether they agreed with the text explanation, and finally whether they would change their own explanation of the day/night cycle and how. Children in the analogy condition were also asked to explain in their own words the similarity between the base (gyros) and the target domain (day/night cycle).

The results of the interview study replicated the results of the first experiment. Additionally, in both conditions some children strongly disagreed either with the analogy (6 out of 19 children) or with the scientific explanation (7 out of 20 children), despite the fact that the children in the analogy condition who disagreed with the analogy presented evidence that they had understood the analogy completely or partially. Usually the disagreement centered on the movement of the Sun vs. the movement of the Earth, or on the role of the Moon.

In conclusion, the findings of the present studies showed that prior knowledge can hinder the understanding of the analogy and of the scientific explanation and that the presence of an instructional analogy in a science text might not be persuasive enough to create conceptual change learning in readers, even when there is evidence that the readers have understood the analogy.

References
Acknowledgment

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Beliefs of a Japanese college student as an English learner: exploring epistemic cognition in language learning

Yukako Ueno & Akiko Fukao (International Christian University)

Keywords: language learning, epistemic cognition, learner beliefs

This empirical case study focuses on a learner of English, with the two research questions to explore: 1) What beliefs does a Japanese college student hold toward English learning? and 2) What factors influence the emergence and revision of an individual learner’s beliefs of English learning?

Researchers of epistemic cognition have focused on versatile dimensions of beliefs about knowledge and knowing across different disciplines, and endeavoured to reveal what affects learner beliefs and how they change (Bendixen, 2002; Chinn et al., 2011). It has been found that epistemic cognition can be situated and context-dependent, socially constructed, and multifaceted systems (Chinn et al., 2011). Contextual factors that can affect epistemic cognition include critiques, logical reasoning, motivation, and effort. Furthermore, it has been suggested that epistemic change can occur in the process of resolving disequilibrium through epistemic doubt, volition, and resolution strategies (Bendixen, 2002).

Researchers in second language learning have also shown interest in learner beliefs. They have proposed that beliefs are socially constructed and situated within the micro- and macro-political contexts and discourses (Barcelos, 2003; Peng, 2011). Moreover, these beliefs are dynamic; they are interactive but can also be dissonant, meaning beliefs and actions might be inconsistent on account of contextual factors (Barcelos, 2003; Barcelos & Kalaja, 2011). Research in second language learning has provided only fragments of the system due to the overwhelming number of factors such as time, context, activities and people that come in contact with the learner, emotions and reflection.

Given the considerable overlaps between these two fields of study, using them together may yield more profound insights into language learners’ beliefs and their trajectory of learning. What still remains to be uncovered includes the interaction among different levels of beliefs, what contextual factors influence understanding of knowledge in a discipline (Hofer, 2016). There is also a need to synthesize empirical results across different disciplines (Sandoval et al., 2016), as well as to conduct cross-cultural research sensitive to different environments, particularly non-Western countries (Hofer, 2016). Further, as the research is moving beyond a mere description of beliefs or attempts to identify a cause and effect relationship between beliefs and behavior, qualitative research needs to be actively conducted in order to delve into the complex, contextual, emerging, and paradoxical nature of learner beliefs.

The current study, which aimed to capture the dynamic process of construction and reconstruction of beliefs an individual English learner holds, was conducted at a private liberal arts university located in Tokyo, Japan. Multiple data collection methods were employed over three months of the data collection period, including semi-structured interviews, weekly learning journals, visual representation of beliefs, and questionnaires, which enabled triangulation of data. All the data was analyzed by two researchers, using Modified Grounded Theory Approach (M-GTA) proposed by Kinoshita (2003) The advantage of M-GTA is that it generates concepts directly from the data, allowing the researchers’ interpretations to be firmly grounded in the data, while also allowing multiple researchers to collaborate at the stage of open coding by bringing in and examining multiple interpretations.
The findings show part of one component of epistemic cognition, the structure of knowledge, in language learning. One of the most significant themes that emerged from the data is the participant’s constant reevaluation of her ideas about English proficiencies, which, in turn, seems to influence her approaches toward English learning. The data reveals that she spends a considerable amount of time thinking about what it means to become proficient in English, as her ideas about English proficiencies undergo transformation. Specifically, four interrelated beliefs have been identified regarding English as the target of learning, influencing her learning behavior: English as an academic subject, English as a communication tool, English for academic purposes, and English for professional purposes.

Based on the findings, the current study supports previous research both in learner beliefs and epistemic cognition in that beliefs are not stable but dynamic in nature. It also identifies numerous factors such as everyday experience of using English, interaction with other English users, and goals and aspirations that seem to lead to a formation of a new belief as well as confirmation and revision of already held beliefs. Further, the study sheds light on the importance of coherency among related beliefs, and the participant’s efforts to attain coherency through adjusting them. These insights can contribute both to learner belief studies in SLA as well as epistemic cognition in regards to the conceptual understanding of language learning.

References


Natural Number Bias when Reasoning about the Effect of Operations

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Keywords: Natural number bias, conceptual change, algebra

Aims
People often misapply natural number properties to non-natural number tasks. This natural number bias (NNB) exerts a dual effect in algebraic problems (Christou, 2015): students think of unknown quantities as natural numbers; and they anticipate that a product is larger than its operands or a quotient is smaller than the dividend. Even adults show these effects, in terms of accuracy and response time (Vamvakoussi et al., 2012).

In this study, we asked whether students showed evidence of the same dual effect of the NNB when solving algebraic equations that contain smaller natural numbers (where automatized multiplication tables may lead to recognition) versus larger ones (referring to non-automatized multiplications).

Methodology
Data come from a larger study on NNB. Participants were 77 undergraduate students aged 18-29 (M=19.16, SD=1.82; 83% female) from a Belgian university.

Participants viewed multiplication problems composed of natural numbers and an unknown operand. Participants answered whether each equation could be true or not; response time and accuracy were recorded.

There were four problem types varying on natural number congruency (i.e., whether the unknown was a natural number) and operation congruency (e.g., whether the product was larger than its operand) (Table 1). For Type1, a natural number made the equation true and the result was consistent with natural number arithmetic. For Type2, a rational number made the equation true, but the operand and result were designed to trigger participants’ associations with natural number arithmetic (e.g., 30x_ =6 evokes ‘5’, but the correct answer is 1/5). For Type3, a rational number made the equation true and the result was consistent with natural number arithmetic. For Type4, a rational number made the equation true and the result was inconsistent with natural number arithmetic.

<table>
<thead>
<tr>
<th>Number Congruent</th>
<th>Operation Congruent</th>
<th>Operation Incongruent</th>
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</thead>
<tbody>
<tr>
<td>Small Numbers</td>
<td>3 x _ = 12</td>
<td>6 x _ = 498</td>
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<tr>
<td>Large Numbers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number Incongruent</td>
<td>Type 1</td>
<td>Type 2</td>
</tr>
<tr>
<td>Small Numbers</td>
<td>4 x _ = 31</td>
<td>30 x _ = 6</td>
</tr>
<tr>
<td>Large Numbers</td>
<td>7 x _ = 384</td>
<td>438 x _ = 3</td>
</tr>
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Table 1. Four types of multiplication problems, Small Number set and Large Number set
As clarified in Table 1, two item sets were created: Items in the Small Number (SN) set contained natural numbers smaller than 100 that appeared in the multiplication table. As such, one could expect that participants were familiar with the combinations of these numbers in a multiplication context, as they have automatized them. Items in the Large Number (LN) set contained numbers that do not appear in the multiplication table.

For both sets, each participant completed three items for each problem type, i.e. 24 items. The experiment as a whole contained an additional item set (with small decimal numbers), items about division, and distractor items, the results of which are not reported due to length restrictions.

We hypothesized that for both item sets, accuracy would be highest and response time lowest for Type1, then Type3, and then Type4 problems. However, since in the SN-set the number combinations in Type1 items were memorized, we expected these effects to be larger in that set. Analyses for Type2 were exploratory.

Results and discussion

Table 2 shows accuracies by set. For the SN-set, there was a main effect of Type ($\chi^2=87.846$, $p<.001$). Pairwise comparisons showed that Type1 problems were associated with higher accuracy than all other problem types. Accuracy was higher for Type2 than Type3 and Type4 problems. There was no statistically significant difference between Types 3 and 4.

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<th>Table 2. Accuracies for each problem type, by item set.</th>
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<td>Type 1</td>
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<tr>
<td>Small Numbers</td>
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<td>Large Numbers</td>
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For the LN-set, there was a main effect of Type ($\chi^2=80.993$, $p<.001$). Pairwise comparisons show that Type1 problems were associated with higher accuracy than other problem types, and that Type2 problems are solved more accurately than Type4 problems. Finally, accuracy was higher on Type3 than Type4.

Table 3 presents the mean response time for each item type per set. For the SN-set, there was a main effect of Type ($\chi^2=8.532$, $p=.036$) indicating that Type1 items were solved significantly faster than the other item types. For the LN-set, there was no significant effect of Type ($\chi^2=5.068$, $p=.167$).

<table>
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<th>Table 3. Response time (ms) for each problem type, by item set.</th>
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<tr>
<td>Type 1</td>
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<td>Small Numbers</td>
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<td>Large Numbers</td>
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</table>

For the SN-set, accuracy was higher for Type1 items than for other item types. This effect was also supported by a reaction time effect, as correct answers on Type1 items occurred faster than those on all other types. The accuracy difference between Type1 and Type3 items indicates that students are
particularly sensitive to whether the unknown number is a natural number rather than a rational one. The lacking difference between Type3 and Type4 items indicates that students are less sensitive to the effect of the multiplication operation, and accept equally well that multiplication may make smaller and larger. Type2 items are exceptional as they have a higher accuracy than Type4 items, even though both were number and operation incongruent. Type2 problems may facilitate accurate responses by triggering associations with natural numbers; future research is needed to explore this possibility.

For the LN-set, the same pattern in accuracies was found, but an additional difference was found between Type3 and Type4, indicating that for these items, students are more likely to accept statements in which multiplication makes larger than statements in which multiplication makes smaller.

Comparing the accuracy patterns between the SN- and LN-set, it becomes apparent that—as expected—the effect of number congruency is larger for the SN-set (difference of 51% between Type1 and Type3) than for the LN-set (25%). This may be because in the SN-set, participants can quickly fill in the missing natural number from memory, while this is not the case for the LN-set. So, the NNB phenomenon is not exclusively associated with the two mechanisms shown so far (i.e. the unknown is rational rather than natural, and multiplication leads to a smaller rather than larger result). Also the fact that certain number combinations are memorized contributes to the extent to which participants accept that certain multiplications involving missing multiplicands are possible.

Our findings suggest the importance of awareness about the challenges of problem solving with rational numbers. To help counteract such challenges, teachers could focus on developing students’ intuitions for rational numbers and explicitly contrasting differences when problem solving with natural and rational numbers.
Intuitive errors in learners’ fraction understanding: A dual-process perspective on the natural number bias
Jo Van Hoof (KU Leuven), Lieven Verschaffel, Wim de Neys (Université Paris Descartes) & Wim van Dooren (KU Leuven)

Keywords: Rational number, conceptual change, time restriction

In the following, we present an ongoing study in which we discuss the theoretical framing and the design. Results and implications will be discussed in the symposium.

Although the importance of good rational number understanding is widely acknowledged, studies have pointed out difficulties that elementary school children, secondary school students, adults, and even (prospective) teachers have with various aspects of rational numbers (e.g., Siegler et al., 2012; Vamvakoussi et al., 2012). Literature ascribes many of learners’ difficulties with the understanding of rational numbers to a phenomenon called the natural number bias, which is the tendency to (inappropriately) apply natural number features in rational number tasks (e.g. Vamvakoussi et al., 2012; Van Hoof, Verschaffel, & Van Dooren, 2015). Learners make systematic mistakes specifically in rational numbers tasks where reasoning purely in terms of natural numbers results in an incorrect solution (incongruent items; e.g. which is the larger one: 1/3 or 1/4?; 4 is larger than 3, but 1/4 is smaller than 1/3). At the same time, much higher accuracy levels are found in rational number tasks where reasoning merely in terms of natural numbers also results in a correct solution (congruent items, e.g., which is the larger one: 4/10 or 7/10?; 7 is larger than 4, just like 7/10 is larger than 4/10).

Most studies investigate the phenomenon of the natural number bias from the conceptual change perspective. A key assumption is that the acquisition of new knowledge is not always merely an enrichment of already existing conceptual structures. Sometimes the acquisition of new knowledge requires a total reorganization of the prior conceptual structures (e.g., Vosniadou, 2013). The conceptual change theory explains why so many learners have difficulties with fractions because they are biased by their prior knowledge of natural numbers and a drastic change in their conceptualization of number is needed to fully understand the various aspects of fractions (e.g., Vosniadou, 2013).

The dual process theory goes further by explaining how it is possible that learners who already have the correct, scientific idea of a concept, can still make mistakes. This is explained by the influence of intuitive thought processes that are not (sufficiently) controlled by the analytical processing system (e.g., Evans & Over, 1996). The dual process theory assumes namely that humans have both an intuitive processing system (S1) and an analytic reasoning system (S2). S1 is deemed fast, automatic, associative, and undemanding of working memory capacity, whereas S2 is deemed slow, controlled, deliberate, and highly demanding of working memory capacity. Fast S1-intuitions are assumed to be engaged in by default, and often lead to correct responses, but they can go wrong in situations where more extensive, analytical thought processes are needed (Gillard et al., 2009). Recently, it has been argued that the dual-process theory in cognitive psychology and its accompanying methodologies could be a valuable tool in establishing the intuitive nature of erroneous reasoning in various mathematical domains (Gillard et al., 2009).

As stated above, numerous studies found evidence for the natural number bias in learners’ lower accuracy levels on incongruent items compared to congruent items. Moreover, recent correlational studies showed that a correct analytic response to an incongruent item is associated with higher reaction times compared to a correct response to a congruent item. However, the reported
correlations do not ascertain the causality that is assumed (De Neys, 2006). Therefore, in this study we will experimentally elicit intuitive reasoning using dual process methodology, making it possible to investigate the causal role of intuitions in the understanding of the size of fractions.

We start from the dual process claim that analytic reasoning takes more time than intuitive reasoning, using a fraction comparison task (further referred to as FCT). Every trial of the FCT contains two fractions that are simultaneously shown on a computer screen (using E-prime software). By pressing on the corresponding key, participants have to indicate which fraction is the larger one. Both congruent (correct response is in line with intuitive natural number processing) and incongruent items (correct response requires analytic reasoning) will be used as well as fractions with and without common components.

Two conditions are used. In the experimental condition, a time restriction is applied so that participants will have sufficient time to respond to the tasks, but not enough time for analytic processes to get involved. In the control condition, the participants have all the time needed to respond to the items, without any time pressure, making it possible for analytic processes to intervene. We hypothesize that if the natural number bias has an intuitive character, time restriction will lead to an increase in natural-number based answers and thus in a decrease in correct answers on incongruent items, while correct answers to congruent items will not, or significantly less, be affected since intuitive reasoning leads a learner to the correct answer in such items.

References
Epistemic cognition in students’ knowledge construction through web search
Nina Vaupotič (University of Münster) & Valentin Bucik (University of Ljubljana)

Keywords: internet search, epistemic cognition, adolescents

Introduction
Epistemic cognition encompasses beliefs about knowledge and knowing, as well as processes through which those beliefs are formed (Hofer & Pintrich, 1997). It is associated with learning and knowledge construction in various environments including the Internet, where users have to choose appropriate key words, evaluate and select the information they come across and combine it with other sources of knowledge (Bråten, Strømsø & Britt, 2009). Even though research has demonstrated that epistemic cognition is linked to strategies of searching for information online and knowledge construction with the help of online sources (Tu, Shih & Tsai, 2007), users do not spontaneously reflect about the certainty, complexity and sources of knowledge found online (Mason, Boldrin & Ariasi, 2010).

The present research was guided by the question of how the reflection on the nature of knowledge can be induced when browsing the Internet. Moreover, we were interested in the role of prior knowledge and searching strategies. A quasi-experiment was designed, in which students were randomly assigned to one of four groups to answer two questions on topics of dinosaur extinction and climate change. One of the questions was open-ended, while the other was structured to prompt the participants to think about the nature of knowledge. Four groups represented four different orders where the type (open vs. structured) and topic (dinosaur extinction vs. climate change) of the question were alternating. In terms of statements reflecting the nature of knowledge, we predicted that students would voice more sophisticated statements, fewer less sophisticated statements and would give answers of better quality when the questions were structured to induce thinking about the nature of knowledge. Furthermore, we predicted a positive association between prior knowledge and epistemic sophistication of answers as well as a positive association between efficient searching strategies and epistemic sophistication of answers.

Method
Altogether 178 students attending three secondary schools with a general academic program participated in the study. The mean age of the sample was 17.5 years (SD = .51). All participants reported using the Internet in their free time and for schoolwork purposes.

An online survey was administered in computer science classrooms. Prior to the assessment students returned the consent forms signed by themselves and their parents if the participants were still underage. Student first filled out their demographic data, which was followed by the short test of their prior knowledge on the two topics. Afterwards they had up to 30 minutes to answer two questions with the help of searching the Internet. Lastly, they reported what searching strategies they used to search the web, and answered questions regarding their motivation.

Prior to the data collection a coding scheme was developed and tested on the pilot sample of 10 participants. It included four dimension of epistemic cognition based on Hofer and Pintrich (1997). Students’ statements were firstly attributed to one of the dimensions and secondly rated as more or less sophisticated. Furthermore, a checklist for assessing the general quality of the answers was developed and tested. The first author carried out the coding.
Results
To verify the absence of prior differences the four orders were first compared in regards to participants’ gender, use of the Internet, pre-knowledge and searching strategies. Afterwards the data was analyzed using R’s nlme package (Pinheiro, Bates, DebRoy, Starkar & R Core Team, 2014). Three mixed effects models were build to predict the effects of question structure, question order and question topic on the number of more and less sophisticated statements and on the quality of answers. As random effects intercepts for subjects and schools were defined. The p – values were obtained using likelihood ratio test in an ANOVA model.

There was a significant effect of the question structure ($X^2(1)$ = 79.79, $p < .001$) and question order ($X^2(3) = 8.66, p = .03$), on the statements reflecting more sophisticated epistemic cognition. Similarly, a significant effect of question structure ($X^2(1) = 7.34, p < .001$) but no significant effect of question order on the quality of participants’ answers was found. However, there was no significant effect ($p > .05$) of question structure and question order, on the statements reflecting less sophisticated epistemic cognition. Post hoc tests using Bonfferoni correction showed significantly more sophisticated statements when answering about dinosaur extinction. Furthermore, students’ pre-knowledge was not significantly related to their answering, while the use of efficient search strategies was marginally linked to more sophisticated epistemic cognition ($r = .16, p = .04$).

Discussion
These results demonstrate that students can be scaffolded to reflect on the certainty and complexity of knowledge found online, discrepancies between various sources and authors. While the short intervention did induce more statements reflecting more sophisticated epistemic cognition, it did not reduce the number of statements presenting less sophisticated epistemic cognition. Therefore we cannot conclude that questions reflecting the nature of knowledge cause epistemic change; however, they do appear to encourage students to voice and reflect on their beliefs, which usually does not happen spontaneously (Mason et al., 2010). Furthermore, our results point to the conclusion that the topic of search is related to knowledge construction, which in turn implies that our conclusions cannot be generalized for a broad range of themes.

References


Through the lens of confidence: students’ misconceptions in physiology
Marjolein Versteeg & Paul Steendijk (Leiden University Medical Center)

Keywords: conceptual change, confidence, physiology

Background and aims
Physiology education is recognised as one of the key pillars on which meaningful medical training is founded (1). Medical physiology is the scientific study of function and mechanisms of the human body. Over the last years, misconceptions have been demonstrated repeatedly in this discipline and appear resistant to change even after instruction (2,3,4). Remarkably, few educational strategies focus on the elimination of misconceptions in biomedical education.

In 2013, Palizvan and colleagues investigated students’ misconceptions of cardiovascular concepts (2). In a 2-tier multiple-choice survey, students indicated their answer in the first section and explained the reasoning underlying their answer in the second section by selecting one of the listed options. Results showed a mean prevalence of misconceptions around 90%. Notably, researchers did not distinguish between the presence of misconceptions and a mere lack of knowledge.

According to a Theory of Conceptual Change (5), a lack of knowledge can easily be remedied with instruction and learning, whereas misconceptions are robust to change. An important role in this educational problem is attributed to the learner’s awareness (6,7). A general finding is that students’ confidence is higher than their actual knowledge, indicating that students often overestimate their knowledge. However, the possible link between confidence and misconceptions has not been explored in medical education. This study aims to investigate the prevalence of misconceptions by measuring students’ performance and associated confidence on exercises regarding physiology.

Methodology
Eighty-two Biomedical Sciences students from Leiden University Medical Center participated in this study. They were asked to answer four questions related to cardiovascular concepts. The structural framework of the questions was similar to Palizvan et al., including a Yes/No section and a subsequent explanation section. Furthermore, students had to rate their confidence in their answer after each question using a 5-point Likert scale; (1) Very unsure (just guessing), (2) Fairly unsure, (3) In doubt (50/50), (4) Fairly sure, (5) Very sure (almost 100%).

Outcomes on the test were scored binary. A correct answer required a correctly chosen answer in both sections (i.e. Yes/No and explanation). Outcomes on the confidence scale were averaged and analysed as dichotomous data. A cut off was set at >3 for high confidence as item 3 indicates the student’s doubt between two answer options. We used Hasan’s decision matrix for data analysis (8). Hasan’s model consists of four quadrants that indicate the level of perceived and determined knowledge (i.e. incorrect/correct answer and low/high confidence).

Findings
An average score of 3.06±0.84 (out of 4) was obtained by students on the first Yes/No sections with a mean confidence grading of 3.63±0.61. Only 38% of the students provided a correct explanation to their correct Yes/No answer. The correlation between the average score and average confidence of students on the explanations was rs= 0.364, p=0.001.
Classification of misconceptions through Hasan’s model showed that 28.7% of all answers could be categorised as misconceptions (i.e. incorrect answers graded with high confidence). Another 32.7% of the answers were incorrect but graded with low confidence, indicating a lack of knowledge. The right conception, as indicated by a correct answer graded with high confidence, was reported on 29.9% of all questions. Only 8.9% of answers were categorised lucky guesses, meaning that a correct answer was provided with low confidence.

Discussion and practical significance
In this study we found that the mean prevalence of misconceptions is about one-third, which is lower than previously reported for similar medical physiology questions. This might be a result of including confidence grading to distinguish between lack of knowledge and true misconceptions. The proportion of misconceptions (incorrect answers graded with high confidence) was comparable to the proportion of answers that indicated a lack of knowledge (incorrect answers graded with low confidence).

In a future study we will investigate how one’s perceived knowledge may play a role in the process of conceptual change. Some researchers suggest that incorrect answers chosen with high confidence are more open to conceptual change than those chosen with low confidence, whereas other suggest the opposite. The former is termed the hypercorrection effect. It would be of great interest to clarify the relation between confidence and conceptual understanding, adding another perspective to the existing theoretical frameworks. Moreover, revealing the putative existence of the hypercorrection effect in medical physiology education may have serious consequences for designing effective educational interventions that aim to alleviate misconceptions and enhance conceptual understanding.

References


Moderating and Mediating Effects of Attitudes and Epistemic Beliefs on Conceptual Change
James A. Vivian & Krista R. Muis (McGill University)

Keywords: attitudes, epistemic beliefs, conceptual change

The rise in number and complexity of socio-scientific issues, alongside wider access to science-related information on the Internet, has led to an upsurge in challenges regarding public understanding of science (Sinatra, Kinehaus, & Hofer, 2014). Controversial socio-scientific topics such as climate change, stem cell therapy, and vaccines have substantial personal, social, economic, political, and environmental ramifications (Sinatra et al. 2014). For example, the vaccine controversy emerged because of a falsified publication by Wakefield et al. (1998) in the Lancet medical journal. The authors claimed a temporal association between the mumps, measles, and rubella vaccine and the onset of autism spectrum disorder. As a result of the publication, vaccination rates dropped in several countries, which led to an increase in cases of measles (Sinatra et al. 2014) and in misconceptions about vaccine safety (Kata, 2012).

Individuals are often fettered by misconceptions regarding issues of importance that contradict scientifically accepted knowledge (Sinatra & Seyranian, 2016). Misconceptions can be counterproductive for learning if individuals are incapable of identifying and modifying their misconceptions, or are unable to discern between evidence-based knowledge and conjecture (Kendeou & van den Broek, 2005). Misconceptions diverge from scientifically-accepted knowledge and arise when individuals encounter information that is counter to their knowledge or understanding (Heddy, Danielson, Sinatra, & Graham, 2017). Changing misconceptions can be especially challenging when evaluating information that has been purposely fashioned to advance others’ furtive social, political, and/or economic agendas (Sinatra & Seyranian, 2016).

Two factors that may facilitate or constrain conceptual change include individuals’ attitudes and epistemic beliefs regarding a topic (Dole & Sinatra, 1998). An attitude is “an organization of several beliefs focused on a specific object...or situation, predisposing one to respond in some preferential manner” (Rokeach, 1968, p. 16). Epistemic beliefs refer to individuals’ doxastic assumptions regarding the nature of knowledge and knowing (Hofer & Pintrich, 1997) and include beliefs about the source, certainty, complexity and justification of knowledge (Hofer & Pintrich, 1997). Taken together, beliefs form the building blocks of attitudes (Dole & Sinatra, 1998; Wogalter, DeJoy, & Laughery, 2005) and may interact to facilitate or constrain conceptual change. Conceptual change involves modifying inaccurate knowledge (Kendeou et al., 2014; Vosniadou, 1994) and conceptually reorganizing epistemological assumptions to achieve more accurate knowledge and understanding (Lombardi, Nussbaum, & Sinatra, 2016). One method by which researchers have generally been successful in facilitating conceptual change is with the use of refutation texts that directly challenge individuals’ misconceptions, state the falseness of inaccurate knowledge, and present causal explanations to refute errors in reasoning. However, to date, very little research has taken into consideration the moderating and mediating roles that attitudes and epistemic beliefs may have on conceptual change. Our research addresses this gap in the literature.

Current Study
The current study investigated the moderating and mediating roles of attitudes, epistemic beliefs, and refutation versus expository texts on the relationship between prior misconceptions and posttest conceptual change while learning about vaccines.
Methods
Participants and Materials
Fifty-two university students participated and were given a prior knowledge test that included 10 true-or-false questions to assess their misconceptions about vaccines. Attitudes towards vaccines were assessed using a four-item measure (Trevors, Muis, Pekrun, Sinatra, & Winne, 2016). A modified version of the Topic-Specific Epistemic Beliefs Questionnaire (TSEBQ; Strømsø, Bråten, & Samuelstuen, 2008) was used to measure participants’ vaccine-related epistemic beliefs. The two experimental texts, expository and refutation, presented information related to vaccines. The refutation text confronted misconceptions about vaccines and presented causal explanations based on scientific evidence to refute incorrect knowledge (Kendeou et al., 2014). The expository text presented the same information, but without the refutation content. To measure post-test learning, participants once again completed the knowledge pretest.

Procedure
Participants first completed the prior knowledge test, the attitudes toward vaccines survey, and the TSEBQ. Following this, participants were randomly assigned to read a refutation or expository text. After reading the text, participants completed the same prior knowledge test about vaccines and a brief demographics survey.

Results
A moderated mediation analysis was conducted using Preacher and Hayes’ (2014) PROCESS macro for SPSS. Results revealed a direct effect of prior misconceptions on post-test conceptual change, $b = .38, t(50) = 3.39, p < .002$. Additionally, prior misconceptions predicted attitudes, $b = .37, t(50) = 4.32, p = .0001$, uncertainty beliefs, $b = -3.25, t(50) = -2.27, p = .028$, complexity beliefs, $b = 2.33, t(50) = 2.57, p = .013$, and source beliefs, $b = 3.88, t(50) = 2.61, p = .012$. Complexity beliefs subsequently predicted conceptual change, $b = -.1138, t(50) = -2.26, p = .03$. Results also revealed conditional indirect effects of prior misconceptions on post-test conceptual change via complexity beliefs ($b = -.1296, CI[-.2900, -.0326]$), attitudes ($b = -.1237, CI[-.2750, -.0019]$), and source beliefs ($b = .0660, CI[.0098, .1863]$) that varied by text condition. That is, participants in the expository text condition with more misconceptions, more negative attitudes, and less constructivist epistemic beliefs regarding the complexity of vaccine knowledge changed significantly less misconceptions at posttest compared to participants presented with a refutation text with the same levels of misconceptions, attitudes and beliefs.

Discussion
The present study contributes to the literature by delineating how individuals interpret, evaluate, and make sense of important socio-scientific issues. Our findings provide evidence for the moderating and mediating effects of attitudes, epistemic beliefs, and refutation texts on conceptual change. Overall, results revealed a significant indirect effect of prior misconceptions on post-test conceptual change via learners’ beliefs in the complexity of vaccine knowledge. Findings also revealed a significant moderated mediation such that participants in the expository text condition with more misconceptions, more negative attitudes, and less constructivist epistemic beliefs regarding the complexity of vaccines knowledge changed significantly less misconceptions at posttest compared to participants presented with a refutation text. Findings of the present study provide additional support for previous studies on the effectiveness of refutation texts in changing misconceptions (Kendeou et al., 2014), as well as attitudes and epistemic beliefs in facilitating or constraining conceptual change (Lombardi et al., 2016).
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Using executive function tasks to investigate links between conceptual change and dual process theories.

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Keywords: dual process theories, mathematics, executive functions

Applications of conceptual change theoretical approaches in mathematics learning claim that the development of number concepts starts by building a natural number concept, which, however, subsequently interferes with rational number reasoning. As a result considerable conceptual changes are needed to understand rational numbers. These conceptual changes are not easy to happen. According to the framework theory approach to conceptual change, many of the mistakes students make when they reason with rational numbers occur in the areas where natural and rational number principles and operations are in conflict (Vosniadou & Verschaffel, 2004; Stafylidou & Vsoniadou, 2004; Vamvakoussi & Vosniadou, 2010). For example, students make mistakes in multiplication between rational numbers because they operate with the understanding, based on natural number reasoning, according to which ‘multiplication always makes bigger’. In addition, experiments with fraction comparison tasks have shown that even adults with considerable mathematical experience take longer to correctly judge which fraction is bigger when the tasks are inconsistent with natural number reasoning, compared to when they are consistent (De Wolf & Vosniadou, 2015).

Dual process theories claim that the architecture of human cognition has two processing systems: An intuitive processing system, System 1, which is fast, automatic and does not pose demands on working memory; and an analytic processing system, System 2, which is slow, deliberate and poses great demands on working memory. Applications of dual process theory to conceptual change approaches to mathematics learning claim that students make mistakes when engaged in rational number tasks that contradict natural number reasoning because they employ processing system 1 instead of 2.

In the present research we investigated the hypothesis that dual process theory can explain students' difficulties in mathematics learning by examining the relationship between mathematical reasoning tasks and executive function tasks. Executive functions are a set of neurocognitive skills, such as working memory, inhibition and shifting, which are implicated in the processing of complex tasks. Executive function has usually been associated with processing system 2. It has been argued that the need to recruit executive function skills, and more specifically the executive skill of inhibition, in the processing of stimuli that are inconsistent with natural number reasoning can explain the finding that these stimuli are less accurate and take longer to respond to compared to stimuli that are consistent with natural number reasoning.

Two kinds of mathematics reasoning tasks were used in the present experiments: Mathematical tasks which were consistent vs. inconsistent with natural number reasoning. Two kinds of Stroop-like executive function tasks were also used: those that required the recruitment of inhibition and those that required the recruitment of shifting. All executive function tasks had a consistent and an inconsistent condition. Both the mathematical and executive function tasks were computer-based reaction time. Dependent measures in the mathematical tasks were both accuracy and speed in the consistent and inconsistent conditions. Dependent measures in the executive function tasks were accuracy and speed in the inconsistent condition.

A hundred and forty elementary school children participated in the study. The results showed that mathematics tasks inconsistent with natural number reasoning were less accurate and took longer to
solve compared to the mathematical tasks which were consistent with natural number reasoning. Significant correlations between accuracy and reaction times in the mathematical reasoning tasks and the executive function tasks were obtained. Regression analyses showed that the participants' scores in the executive function tasks predicted their performance in the mathematical reasoning tasks, even after controlling for age and intellectual ability. More specifically, the results showed that inhibition was recruited in the inconsistent tasks in which the employment of rational number reasoning conflicted with natural number reasoning. This finding is consistent with prior research which implicates inhibition in the reasoning of mathematical tasks inconsistent with natural number principles and operations.

On the other hand, the other executive function skill, that of shifting, was found to be recruited in the employment not only of the inconsistent mathematical tasks but also the ones consistent with natural number reasoning and to account for a large percent of their variance. The finding that the executive function skill of shifting accounted for a large percent of the variance in the consistent mathematical tasks does not agree with the claim that these tasks are processed automatically and do not pose demands on working memory. Thus, this finding is not consistent with the hypothesis that the processing of mathematical tasks consistent with natural number reasoning are processed by processing System 1. The results suggest that dual process theory cannot be directly applied to the domain of mathematics learning, at least as tested in the present research.

References


A conceptual change approach to professional development of university teachers?
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Keywords: conceptual change, professional development, university teacher

Introduction
Conceptual change is defined as the kind of learning where learners’ existing conceptions change and the “alternative frameworks” (Driver & Easley, 1978) are constructed. Conceptual change approach was proposed as an effective way to professional development of university teachers. This echoed the findings that conceptual change approach to university teaching was a more advanced level of teaching comparing to the information transmission or teacher-focused approach to teaching (Trigwell & Prosser, 1997). The former focused on helping learners construct their own knowledge and change their conceptual understanding of the subject. The later focused on detailed information and aimed at transmitting information to the learners instead of encouraging learners to identify the relationships among concepts. In contrast to the enormous research on teaching and learning in higher education, there were much less study on the professional learning of university teachers. This study was an attempt to systematically explore the impact of a commonly used professional development strategy, peer review of teaching (PRT), investigating the learning experience of university teachers during the implementation of this strategy and looking for implications on how the professional development of university teachers can be better facilitated.

The purpose of the study
This study chose PRT, one of the most commonly used professional development strategies in higher education, as the focus of the analysis. A systematic review was conducted on the demonstrated evidence about PRT published in peer-reviewed journals in the past 15 years (2002-2017). The analysis focused on identifying the types and levels of impact PRT had on the professional development of university teachers.

Methodology
In line with the previous definitions of conceptual change (Chi, Slotta, & De Leeuw, 1994; Posner, Strike, Hewson, & Gertzog, 1982) and conceptual change approach to teacher development (Ho, Watkins, & Kelly, 2001), this study explored whether or not PRT resulted in changes of university teachers’ frameworks for conceptuaising teaching and learning and their practices. The impact on cognitive (the understanding of teaching and learning), behavioural (change in teaching practices), and affective (attitude toward teaching and professional development) domains were used as the indicators of conceptual change in the analysis. Bloom’s taxonomies of learning (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956; Krathwohl, Bloom, & Masia, 1973) were contextualized for the thematic analysis in this review. The credibility and reliability of the study were taken good care of following the typical practices for qualitative study.

Findings
The review identified evidence of impact in all three domains. Positive impact include positive attitudes toward and commitment to future PRT opportunities (affective), both technical and pedagogical changes in teachers’ practices (behavioural), and teachers’ reflection which brought together ones’ PRT experiences for initiating one’s own instructional design (cognitive). However, most reported evidence of achievement centred around the middle levels of the three domains, indicating moderate levels of conceptual change among university teachers as the result of their
participations in PRT. The inclusion of reflection seemed not necessarily resulting in the impact on teachers’ conceptions of teaching and learning. The analysis also identified the concurrence of low levels of achievement in cognitive domain and changes in teaching behaviour. The other major finding was the identification of three new levels of learning outcomes in affective and cognitive domains, which were not specified in Bloom’s Taxonomy. This was easy to understand as Bloom’s taxonomies were based on the analysis of the intended learning objectives while this study focused on the actual outcomes achieved. Other findings and the implications for conceptual change approach to professional development of university teachers were discussed in the paper.

References


Minimal Productive Failure Interventions in Mathematics Education

Esther Ziegler & Manu Kapur (ETH Zurich)

Keywords: productive failure, problem-solving, manipulation skills

Research on productive failure (Kapur, 2008, 2014) suggests that when students are given the opportunity to generate their own solutions prior to instruction, they often fail to produce correct solutions, yet they learn better from subsequent instruction (Schwartz & Bransford, 1998). Furthermore, these effects were strong on conceptual and transfer measures of problem-solving, but not reported on procedural measures (Kapur, 2014).

The productive failure effect is an effect shown in the context of conceptual problem-solving material. In the productive failure paradigm, learning results from the struggle to find a solution to a conceptual complex problem and considering multiple possible solution options (Kapur, 2008). When presented with the correct solution, it fosters students’ consideration of why their solution was not the canonical solution and how the canonical solution differed from their attempts. Hence students’ attention is drawn to critical aspects of the canonical solution. Thus, productive failure acts as struggle and thereby desirable difficulty.

The aim of this study was to examine whether productive failure is similarly helpful in the context of manipulation problem-solving material. Typically, demanding manipulation problem-solving material consists of a series of principles to be introduced. Thus, many short occasions of failure, always before a new principle is introduced, may be appropriate for manipulation material compared to one extended occasion of struggle and failure for a conceptually complex concept. Manipulation problem-solving is often introduced by demonstrating solution procedures followed by practicing isomorphic problems before continuing to a subsequent type of problem. Thus, a way to apply failure occasions would be to always precede the introduction of a new problem type by a guessing and failure phase to prepare for subsequent learning. As the single problems are short and the rules in themselves not difficult, these attempts would only be short moments of guessing and failure.

In our study, students were presented algebraic expression simplification material with the two easily confusable principles addition and multiplication, thus demanding manipulation material. This material was not considered to introduce students in algebraic conceptual understanding but in flexible simplification skills, i.e., to promote the ability to distinguish and correctly simplify algebraic additions and multiplications. This ability is seen as basis for a later flexible use in applications and for conceptual understanding and therefore an important goal of instruction (Kirshner & Awtry, 2004).

Method

85 sixth-graders received an introduction in algebraic expression simplification. Students participated in three 2-hour interventions with 6 intervention units, and two follow-up assessments. Each intervention unit consisted of manipulation problems, instruction problems, practice problems and an immediate learning test. The productive failure condition started with manipulation problems followed by instruction and practice, the additional practice condition started with instruction and practice problems followed by manipulation problems as additional practice.

As an indicator for immediate learning gains, all students solved a learning test after each intervention unit. The follow-up assessments (one-day and one-week later) assessed isomorphic manipulation skills, verbal concept retention and transfer.
Results
We used a MANOVA for the intervention measures, and 2x2 mixed-factorial ANOVAs for the follow-up measures (condition: productive-failure, additional-practice, and time: one-day, one-week). For the intervention measures, the MANOVA showed that the manipulation problems worked perfectly with the expected disadvantage of the productive failure condition, but that this initial failure of the productive failure condition reversed to an advantage on the practice problems and the immediate learning tests. This reversal during the intervention already points to the advantage of the productive failure condition in the follow-up. For the follow-up measures, there was an advantage of the productive failure condition on the isomorphic manipulation problems, $F(1,72)=9.11$, $p=.004$, $\eta^2_p=.11$ but neither a time effect nor an interaction effect. However, there was no effect of instruction on verbal concept retention, $p=.558$, as well as no effect on transfer, $p=.936$, indicating that the effect of the productive failure condition was a specific effect on isomorphic problems that were trained in the intervention.

Discussion
Our study examined the effect of short productive failure occasions in an introduction to simplifying algebraic expressions. Surprisingly, our results showed that just a minimal intervention impacted flexible manipulation skills. There was a stable effect of offering short productive failure occasions on isomorphic problems. The intervention however was not strong enough to show effects on the verbal conceptual or transfer measures.

These findings of productive failure in the context of manipulation problems solving material are contrary to earlier findings of productive failure in the context of conceptual problem-solving material (Kapur, 2014). While the latter findings revealed effects on the verbal conceptual measure and transfer but not on the procedural measure, our findings showed effects on procedural but not on the verbal conceptual measures and transfer. Considering the design principles for effective productive failure problems articulated by Kapur and Bielaczyc (2012), the productive failure design principles are violated in the tasks used in this study. The problems used by Kapur were conceptual problem-solving tasks intended to provoke multiple and elaborated solution methods. In this study students were just prompted to guess one single solution before being presented the new rules. These problems were not difficult but students had guessed all the new principles introduced over all nine worksheets before studying them. Nevertheless, this continuous and repeated guessing triggered learning even though only with an effect on isomorphic manipulation problems. We assume that each guessing, i.e., all these minimal failure occasions, served as an impasse that students had to overcome and that may have improved students’ attention in the subsequent instruction. Further, because students got used to the guessing phase, the repetitions might have led to increased expectation during instruction in the sense of paying more attention to the crucial principles they failed on before.

References
Keywords: Chemical bonding, Energy & Forces, Embodied learning

Introduction
This study seeks to develop and explore high-school chemistry students' conceptual understanding regarding chemical bonding and the associated energetics. Having no access to the molecular world and lacking the force-based explanation of chemical bonding, students rely on incorrect interpretations and intuitive heuristics, such as the 'octet-rule', i.e. eight electrons in the outer energy level (Taber, 2002). Most of them view chemical bonds as attached solid spheres for which energy is needed to bring them together (Boo, 1998), or as coiled springs that release energy when relaxed (Hapkiewicz, 1991).

We designed and developed an Embodied Learning Interactive environment, ELI-Chem to alleviate these difficulties: (1) ELI-Chem removes the abstraction by providing bodily experience with the molecular level as proposed by embodied learning theory (Barsalou, 1999); and (2) ELI-Chem is based on a mathematical simulation of attraction-repulsion forces between atoms, supporting a force-based teaching approach (Nahum-Levy et al., 2007; Taber, 2002).

Herein, we describe the ELI-Chem learning environment and the pilot research we conducted with students with the base of the learning environment – the chemical bonding simulation. Using a mouse, students interacted as an atom with another atom, exploring forces and potential energy diagrams. In the first phase of the pilot (Autors, 2017), we found that chemical bonding was learned as dynamic equilibrium between attractive and repulsive forces. In the second phase, the students explored the concept of chemical energy based on attraction and repulsion forces. As the pilot of research showed a shift to force-based reasoning, we next explore whether increasing the degree of embodiment will impact students' reasoning.

The working hypothesis is that more intense (in terms of force and distance moved) physical experience with the underlying electrical forces provides a stronger foundation for understanding energy changes during chemical bonding, and related concepts e.g. chemical stability.

Methods
We use quantitative and qualitative data analysis in a pretest-intervention-posttest design. The participants are 10th to 12th grade chemistry students. Main concepts addressed: repulsive-attractive forces, chemical stability and energy changes. Data collection tools include pre-post semi-structured interviews, questionnaires and the activities' worksheets.

The Learning Environment
The ELI-Chem offers sensory-motor experiences of the attraction and repulsion forces when two atoms approach each other, at four increasing degrees of embodiment (Figure 1): (1) observing videos that involves no action; (2) using a mouse to move an atom in the simulation; (3) using a joystick that moves a greater distance than the mouse; and (4) using a haptic device at greater distance and greater force than the mouse. The first non-interacting degree is a comparison group for the rest.
Findings
We present the pilot research we conducted with students using the simulation (mouse interaction) for two activities: forces and energy.

Forces in Chemical Bonding Activity
In both pre- and post-interviews students were asked to describe verbally and by gesturing what a chemical bond is and what a stable bond means, to provide an analogue for bonding from everyday life and to assess how close atoms can approach each other. Findings show that before the intervention, students did not consider repulsion forces when reasoning about the chemical bond, a new finding in describing conceptual understanding in chemistry. Learning with the ELI-Chem environment helps students shift from a naïve perception of bonding to a more scientific understanding as shown in Table 1. From a naïve explanation depicting the atoms as static "touching" balls, students turn to consider the role of both attraction and repulsion forces and the dynamic balance between the forces.

<table>
<thead>
<tr>
<th>Type of Conceptual understanding</th>
<th>Pre-test</th>
<th></th>
<th>Post-test</th>
<th></th>
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</thead>
<tbody>
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<td></td>
<td>#</td>
<td>%</td>
<td>#</td>
<td>%</td>
</tr>
<tr>
<td>Force-based reasoning</td>
<td>0</td>
<td>0</td>
<td>17</td>
<td>81</td>
</tr>
<tr>
<td>Force-based and naïve reasoning</td>
<td>5</td>
<td>24</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>Naïve reasoning</td>
<td>16</td>
<td>76</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>100</td>
<td>21</td>
<td>100</td>
</tr>
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</table>

Chemical Energy Activity
In the interviews students were asked to define chemical energy, to describe the energy changes during bonding, to explain bond stability and bond strength. Nine common knowledge-elements (Sherin, 2013) emerged and were categorized by their related theoretical underpinnings (Figure 2).
Findings show that before the intervention students did not use force-based explanations; their explanations of energy changes were confused and inconsistent. Learning with the ELI-Chem environment provided students the vocabulary, concepts, principles and analogical sensorimotor schemes that are required to shift from a naïve explanation to one that is force-based and involves using the octet rule only in appropriate problems.

Based on pilot’s results, we designed the questionnaires and the one comparable activity that will be used in all four degrees of embodiment. In these days, we are collecting data with students for the main study, at all degrees of embodiment.

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