ESERA
Summer School 2019
BOOK OF SYNOPSIS
June 4 - 9, 2019
Crete - Greece
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1. ESERA SUMMER SCHOOLS

ESERA (European Science Education Research Association) was formed in Leeds, England, in April 1995. The main aims of this association are to: (a) enhance range and quality of research and research training in science education in Europe, (b) provide a forum for collaboration in science education research between European countries, (c) represent the professional interests of science education researchers in Europe, (d) seek to relate research to the policy and practice of science education in Europe and (e) foster links between science education researchers in Europe and similar communities elsewhere in the world.

The activities of ESERA, among others, include conferences every two years as well as summer schools for science education PhD students. After 2016, the summer schools have taken place every year.

The summer schools offer to PhD students possibilities to present their research work and to discuss its strengths and weaknesses. Students work in the small groups of approximately seven students and two experienced mentors. The participants of the summer school also attend plenary lectures and workshops provided by experienced tutors as well as social events prepared by the organizing committee. The maximum number of participants is 49 so students work in seven groups. The number of staff members differ each summer school but normally it is about 15 – 20 persons. If more than this number applies, then participants are selected to ensure diversity of countries, gender and fields of interest.

Any PhD students who are members of ESERA are welcomed to apply for the summer school. Participant should not be too near to the beginning or end of their PhD study to be able to contribute of the attendance in their future work as well as discuss their preliminary findings. All staff members have to be members of ESERA. These experienced researchers and supervisors act as mentors and some of them also provide plenary lectures or workshops.

The first ESERA summer school was held in the Netherlands in 1993, and the second summer school took place in Greece in 1994. After that, 11 summer schools were held at two years intervals. After 2016, the summer schools have taken place every year.

List of ESERA Summer Schools

2019: Crete, Greece
2018: Jyväskylä, Finland
2017: Ceské Budejovice, Czech Republic
2016: Ceské Budejovice, Czech Republic
2014: Cappadocia, Turkey
2012: Bad Honnef, Germany
2010: Udine, Italy
2008: York, United Kingdom
2006: Braga, Portugal  
2004: Mülheim, Germany  
2002: Radovljica, Slovenia  
2000: Gilleleje, Denmark  
1998: Marly-le-Roi, France  
1996: Barcelona, Spain  
1994: Thessaloniki, Greece  
1993: Zeist, Netherlands

2. ESERA SUMMER SCHOOL 2019

The ESERA Summer School 2019 is held in the seaside village of Kolymbari (Chania), in Crete, Greece. A total number of 49 PhD students from 16 different nations and 17 staff members from 9 different countries will participate at the ESERA Summer School 2019. The first ESERA President (1995 – 1999) is invited to give the opening lecture. In the Summer School 2019, the selected students (49) will work in seven groups, which are based on the names of the following ancient Greek philosophers:

I. Aristotle  
II. Democritus  
III. Aristarchus  
IV. Heraclitus  
V. Eratosthenes  
VI. Pythagoras  
VII. Archimedes

The summer school is organized by the committee of six members from the Faculty of Education, University of Crete.

2.1 Organizer: University of Crete

The University of Crete (www.uoc.gr) was established in 1973. It is a multi-disciplinary, research-oriented public educational institution, located at two campuses in the cities of Heraklion and Rethymnon. It has 16 Departments in 5 Schools (Philosophy, Education, Social Sciences, Sciences & Engineering, and Medicine) as well as a number of affiliated research-oriented institutions, including the Skinakas Observatory and the Natural History Museum of Crete. Research and research training at all levels benefit also from the close collaboration between many of the University’s research groups with the Institutes of the Foundation for Research and Technology – Hellas (FORTH) and the Institute of Marine Biology & Genetics (IMBG). The University offers degrees at three levels: Bachelor, Masters and PhD. Today there are over 16.000 registered undergraduates and 2.500 registered postgraduates students, in both cities, Rethymno and Heraklion. They are educated by an outward looking academic faculty of around 500 members, supported by adjunct lecturers, post-doctoral researchers, and laboratory instructors as well as around 300 technical and administrative staff.
The School of Education is situated in the city of Rethymno and includes two Departments (Department of Primary Education and Department of Pre-School Education). The science teaching laboratory is since 1989 established in the School of Education and aims to:

- Train undergraduate and postgraduate students on teaching sciences by familiarizing them with experimental process and by supporting their assistantship to schools.
- Conduct research on science education.
- Promote the cooperation among diverse stakeholders in order to reinforce the relationship between science and society.

2.2 Organizing Committee of ESERA SUMMER SCHOOL 2019

- **Dimitris Stavrou**, *head of the organizing committee*

Dimitris Stavrou is Professor of Science Education and Director of the Science Education Laboratory in the Department of Primary Education at the University of Crete, Greece. He has graduated the Chemistry Department at the National and Kapodistrian University of Athens and continued his post – graduate studies in IPN, Kiel, Germany. His research interests are focused on: (a) pre- and in-service teacher education, (b) teaching of contemporary scientific subjects and (c) science education and educational technology. He is an ESERA member since 1999 and he has attended all the ESERA Conferences therefore. He has also attended the ESERA Summer School 2002 in Radovljica, Slovenia as a PhD student. In the ESERA Summer School 2014 in Kapadokya, Turkey he took part as a mentor and held a plenary lecture and he also participated to the ESERA Summer School 2018 in Jyväskylä, Finland as a group mentor.
Michail Kalogiannakis, vice-Head of the organizing committee

Michail Kalogiannakis is an Assistant Professor of the Department of Preschool Education, University of Crete and member of ESERA since 2001. He graduated from the Physics Department of the University of Crete and continued his post-graduate studies at the University Paris 7-Denis Diderot (D.E.A. in Didactic of Physics), University Paris 5-René Descartes-Sorbonne (D.E.A. in Science Education) and received his Ph.D degree at the University Paris 5-René Descartes-Sorbonne (PhD in Science Education). His research interests include: science education in early childhood, science teaching and learning, e-learning, the use of ICT in science education, distant and adult education and mobile learning. Part of his work could be found in the following link: https://www.researchgate.net/profile/Michail_Kalogiannakis

Emily Michailidi, member of the organizing committee

Emily Michailidi is a Post Doc researcher and lecturer in the Department of Primary Education, University of Crete, Greece. She has graduated the Primary Education Department at the University of Crete, Greece and she has recently completed her PhD studies on mentoring in-service teacher education on contemporary scientific subjects. Her research interests are focused on teacher education and science teacher identity. She has attended the Summer School in České Budějovice, Czech Republic in 2016 and the ESERA Conferences in Helsinki (2015) and Dublin (2017).

Athanasia Kokolaki, member of the organizing committee

Athanasia Kokolaki is a Phd Student in the Department of Primary Education, University of Crete, Greece. She has graduated the Primary Education Department at the University of Crete, Greece and she has completed her master studies in Science Education. Her research interest is focused on pre and in service teacher education on socioscientific issues. She is an ESERA member since 2019.
- **Argyris Nipyrakis**, member of the organizing committee

Argyris Nipyrakis is a PhD Student in the Department of Primary Education, University of Crete, Greece. He has graduated the Physics Department at the University of Crete, Greece and he has completed his master studies in Science Education. His research interests are focused on the relation between science and technology as well as on STEM approach. He is an ESERA member since 2018.

- **Nikos Kapelonis**, member of the organizing committee

Nikos Kapelonis studied Electronic Engineering in School of Applied Sciences in Technological Educational Institute of Crete. He completed a post-graduate MPhil program in Electronic and Computer Engineering of Brunel University (London). Before the completion of his studies, he had personal avocation with the Information Technology. In 2004, he became a member of the IT Department of School of Education of the University of Crete. Soon after his join in the IT Department, he got involved in a notable number of projects (National and European), with main objective in Social and Humanity Sciences. During the last five years, his interests focused at Distance Learning Systems.

### 2.3 The Summer School Venue: Orthodox Academy of Crete

The lecture and workshop rooms as well as the rooms for accommodation and the dining rooms are located at the building of the Orthodox Academy of Crete (OAC). The OAC is a public welfare institution in the category of National Foundations. OAC is located in Kolymbari, a village by the sea in the west of the town of Chania (24 km from the city of Chania). The OAC:

- Organizes and hosts local, national and international conferences on its own initiative or in cooperation with churches, universities or other organizations.
- Runs various programs and activities of an educational and/or practical nature (e.g. seminars introducing Orthodoxy, iconography, Cretan cuisine and nutrition, seminars about Crete, its history and culture).
- Produces scientific work in the fields of theology and the environment.
2.4 Travel Information

The easiest way to reach OAC is to fly to Chania Airport “Ioannis Daskalogiannis” and then travel by bus to Kolymbari. Since the Chania airport is in the suburbs, you should firstly travel until the central bus station of Chania (about 20 minutes) and then, from there, by another bus to Kolymbari (about 30 minutes). During summer season, buses depart from the central bus station of Chania to Kolymbari every 15 minutes.

When you arrive to the final bus station of Kolymbari you should walk approximately about 15-20 minutes in order to reach OAC according to the route of the following figure (Figure 4).
Figure 3. The route from the “Aura Imperial Hotel” (the final bus stop in Kolymbari) to the summer school venue is marked with the blue line

You may also use a taxi from the Chania Airport to Kolymbari, which takes about 30 – 40 minutes.

The Summer School venue can also be accessed from the Heraklion Airport “N. Kazantzakis”. If you prefer to travel from Heraklion, you should take an urban bus (numbers: 6/ 7/ 8/ 10/ 12/ 14/ 15/ 19/ 31) from the Heraklion Airport to the central bus station of Heraklion (about 10 minutes). From the central bus station of Heraklion, you should take a bus to the central bus station of Chania (about 2,5 hours) and then another bus to Kolymbari (about 30 minutes).

Information about the bus schedules (Heraklion to Chania as well as from Chania to Kolymbari) is provided in the following link that is updated near the summer season:

https://www.e-ktel.com/en/services/dromologia (with departure from Chania)

More detailed information about the local bus schedules will be provided around May, when the schedules are updated, in the ESERA Summer School 2019 website (https://esera2019.edc.uoc.gr/index.php/esera2019/esera2019/announcement/view/2) and in our page in Facebook (https://www.facebook.com/ESERA-Summerschool-2019).
## 2.5 ESERA Summer School 2019 Programme

<table>
<thead>
<tr>
<th>Time</th>
<th>Tuesday 4 June</th>
<th>Wednesday 5 June</th>
<th>Thursday 6 June</th>
<th>Friday 7 June</th>
<th>Saturday 8 June</th>
<th>Sunday 9 June</th>
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<tbody>
<tr>
<td>9:00-9:30</td>
<td>Arrivals / Registrations</td>
<td>Group Meetings (1)</td>
<td>Group Meetings (3)</td>
<td>Group Meetings (5)</td>
<td>Group Meetings (6)</td>
<td>Group Presentations</td>
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<tr>
<td>9:30-10:00</td>
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<td>Closing Ceremony</td>
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<tr>
<td>10:30-11:00</td>
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<tr>
<td>11:00-11:30</td>
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<td>Staff meeting</td>
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<tr>
<td>12:00-12:30</td>
<td>Lunch/Informal Time</td>
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<td>Group Meetings (7)</td>
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<tr>
<td>15:30-16:00</td>
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<td>Informal Time</td>
<td>Coffee Break/Posters</td>
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<tr>
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<td>Workshops</td>
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<tr>
<td>18:00-18:30</td>
<td>Opening</td>
<td>Poster Session</td>
<td>Poster Session</td>
<td>Excursion to Chania &amp; Dinner</td>
<td>Group work presentation</td>
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<tr>
<td>18:30-19:00</td>
<td>Invited Lecture</td>
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<td>19:30-20:00</td>
<td>Initial Group meeting</td>
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<td>20:00-20:30</td>
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<td>Dinner</td>
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<td>Traditional Dinner with</td>
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</table>
3. REVIEWERS

A total number of 20 reviewers from 9 different countries participated in the review process. The reviews were double and blind per proposal and the main criteria were:

- The topic of the proposal should be related with the reviewer's research interests.
- The reviewer's nationality should be different from the Phd student’s nationality.

3.1 List of ESERA Summer School 2019 Reviewers

- Sevil Akaygun, Bogazici University, Turkey
- Lucy Avraamidou, University of Groningen, The Netherlands
- Digna Couso, Universitat Autònoma de Barcelona, Spain
- Mariona Espinet, Universitat Autònoma de Barcelona, Spain
- Robert Evans, University of Copenhagen, Denmark
- Cory Forbes, University of Nebraska-Lincoln, US
- Sari Harmoinen, University of Oulu, Finland
- Koos Kortland, University of Utrecht, The Netherlands
- Antti Laherto, University of Helsinki, Finland
- Pasi Nieminen, University of Jyväskylä, Finland
- Blanca Puig, Universidade de Santiago de Compostela, Spain
- Mathias Ropohl, University of Duisburg-Essen, Germany
- Martin Rusek, Charles University, Czech republic
- Annette Scheersoi, University of Bonn, Germany
- Renee Schwartz, Georgia State University, US
- Asli Sezen-Barrie, University of Maine, US
- Helena van Vorst, Duisburg-Essen University, Germany
- Veli-Matti Vesterinen, University of Turku, Finland
- Andreas Vorholzer, Justus Liebig University Giessen, Germany
- Roger Wood, Oxford Brookes University, UK
PhD STUDENTS
4. PARTICIPANTS

The following 49 PhD students from 17 different countries will meet in Crete this summer:

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rachel Askew</td>
<td>University of Memphis</td>
<td>US</td>
</tr>
<tr>
<td>Polly Bell</td>
<td>Oxford Brookes University</td>
<td>UK</td>
</tr>
<tr>
<td>Arne Bewersdorff</td>
<td>Heidelberg University of Education</td>
<td>Germany</td>
</tr>
<tr>
<td>Judith Breuer</td>
<td>University of Paderborn</td>
<td>Germany</td>
</tr>
<tr>
<td>Name</td>
<td>University</td>
<td>Location</td>
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</tr>
<tr>
<td>Steffen Brockmüller</td>
<td>University of Duisburg-Essen</td>
<td>Germany</td>
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<tr>
<td>Ainsley Carnarvon</td>
<td>University of Aberdeen</td>
<td>UK</td>
</tr>
<tr>
<td>Franziska Detken</td>
<td>Zurich University of Teacher Education</td>
<td>Switzerland</td>
</tr>
<tr>
<td>Irene Drymiotou</td>
<td>University of Cyprus</td>
<td>Cyprus</td>
</tr>
<tr>
<td>Name</td>
<td>Affiliation</td>
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</tr>
<tr>
<td>Kristin Fiedler</td>
<td>IPN at the University of Kiel</td>
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Ernest Mazibe  
*University of Pretoria*  
*South Africa*

Ines Mosquera Bargiela  
*University of Santiago de Compostela*  
*Spain*

Christoph Münster  
*Justus Liebig University Giessen*  
*Germany*

Yakhoub Ndiaye  
*Aix-Marseille University*  
*France*
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5. STAFF MEMBERS

5.1 List of ESERA Summer School 2019 Staff Members

Seventeen persons from nine different countries will serve as staff members at the ESERA Summer School 2019. Fourteen of them will be group mentors and they will work in small groups with PhD students while three of them will be roving mentors, responsible for the poster sessions. Four staff members will also give plenary lectures and seven of them will be involved in workshops. The first ESERA President is invited to give the opening lecture. In detail the staff members are:

INVITED SPEAKER

Dimitris Psillos
Aristotle University of Thessaloniki
Greece

- Organizer of the ESERA Summer School 1994

Sevil Akaygun
Bogazici University
Turkey

Research Interests:
- Visualizations in teaching and learning science
- Nanotechnology education
- STEM education
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<td>Lucy Avraamidou</td>
<td>University of Groningen</td>
<td>The Netherlands</td>
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<td>Nicoleta Gaciu</td>
<td>Oxford University</td>
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<td>Mariona Espinet</td>
<td>Autonomous University of Barcelona</td>
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<td>Robert Evans</td>
<td>University of Copenhagen</td>
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**Research Interests:**

- **Lucy Avraamidou**
  - Science identity
  - Qualitative research
  - Preservice elementary education

- **Nicoleta Gaciu**
  - Physics
  - Research methods in education
  - Quantitative data analysis

- **Mariona Espinet**
  - Science education in multilingual contexts
  - Environmental education and education for sustainability
  - Context based science education in teacher education

- **Robert Evans**
  - Self-efficacy
  - Inquiry-based science teaching
  - Formative assessment
Cory Forbes
University of Nebraska-Lincoln
US

Research Interests:
- Geoscience education
- Modeling
- Mixed-methods

Koos Kortland
Freudenthal Institute, University of Utrecht
The Netherlands

Research Interests:
- Design-based research
- Teaching-learning sequences
- Socioscientific issues

Deb McGregor
Oxford University
UK

Research Interests:
- Creativity in science
- Pedagogies and learning in science
- History of science

Pasi Nieminen
University of Jyväskylä
Finland

Research Interests:
- Formative assessment
- Argumentation
- Multiple representations
Lukas Rokos  
University of South Bohemia  
Czech republic

*Research Interests:*  
- Formative assessment  
- Inquiry-based science education  
- Teachers' professional development

Mathias Ropohl  
University of Duisburg-Essen  
Germany

*Research Interests:*  
- Formative assessment practices  
- Use of digital media in chemistry  
- Chemistry (pre-service) teachers competences

Martin Rusek  
Charles University  
Czech republic

*Research Interests:*  
- Chemistry textbook analysis  
- Scientific literacy  
- Project-based education

Annette Scheersoi  
University of Bonn  
Germany

*Research Interests:*  
- Out-of-school science (biology) learning,  
- Interest development,  
- Design-based research
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<tr>
<th>Name</th>
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| Renee Schwartz              | Georgia State University, US | - Science epistemology  
- Scientific inquiry  
- Science teacher preparation                                                        |
| Mehmet – Fatih Tasar        | Gazi University, Turkey | - Physics Education  
- History & Philosophy of Science  
- Learning Process Studies                                                            |
| Giulia Tasquier             | University of Bologna, Italy | - Climate Change Education  
- Qualitative Methods  
- Socioscientific Issues                                                             |
| Andreas Vorholzer           | Justus Liebig University, Giessen, Germany | - Scientific inquiry  
- Video analysis  
- Rasch measurement                                                                  |
5.2 Staff members’ roles in ESERA SUMMER SCHOOL 2019

**Invited Speaker**
- Dimitris Psillos

**Plenary Speakers**
- Lucy Avraamidou
- Cory Forbes
- Mathias Ropohl
- Martin Rusek

**Workshop Leaders**
- Mariona Espinet
- Robert Evans
- Koos Kortland
- Annette Scheersoi
- Renee Schwartz
- Mehmet – Fatih Tasar
- Andreas Vorholzer

**Group Mentors**
- Sevil Akaygun (*Aristarchus*)
- Lucy Avraamidou (*Aristotle*)
- Mariona Espinet (*Pythagoras*)
- Robert Evans (*Eratosthenes*)
- Koos Kortland (*Aristarchus*)
- Deb McGregor (*Archimedes*)
- Pasi Nieminen (*Pythagoras*)
- Lukas Rokos (*Eratosthenes*)
- Mathias Ropohl (*Aristotle*)
- Martin Rusek (*Democritus*)
- Annette Scheersoi (*Democritus*)
- Renee Schwartz (*Heraclitus*)
- Fatih – Mehmet Tasar (*Arcimedes*)
- Andreas Vorholzer (*Heraclitus*)

**Roving Mentors and poster feedback**
- Cory Forbes
- Giulia Tasquier
- Nicoleta Gaciu
6. PLENARY LECTURES OVERVIEW

Lecture 1 (Invited): On the design and development of Teaching-Learning Sequences

*Dimitris Psillos*

*Aristotle University of Thessaloniki, Greece*

**Tuesday, June 4th, 18:30 – 19:30**

A notable line of science education research and development involves the design, implementation, and evaluation of coherent topic/domain-specific sequences for teaching and learning (TLSs). Designing based interventions in classroom contexts contributes to the advancement of science education research by the development of theoretical and pragmatic insights on teaching and learning and the development of empirically validated artifacts. In the present paper, we provide an overview of developments and trends with regard to TLS and their classroom implementation, discussing and comparing suggested design frames and their features, recent empirical studies and approaches to describing the design of sequences. We suggest that there is progress but more work is needed towards elaborating on the decisions and principles for developing and validating TLS. Examples of the design and iterative development of two Teaching-Learning Sequences one about phenomena related to light propagation in materials, the other about heat transfer are presented. The TLSs aim at fostering students’ understanding of the concepts and models related to these phenomena through an inquiry-based approach based on hands-on and computer-based simulation activities. Specific suggestions for instructional designers for how concerning iterative development of TLS are presented.


*Cory Forbes*

*University of Nebraska-Lincoln, US*

**Wednesday, June 5th, 11:00 – 12:00**

Scientific literacy is a global goal of science education. The Programme for International Student Assessment (PISA) provides a measure of scientific literacy of secondary students in 72 countries, as well as the instruction they report experiencing, defining scientific literacy as “the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen” (OECD, 2016, pg. 28). Previous studies on PISA science data have identified important relationships between science instruction and students’ scientific literacy (e.g., Prenzel, Seidel, & Kobarg, 2012). As a contribution to this discussion, we present results of analysis of PISA 2015 science data involving an international collaboration between researchers in the United States and Germany.
supported, in part, by the Fulbright Scholar Program. These analyses focus on observed relationships between reported science instruction (teacher-directed, inquiry-based, feedback, and adaptive instruction) and students’ scientific literacy, including its underlying subdimensions. Specifically, we share findings from Latent Profile Analysis that help identify instructional profiles associated with varying levels of students’ scientific literacy, discuss potential implications for theory and research in science education, secondary science teaching and learning, including teacher education, and describe longer-term objectives for this collaborative work.

**Lecture 3: Science Identity: theoretical, methodological, and empirical explorations**

*Lucy Avraamidou*

*University of Groningen, The Netherlands*

**Thursday, June 6th, 11:00 – 12:00**

The aim of this interactive lecture is to provide an overview of the diverse perspectives, frameworks, and tools that researchers in different parts of the world have adopted to study science identity and how it develops over time. Building on this overview of existing knowledge, the participants will engage in discussions about what an identity perspective might imply for research on science teaching and learning as well as for widening and diversifying science participation. Following on that, the participants will have an opportunity to engage with authentic qualitative data drawn out of a life-history research study that explores women’s in STEM identity trajectories.

**Lecture 4: What are formative assessments and why should science teachers use them?**

*Mathias Ropohl*

*University of Duisburg-Essen, Germany*

**Friday, June 7th, 11:00 – 12:00**

Since two decades, formative assessment is a key topic in science education research. But till today, there is an ongoing debate about what it is and how it works. Based on a literature review, the lecture gives you an overview about the different theoretical perspectives on formative assessment picking up the mentioned debate. A focus will be put on key characteristics like feedback. Besides, the distinction between formative and summative assessment will be highlighted. Based on the first theoretical part, the lecture will then summarize empirical results that show how formative assessment might affect students learning. However, results in that research field are contradicting. One reason could be that there are different possibilities to realize formative assessment and that these possibilities might vary a lot. Thus, in this part of the lecture also different degrees
of formative assessment as well as different methods will be explained. In the third and last part, the lecture will forge a bridge to (pre-service) teachers’ formative assessment practices answering the question what (pre-service) teachers should be able to do in order to support student learning by formative assessment. Overall, the lecture gives the audience an introduction to the research field of formative assessment.

Lecture 5: Analyzing students' problem-solving strategies

**Martin Rusek**

*Charles University, Czech republic*

**Saturday, June 8th, 11:00 – 12:00**

Students’ problem-solving skills are usually measured with the use of problem tasks. Nevertheless, several studies show limits of such a procedure. Moreover, the results do not provide educators with sufficient information about the students’ strengths and weaknesses, i.e. areas which need to be developed or supported. For this reason, a complex research plan was developed. First, problem tasks were piloted. To do so, sets of tasks were built. In the second step, different students were given the tasks and their problem-solving process was mapped using the concurrent think-aloud method. In the third, the concurrent think-aloud was replaced by retrospective think-aloud supported by an eye-tracking camera. Compared to the pilot, students whose problem-solving process was studied more closely, were less successful. Partly because several of their answers were discovered to be false positive. In this presentation, the methodology of the second and third stage of the project will be presented together with the results of the eye-tracker supported retrospective think-aloud.
7. WORKSHOPS OVERVIEW

**Workshop 1: Strategies for making sense of data: Conventions and ways to a valid interpretation of data**

*Renee Schwartz*
*Georgia State University, US*

**Wednesday, June 5th, 16:00 – 18:00 & Friday, June 7th, 13:30 – 15:30**

When publishing or presenting our research, we need to establish a good link between our local project and the bigger picture. The idea of the workshop is to experience how it feels to make sense of data from these two different points of view: one up close and the other as an overview. For the close look, participants will be given analysed data from a science museum study and asked to discover if all of the data's potential has been realised. As they will work through strategies for getting the most out of this example, they reflect on applications to their own work.

The workshop will then take a meta-view of this museum study and map it using a theoretical model. With this example in hand, participants will map their own PhD research. This mapping activity should help establish a link in PhD research projects between theoretical backgrounds, literature review, empirical data, research questions and methods of analysis. This overview can then help participants decide on appropriate methods for data analysis, how to use data to underpin assumptions and interpretations, and to decide what results are important to present.

**Workshop 2: Researching Views of Nature of Science: Data collection, analysis, and reporting**

*Renee Schwartz*
*Georgia State University, US*

**Wednesday, June 5th, 16:00 – 18:00 & Friday, June 7th, 13:30 – 15:30**

This workshop will focus on current research methods for assessing learners' knowledge about the nature of science (NOS) and the nature of scientific inquiry (NOSI). There will be an overview of how NOS and NOSI are conceptualized, with a brief walk through the historical development of the concepts and research approaches. Various types of assessment and research instruments will be introduced, highlighting strengths and limitations of each. Current research methods that utilize open-ended survey instruments will be the main focus of the workshop. We will look at the Views of Nature of Science (VNOS) and Views of/about nature of scientific inquiry (VOSI/VASI) surveys. Students will examine the instruments, target aspects, survey data, and interview data. Discussion will focus on interpretation of data and methods of reporting results.
Workshop 3: “Meaning, not numbers" - Qualitative research methods

Annette Scheersoi

University of Bonn, Germany

Wednesday, June 5\textsuperscript{th}, 16:00 – 18:00 & Friday, June 7\textsuperscript{th}, 13:30 – 15:30

The workshop will provide an overview of qualitative methodology. We discuss when to use qualitative methods, how to define a study sample, and the difference between qualitative and quantitative research methods. The course will briefly cover data analysis but will largely focus on research design and data collection. Participants will find out about different methods of collecting qualitative data (e.g. observations, interviews) and will discuss about advantages and disadvantages. The workshop will involve opportunities for hands-on exercises.

Workshop 4: “Validity as argument” – a powerful framework for qualitative and quantitative research in science education

Andreas Vorholzer

Justus Liebig University Giessen, Germany

Wednesday, June 5\textsuperscript{th}, 16:00 – 18:00 & Friday, June 7\textsuperscript{th}, 13:30 – 15:30

Validity is a central issue for meaningful research, regardless of whether it is of qualitative or quantitative nature and whether it is in science education or in any other field. A good understanding of what validity means and how it may be assessed does not only help researchers to design and reflect upon their own work, but also to evaluate research of others. Validity is often defined as whether an instrument accurately measures what it is intended to measure. Such definitions are misleading, as they characterize validity merely as feature of a test instrument. The aim of the workshop is to present a more powerful vision of validity that is based on the validity as argument framework of Messick (1995) and to illustrate how this framework may be applied to qualitative and quantitative studies. After an introduction to the framework, the workshop will provide interactive phases in which you, the PhD students, explore:

1) to what questions regarding one’s own work or the work of others a validity as argument perspective may lead,

2) how these questions might be addressed empirically as well as theoretically,

3) how to use it for crafting better and stronger arguments for your interpretations.
Workshop 5: Developing an analytical framework for science education research: Making the most of your theoretical framework

Mariona Espinet  
Autonomous University of Barcelona, Spain

Thursday, June 6th, 16:00 – 18:00 & Saturday, June 8th, 16:00 – 18:00

Science education researchers often adopt theoretical frameworks that come from outside the field. These frameworks are useful since they provide the researchers with the lenses to delimit the phenomena under study but they lack the conceptual tools necessary to orient the research questions and design ways to interact with data. Analytical frameworks as well as conceptual frameworks are seen as tools to facilitate a more fluid relationship between theory and data in the process of data analysis. This workshop aims at first helping doctoral students share their own theoretical frameworks at the stage they feel they are in their development and engage into clarification of what theoretical, conceptual and analytical frameworks mean. Secondly, the workshop aims at providing participants some strategies that can be used to develop an analytical framework based on examples coming from my own research on experience narratives in science learning in multilingual contexts.

Workshop 6: Design-based Research: Developing, Implementing and Evaluating a Teaching Intervention

Koos Kortland  
University of Utrecht, The Netherlands

Thursday, June 6th, 16:00 – 18:00 & Saturday, June 8th, 16:00 – 18:00

A PhD-study might include something like “developing a teaching intervention”, and, of course, “assessing its effectiveness in a classroom trial”. Such a teaching intervention can be a sequence of lessons about a specific topic, or with a specific didactic approach, or both. Quite often, in the synopses for an ESERA Summer School this “developing a teaching intervention”, if present, is mentioned in just a few sentences as something to be done in future – sometimes labelled as “design-based research”.

This workshop deals with the question of how to develop, implement and evaluate a teaching intervention with sufficient didactical quality: what has to be done before development even starts, what choices to make in the development phase, what to do during the implementation or trial phase, how to assess the effectiveness of the design in the evaluation phase – and what to do after that? Or, in short: what does design-based research look like in practice? We will try to (partly) answer this question, as much as possible based on the ideas workshop participants already have about this part of their research project.
Workshop 7: Writing for academic journals

Mehmet – Fatih Tasar
Gazi University, Turkey

Thursday, June 6th, 16:00 – 18:00 & Saturday, June 8th, 16:00 – 18:00

Writing for academic journals In this lecture I will give examples of doing and reporting a literature review and thinking about limitations of a proposed research study in science education. I will also talk about the meanings of terms such as assumptions, implications, recommendations, suggestions, findings, results, and conclusion regarding a research study. A research study begins with identifying research problem/questions which is/are to stem from existing literature base. Researchers need to think about ‘how and in what ways a proposed study is going to make a contribution to the literature.’ That requires knowing/identifying the gap(s) in the literature. Applying a known method (perhaps from another field) to an old problem in order to solve methodological problems may help. Also, finding out a new field of observation that will test an existing theory and/or its assumptions could make an original contribution. More dramatically, one can invent a totally new method (or modify existing methods) in order to fine tune for the requirements of a proposed study can prove originality. This can eliminate the limitations stemming from previously applied methods. The process leading to a publication proceeds with data collection, data analysis, drawing findings, interpreting findings, and reaching results based on the research problem/questions that was set in the beginning. Leading journals have strict criteria for reviewing and improving articles before they qualify to be accepted for publication. The first criterion is the significance of the research problem/questions and the contribution to the literature. Handling of all the phases of a research study in a sound scholarly manner is also deeply scrutinized by the editors and reviewers. Authors need to show a high level of scholarship in interpretation of findings in reaching their conclusions.
1. The synopses were not corrected by the editors of this booklet. Authors of the papers are responsible for their quality, using appropriate references and grammar.
Aristotle

Mentors: Lucy Avraamidou, Mathias Ropohl
Educational Robotics and Interest in STEM

Georg Jäggle

Vienna University of Technology, Austria

Abstract

There is currently a lack of interest in STEM subjects at schools and universities though there is an increasing demand for STEM staff in Austria. Educational Robotics has proven to be a valuable tool for practical learning, not only of robotics but also of STEM topics in general. The robotic project will engage 1800 secondary school students over the next four years. The robotic workshops will allow participants to familiarise themselves with the world of robots and will foster their creativity and collaboration skills. Equally important is to increase the interest in STEM and self-efficacy of the students during robotics workshops for increasing the chance of a STEM career. The didactic design includes both constructivist-oriented and instructionism-oriented approach. A comprehensive quantitative and qualitative assessment of all workshops are to be used to review the goals.

Educational Context

The project’s didactic design and teaching materials are intended to alert students to STEM topics. The project takes a constructionism approach using educational robotics, and the workshop sessions are split into instructive and constructive parts. The students learn during hands-on activities that enable them to programme and/or design a robot. At the end of the sessions, they present their artefacts to the workshop group. The goals of the workshops are to foster collaboration and creative skills and to increase interest in STEM fields. Several factors influence young students’ interest in STEM careers. Students tend to be more motivated if they engage in hands-on activities in STEM fields. Role models, such as teachers or workshop tutors, also influence students in pursuing STEM careers. Finally, students with more interest in STEM and high self-efficacy are more likely to choose STEM careers (Bandura 1994). The goals of this project are to increase interest in STEM subjects, increase self-efficacy during the workshops, provide students with role models, and motivate them with hands-on activities. The workshop success in achieving these goals will be assessed using questionnaires before and after the workshops. (The IET 2008) (Stager 2010).

Key terms


Relevant Literature

Several institutions started projects with campaigns to interest students in science, technology, engineering and math (STEM). In most European countries interest in the STEM field is declining. However, more than 800,000 technology posts will be unfilled by 2020. Lower-level positions will require higher-level STEM knowledge and competence. This mismatch between demand and supply for qualified STEM professionals in the European Union, combined with a decreased interest in STEM studies and careers, is the result of low graduation rates in the STEM field. The problem the European Union faces is the growing gap between recruitment for the STEM sector and the declining number of STEM graduates. Multiple research studies show a growing
disengagement among young people with STEM subjects in school. The number of STEM enrolments and graduates in Europe has been declining in recent years—from 24.3% in 2002 to 22.6% in 2011 according to Eurostat (Joyce 2014). A study from 2016 explicitly details secondary-school pupils’ opinions about the STEM industry and associated careers (Kudenko 2016). The researchers tried to measure the level of pupils’ interest in and enjoyment of science, mathematics and technology in and out of school. They ascertained that while more than 70% of the pupils were interested in science and technology, just 60% of the boys and 44% of the girls stated that they were learning science and technology. This reveals that pupils’ primary exposure to and experience with STEM is in school. Therefore, policy institutions offer several international co-operation endeavours to learn more about the STEM disciplines in modern ways. The realm outside of school is rife with opportunities to increase the interest of young pupils in STEM. Pupils’ social view and personal understanding of the relevance of STEM as a career are also factors that play a role in cultivating interest in STEM. (Kudenko 2016). There are several factors that positively influence interest in STEM. Increasing the students’ self-efficacy through more practical, hands-on lessons and establishing a good relationship between teachers and students will foster learning and will give students a feeling of success. It is necessary to coordinate in- and out-of-school activities with shared spaces for the different disciplines of STEM, and it is also advisable to implement constructionist activities in those shared spaces to allow the students to express their results and ideas in and outside of classrooms. These factors were applied in the activities of robotic workshops to increase the students’ interest in the STEM field.

**Research Question**

This study examines the following main question:

How do robotic workshops influence students’ interest in STEM?

Further questions include:

What do students learn during the workshops?

Which factors are necessary to increase the interest in STEM during the robotic workshops?

What does a useful evaluation tool need?

**Methods**

This study employs a mixed methods approach to evaluation, as well as a case study approach. Each activity can be evaluated on a case-by-case basis, which allows the activities to be analysed in depth (Baxter 2008). Each evaluation provides data on students’ engagement in the workshop concerning age, gender and nationality. This allows practice examples to be identified which can be used for further political decisions and activities in robotic workshops in the future. Evaluations are obtained through multiple data sources, such as questionnaires, group interviews, observation sheets, reflections, and learning artefacts. The evaluation process starts with questionnaires at the beginning of every workshop. Every student is anonymised with an ID number and fills out a questionnaire. Every project partner designs their workshop plan, which will include several activity blocks and takes 4 hours. Our workshops in the first project year start with an activity block, which is named “Lecture about robots” and has an instructionism-oriented approach. After that, all other activity blocks are based on constructivism-oriented approach. They are named “Explore a robot”, “Program a robot” and “Technical inner life of a robot”. During the workshops, an observer takes pictures with cameras about their learning artefacts. The tutors observe the activities and record their observations on a dedicated sheet. After the workshops, the students fill out another questionnaire and tutors conduct interviews.
with focus groups. The tutors fill out reflection sheets after the workshop. (Girvan 2018) The data analysis is divided into two fields – quantitative and qualitative data. The quantitative data from the questionnaires will be analysed with SPSS 25 software program. The questionnaires at the beginning of the workshop provide information about gender, age, job plans for the future, interest in STEM, and prior experience with educational robotics. The questionnaires after the workshop provide information about how the workshops foster collaboration skills, influence interest in a STEM career, provide role models, increase the student’s self-efficacy and motivation. The tutors’ reflections provide information about the workshop’s design and possible changes for the next workshops. The qualitative data from the interviews, tutors’ observation sheets, and photos will be analysed with Maxqda Software 2018. All data will be analysed based on the approach of design-based research (Baxter 2008) and mixed method (Leech 2009).

Results
At a previous project, as a pilot project for this project, were evaluated 388 students during robotic workshops at the Automation and Control Institute at the Vienna University of technology. The evaluation design of this previous project was similar to the evaluation for this project and the Questionnaires before the workshops reported that 31% of the participant had ever built a robot before. The Questionnaires after the workshops showed that 57% of the students answered with “Yes” at the statement “I am now more interested in studying science.”, 83% answered with “Yes” at the statement “I would like to do more activities like this one”. 83% of the students answered with “Strongly agree and “agree” at the statement “Working with robots was interesting” and 70% answered with “Strongly agree and “agree” at the statement “Working in a team was interesting.” These results show the positive influence of robotic workshop. The next evaluations will report more about self-efficacy, creativity, role-model, learning outcomes and the activities during the workshops.

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Knowing Failure: Understanding Students’ Perspectives on Failure in Science

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Problem and Purpose
Science, as an endeavor, always strives to go just beyond the understood into the realm of what is unknown and often what is thought to be impossible. In the pursuit of scientific understanding, we should be preparing our post-secondary students to think like scientists, not simply absorb science content. Understanding the effect of the values of science on learning science could potentially revolutionise the way in which science is taught, learnt, and acted upon by students as citizens and future policy-makers. Whilst science as a discipline implies an understanding of the values inherent to science agreed upon by members of its community, science education does not adequately communicate these values such that learners at the periphery of this community experience these values explicitly.

The value of science of particular interest in this study is that of failure. Many scientists regard failure as being inherent and integral to the processes of science (e.g., Firestein, 2015; Simpson & Maltese, 2017) and yet it is not given any attention in science education (Tawfik et al., 2015). Failure, according to this researcher, is not simply an outcome but an experience – one that involves both the thought processes leading up to a recognition of an unexpected outcome, and the response to that particular outcome. Given the unique position of undergraduate students as leaving the culture of education to enter the culture of science, an understanding of the values of science may be what determines whether they make that transition successfully or whether they choose not to pursue the discipline. In particular, lab courses designed to allow for students to participate in inquiry create more spaces for students to engage in more authentic practices of science, where values such as failure more easily manifest – as compared to lecture settings. As such, looking at how students perceive failure in inquiry labs could potentially allow us to see how we can construct more positive experiences of failure for students such that they learn to respond to future failures through the lens of science rather than the lens of assessment.

Review of Literature
In combing the science education literature on the topic of failure, a preliminary grouping of the articles by the content matter became possible. For the most part, literature in failure situates itself within the attributional research in motivation, in failure-based learning pedagogies within math and science education (e.g. Tawfik et al., 2015); couched implicitly within the language of “persistence”, “grit” and “resilience” literature (e.g. Maltese & Tai, 2011; Duckworth et al, 2007); and railed against in historical documents of educational reform (e.g. DeJarnette, 2012). A few articles exist that discuss
the role of failure in the development of STEM professionals (e.g. Simpson & Maltese, 2017), but only two studies were found to involve students discussing failure (Demirci Guler, 2013; Estabrook & Couch, 2018), and these were both conducted with secondary students. Failure has been conceptualized in many ways (as low-achievement, as incorrect solutions, etc.), the often implicit definition revolved around some measure of assessment, and even then defined by its opposite – as a lack of success in achieving a definite end.

A few articles in the undergraduate inquiry literatures showed how true inquiry experiences also facilitate students’ experience of failure as learning experiences. Kazempour and colleagues (2012) found that through inquiry, students came to realize that failure experiences were expected in science, and this led to the understanding that science is not a linear process, but iterative. Russell and colleagues (2015) shared a prime example of this with their discussion of the Ecology student who, after correctly identifying their organism, received from their Biology partner a completely different identification based on DNA analysis. The investigative nature of the project allowed the student to use the tools they had learnt to discover that their organism had been infested by another - leading to other ecological concepts of complex species interaction (going beyond just the goal of the project as identification of local organisms).

Not only is there a different definition for failure in difference situations, we have also not studied the student perspective on failure. Especially given the discrepancy between how failure is utilized in science and how failure is conceived of in relation to assessment-oriented education, understanding students’ conceptions of failure provides a wholesome view of what students gain from science education. Obtaining the student perspective could study whether students are able to utilize failure in science learning in the same way that scientists say that they do (Estabrooks & Couch, 2018; Simpson & Maltese, 2017) and how they conceive of failure in science. As such, the research questions that developed revolved around ascertaining the student perspective of failure. Combining that with the experiences we expect collegiate students to have of the discipline of science, led me to also ask about how failure plays a role in lab settings.

**Research Questions**

1. What are university students’ perspectives of failure in science and science education?
2. How do university students’ perceptions of failure in science education impact their understanding of the discipline of science?
3. What experiences in the inquiry laboratory environment cultivated an understanding of the role of failure in science?

**Research Design and Methods**

Participants. This pilot study was conducted in the laboratory course associated with an introductory biology course for science majors in a doctoral university of highest
research activity (according to Carnegie classification) in the Southeastern United States. All students in the course pursued degrees in the sciences \((n = 16)\), of which, half consented to participate in this project \((n=8)\). While the lab section was randomly selected, the lab course was purposefully chosen due to emphasis on inquiry methods.

**Methods.** This study utilizes qualitative inquiry, using observations and interviews to elicit student perspectives of failure. Students enrolled in the class were observed in the laboratory setting, with each aspect of their laboratory experience analyzed through the lens of the processes of science inherent in each aspect – from pre-lab assignments, to in-lab discussions, to post-lab assignments. The main tool of data collection are semi-structured interviews, chosen for the reason that a few questions would lead students to expand on their understanding of failure, but their responses would then lead to and by clarified by further questions. An interview protocol developed by the researcher included observations from the laboratory setting. The interviews ran from 30 minutes to 90 minutes. Responses from the interviews underwent thematic analysis (Braun & Clarke, 2006) by a single researcher, coded both inductively and deductively to arrive at general themes. The exploration of those themes involved commonalities across the dataset as well as a more nuanced account of more interesting themes. The theoretical frameworks guiding both the design of the research and methods are that of constructivism and interpretivism (Schwandt, 1994). Constructivism addresses the sense-making processes whereby students develop an understanding of what it means to fail in science. Within constructivism, interpretivism best describes the process of meaning-making that students develop around failure and their experiences both as students and as observers of science. The inclusion of the laboratory setting is underscored by the knowledge that science learning is situated (Lave & Wenger, 1991).

**Preliminary Findings**

Data from interviews conducted yielded over 100 inductive codes (for example: “scientist knowledge vs. public knowledge”; “learning for learning’s sake”; “effort above result”). These codes were then categorized using inductive and deductive groupings (an example of the latter: “communication”; an example of the former: “effort”), from which emerged particular themes. Three of the themes are presented here and organized by the research questions they addressed:

1. “Failure” most often translates to a lack of proper communication of understanding from expert to novice learner: Students also described failure in science as a lack of progress

2. Emotional associations with failure in science education impact the depth of analysis of failure in science: Several students believed that early academic and non-academic failure experiences in life better prepare students to deal with failure in science education and understand failure in science
3. Aspects of collaborative inquiry and how “mistakes” can be mitigated in true collaboration can be understood in laboratory settings: Students said that the lab setting was most closely associated with how scientists practice science both in the division of labour and in the dynamics of support.

**Significance**
While so much of the language around education is achievement oriented, this does not accurately portray the values of science. Science, as an endeavor, seeks to understand, and that can be accomplished even through failure. If the goal of science education is to introduce students to the culture of science, to inculcate them to the ways of scientific thinking, understanding the role of failure as an inherent value of science should be one of the goals of science education, from primary grades to post-secondary grades. As science education researchers often bridge the gap between science education and science, we should study the extent to which the values of the discipline of science translate into the teaching and learning of it. This may entail reframing how students experience failure to enable more constructive failure experiences in the classroom. In renegotiating the role of failure in science education, not only do we add to the literature in educational research, but we extend the arm of science to become a more inclusive environment and more representative of the world it studies.

**References**


If you were to think of a scientist, you would most likely imagine a Caucasian male, with glasses and facial hair. He would be wearing a lab coat and working with some sort of chemistry equipment. This is also the predominant picture depicted by children when asked to draw a scientist (see Finson, 2002). Chambers’ (1983) Draw-A-Scientist Test (DAST) showed that this popular portrait was developed during second and third grade. Due to its simplicity, DAST has been one of the most used instruments to examine especially children’s conceptions and views about scientists and science (see Finson, 2002). Draw-a-picture approach has been proved rather versatile tool for researching student’s conceptions. In addition, draw-a-picture assignments have been used to study for example students’ conceptions of science learning (e.g. Hsieh & Tsai, 2018), assessment (e.g. Brown & Wang, 2013) and use of ICTs (e.g. Selwyn, Boraschi, & Özkula, 2009). However, the DAST has also received fair amount of critique for example about the interpretations, the children’s ability do draw and present their conceptions through drawings (e.g. Ehrlen, 2009; Reinisch et al., 2017). Therefore, researchers have modified DAST to improve the reliability and to better suit their research questions (e.g. Finson et al., 1995; Symington & Spurling, 1990, Walls, 2012). At the same time, many researchers have voiced the importance of this field of study and stated that new methods should be explored (Farland-Smith, 2012; Finson, 2002; Reinisch et al., 2017; Schibeci, 2006).

The image of a scientist has been strongly influenced by media and popular culture through times (Basalla, 1976; Türkmen, 2008). In movies and comics we see scientists presented in numerous ways, but more often than not, these images do not present scientists or the work they do and even adults have distorted or false images of scientists (see Reinisch et al., 2017). At first it may seem harmless, but the stereotypical picture affects attitudes and preconceptions about science and scientists (see Finson, 2002) and these attitudes impact on the attention given to learning or even teaching science (Christidou, 2011; Kind, 2016). In addition, the stereotype also contributes to self-image, locus of control and self-efficacy (O‘brien, Kopala, & Martinez-Pons, 1999). As the stereotype paints a negative image of a scientist as a lone genius who has nothing but his work, someone possessing this kind of image is unlikely to participate in science courses or pursue scientific career (Finson, 2002; NSTA, 1992). The aforementioned negative attitudes can be seen in several studies. For example, in a recent study by Kärnä, Hakonen and Kuusela (2012) Finnish secondary school students acknowledged the importance of natural sciences, but at the same time they consider physics and chemistry off-putting. Jenkins and Nelson (2005) had similar results when studying students views about science lessons in English secondary schools. The images and attitudes form
already in primary school (e.g. DeWitt & Archer, 2015), and they continue to exist through high school (e.g. Rahm & Charbonneau, 1997). Therefore it is important to address these stereotypes at an early age, and therefore we must have a more accurate understanding about the preconceptions and attitudes people possess (e.g. Campbell et al., 2016; Farland-Smith et al., 2012). Furthermore, researchers have underlined the need for systematic studies linking conceptions and attitudes with science interventions, curriculum, social and cultural aspects (Cakmakci et al., 2011; Christidou, 2011).

To address the critique and to expand the field of study, we have developed an alternative method for studying the children’s conceptions and views about science. The Draw-A-Science-Comic test is based on the DAST, and the goal is to maintain the positive aspects while addressing the negative issues regarding the test. The participant is asked to draw a comic about how science is made and the comic is then analysed for different elements such as appearance and scientific activity. The effectiveness of creating a comic for data collection stems from the ability to tell a story through a combination of words and images (Kuttner, Sousanis, & Weaver-Hightower, 2017). In respect to text or a single picture, the comics can be described as multimodal and they offer a wider array of modes of communication (Kress, 2010). It is something that allows the children to express in detail how scientists work, what kind of thought processes are involved, and what kind of interactions they have with possible colleagues. The aim is to offer a more in-depth view about children’s views and attitudes about science and to help us understand why they are not interested in science and scientific careers.

**Research plan**

The research consists of four studies and the goal is to develop the test further with each study. First we need to establish the reliability and the validity of the study. Then we develop the test with different command prompts which help us to focus on different school subjects (physics, chemistry, biology etc.) and different aspects of scientists and their work (appearance, location, activity). Finally we conduct a nationwide study in elementary schools in Finland where we focus on dominant views, how they affect the attitudes and how they evolve or change during different grades.

**Study 1: Introducing and testing of DASC**

The data has been gathered and the manuscript is currently under review. We gathered over a hundred comics from children aged 8-13. From these comics we evaluated what kind of image the children convey and how they portray scientists, their working environment and their work. The method proved to be effective and allows us to examine thought processes, social interactions, emotions and much more. For example, one of the comics illustrated how scientific experiment can fail causing anger and frustration, but talking to a colleague will help through hardships. In the end the hard work is paid off. However, some issues remain as with DAST and modified DAST, but it seems to give an advantage in regards of scientific activities and attitudes.
Study 2: Comparing to other formats
The study 1 had a slight issue of fictive characters which might be caused by the word comic. Furthermore, it may invite to draw more silly or unrealistic elements like explosions. Therefore, the next step is to study alternative formats for comic, such as a story or a set of picture. Most of the data has been already gathered but some groups will participate in the beginning of 2019. Preliminary results show that the story format invites to write more explanations but at the same time they express less activities and interactions. The set of picture method proved quite difficult and many participants felt frustrated and anxious. Although it gave a small advantage comparing to comics, it is not suitable for the youngest participants.

Study 3: Focusing on different school subjects and aspects with the prompt
Many studies have shown that particular school subjects are seen as negative in many aspects. Therefore, it is important to focus on different subjects and how they are seen. Thus, we can focus on specific issues within a subject and compare similarities and differences. Most interesting is the comparison between physics and biology. According to Kärnä et al. (2012) most students see biology in a positive light whereas physics is seen as a rather negative subject.

Study 4: Creating an evaluation tool
From all the data gathered so far, we create an evaluation tool for the DASC. The idea is to strengthen the reliability and validity of the test and to enable comparison between different studies. Similar system has been used with DAST and it has been proven very useful (e.g. Farland-Smith, 2012). If needed, further data is gathered in order to create a comprehensive spectrum of illustrations and views, and their impact on attitudes.

Study 5: A nationwide study
Last but not least, is to utilize the created evaluation tool to conduct a nationwide study in Finland. From all provinces the largest 5 cities are included and every elementary school is contacted and asked to participate in this study. As the assignment is done as a part of art class, we have seen that teachers easily participate in this study. The end result is what sums up the whole research: a comprehensive analysis nationwide about what kind of views children have, how they affect the attitudes and how this differs regionally. By understanding the underlying factors, we are able to offer solutions and proposals to address issues regarding the interest and the attraction towards scientific subjects.

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Cookbook Inquiry Based Science Education

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Focus of Study
The importance of guidance from the teacher in inquiry based settings is stated in literature (Kirschner, Sweller, & Clark, 2006). The nature of inquiry based science education (IBSE) and the constructivism embedded in this way of facilitating learning is balancing between the children led or teacher led activities. The question to ask is not just how much guidance but also the quality of the guidance the teacher offers must be unfolded. The aim of present study is to explore how guidance from the teacher fosters two central elements in IBSE 1) procedural learning and 2) conceptual learning. Procedural learning indicates the children’s understanding of the process of IBSE. Conceptual learning refers to the knowledge connected to the scientific topic. Procedural learning is a core element in IBSE and is a main factor that distinguishes IBSE from traditional science education, while the children are engaged in asking questions and decisions about how to explore the problem. A critique of IBSE is that emphasis on procedural learning entails lack of conceptual understanding. Both procedural and conceptual learning is taken into account while both elements are desirable to achieve. Obviously continuity and progression in learning in educational systems is a goal. A goal which is hard to achieve in education when it includes a transition from one institutional context to another (Little, Cohen-Vogel, & Curran, 2016). One suggestion to bridge the gap in lack of coherence in transitions is IBSE activities before and after the transition, this requires the teacher’s awareness and cooperation on alignment in procedure and topic.

Review of literature
IBSE is widespread around the world and is implemented in varied versions in diverse settings (Alake-Tuenter et al., 2012; Furtak, Seidel, Iverson, & Briggs, 2012; Minner, 2010; Pedaste, 2015; Rönnebeck, 2016). Dewey (1933) outlined early a framework of IBSE by dividing important aspects into defining problem, formulating hypothesis and conducting test. Later these aspects are elaborated into phases. Varied inquiry phases and cycles is identified in literature. The approach to learning inquiry is to be found from the work of Jean Piaget, Lev Vygotsky and David Ausubel. Their theories are merged to what is now labelled constructivism. The inquiry based and with it constructivistic approach emphasises that the construction of knowledge is created by active thinking in each individual in interaction with the social context and scientific objects (Minner, 2010). The definition of IBSE current paper draws on is based on Pedaste (2015) who identified five distinct general inquiry phases: Orientation, conceptualization, investigation, conclusion and discussion.
The phases investigated in present study are orientation and conceptualization. Orientation focuses on stimulation curiosity related to the problem, the teacher, the environment or the pupils introduce the topic. Variables are identified and the result is problem statement. The phase of conceptualisation is divided into two sub-phases 1) the process of generating research questions 2) hypothesis generation. Conceptualisation phase offer pupils the opportunity to put procedural skills and conceptual understanding into play.

Most studies indicate that communication is essential in IBSE both regarding understanding of scientific concepts and scientific procedures, this is not restricted to specific stages of inquiry (Rönnebeck, 2016). Teachers and pupils look back to and reflecting dialog about last time the topic was on the blackboard is essential in the aim of creating continuity in educational settings after a transition. The concept of transition is broadly used describing a process of moving from one context to another. The importance of a positive transition to school is widely acknowledged and much attention has been directed to transition programs (Huser, Dockett, & Perry, 2016).

In IBSE active reflection from the pupils are essential. To foster pupil’s reflection and active participation in IBSE activities, the teacher’s way of guide the phases of IBSE and conceptual knowledge is important. Repetition and retrospect at IBSE activity could maybe offer recognition in both content and structure in a new context after transition.

Research question

*How do teachers qualitative guide young children’s development of conceptual and procedural learning in inquiry based science education in orientation and conceptualisation phases within and after preschool class by repeating the topic plant processes? How can such coherent process ensure continuity?*

Research design and methods

This paper is a part of a lager project concerning how IBSE in eye level in early childhood may support transition. The research design in the intervention was action research. Aligned with constructivism, action research supports the view of learning and development as a social construction. In action research all stakeholders contribute and learn from each other. The combination of action and research gives the opportunity to try out new strategies and carefully; observe, reflect and measure the outcomes (Johnson & Christensen, 2008).

The project “Science at children’s eye level” took place over eight months in two phases. One case considered one kindergarten, one preschool class and a first year of primary school and their science teachers. In total three cases participated in the project. The children involved are from five to eight years old. Three IBSE activities are conducted in each of the two phases. The teachers participated in workshops in between each IBSE topic.

Nevertheless the purpose in current paper is to investigate the quality of teachers guiding of pupils procedural and conceptual learning in an IBSE context.
The IBSE phases orientation and conceptualisation defined by Pedaste (2015), are in most cases the moment where the teacher setting the scene, this moment is crucial in the considerations of balancing the degree of guiding in the IBSE activity. These phases are those investigated. This study embodies 40 children and 4 teachers. Data are collected during plant process activities in classroom from preschool class spring 2017 and after the transition autumn 2017 in first year primary enabling the same children to be followed across the two settings. The classrooms are video recorded and group work situations are audio recorded. Author am participating and supporting the real teacher. After each phase a semi structured group interview was conducted with the children. Size of the groups varied from 2 to 6 children. Interviews were video recorded.

Analysis
A directed qualitative content analysis (Hsieh & Shannon, 2006) is conducted. Material used in present paper is focused to adress situations where teachers guiding the children. Child – teacher dialog episodes in the activities are selected and labelled “dialog”. Transcriptions of dialog episodes are conducted. Interviews are fully transcribed. Transcribed materiel is coded inspired from van Uum, Verhoeff, and Peeters (2016) in following themes i) conceptual understanding, sub coded; positive conceptual understanding and negative conceptual understanding ii) procedural understanding iii) Teacher questions, sub code; children answer. iv) Children’s question. In phase 2 v) recognition and ix) no recognition, are added. After coding “dialog” episodes are compared to find any patterns regarding to (un)successful pedagogical guiding. Data from interviews underpin finding in data from the activities.

Preliminary Findings
The aim of this paper is to explore the quality of teacher scaffolding children’s conceptual and procedural learning. The preliminary findings indicates that the children had a satisfactory learning output regarding conceptual learning, but regarding procedural understanding the result is 0. This is a stark contrast to 60 questions stated by the teacher. Phase 2, everyone except one remember the plant process activity. These findings indicate that running an IBSE lessons and rely on the inquiry model as a recipe is insufficient. In that case we end up having a cookbook inquiry and forget the constructivism embedded. Instead of using IBSE phase to a framework to improvise within is seems to be a tight program to follow with low degree of possibility to active reflection for the child. The teacher needs knowledge and experience about the importance of the nuances and quality in each phase. The teachers in the project really tried hard, but “real” inquiry is not easy to implement and it takes time to learn both regarding children and teachers. The teachers play a crucial role in the way they facilitate IBSE in the educational system.
References


Investigation of the impact an innovative approach on Turkish middle school students’ understanding of scientific inquiry

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Subject / Problem
In the era of the knowledge evolution, where every unit of knowledge is subject to change in each minute, societies need a constant change as well as in educational policies. Especially since the beginning of 1980s, the work life has been changed in order to meet the demands of the New Era, business leaders; whom are increasingly asking schools to develop specific skills on students those who can easily adapt rapid changes of global world; become quick and rationale decision makers, such as problem solving, critical thinking, communication, creativity, collaboration—often referred to as “21st century skills” (NRC, 2012; Tucker, 2014). Some scholars also include “scientific inquiry” (SI) to the list of 21st century skills, since it is considered as an anchor for complex thinking processes within its investigative nature, which requires the learners to solve a problem or to answer a question by carrying out investigations. As known, the development of adequate SI views on students’ in conjunction with the adequate understandings of the NOS and its’ historical background (HOS), would lead the students to achieve another ultimate goal of contemporary science education curriculum in many different countries, namely “scientific literacy”. Despite the changes and reforms, many countries -including Turkey- still suffer from inadequate SI levels (Lederman, 2017), scientific literacy (please see recent PISA results) and low individual or collaborative problem-solving skill levels (OECD, 2014; 2017) according to international assessment test results. In this vein, instructional designs require a paradigm shift and a need for different innovative instructional strategies to be embedded in the curricula emerges. One of these strategies in the literature recommend the complex skill & content integrated teaching that includes more inquiry-based intertwined approaches with content and problem-solving strategies coherent with 21st century skills that is considered essential since they are appraised inseparable and to be developed concurrently. Yet, the effectiveness of these contemporary inquiry strategies should be investigated (Chinn & Malhotra, 2002) and should be tested since these kinds of integrated instructions are a blur area especially in terms of middle school children (Gibson & Chase, 2002). Therefore, based on the need of such designs and testing their effectiveness, we generated an innovative way to acquire problem solving skills and to improve students’ SI understandings as well as their creativity by utilizing inquiry-based learning (IBL), problem-based learning (PBL) approaches combined with history of science (HOS) approach and content acquisition, namely complementary PBL&HOS approach. Therefore, the ultimate aim of this proposal is to investigate the effectiveness of the proposed complementary PBL & HOS approach interventions upon groups of middle
school students’ (5th, 6th, 7th graders), whose age ranges are in between 10-13, understanding about SI.

Methodology
Methodology of the study is basically designated as two-group pretest–posttest quasi experimental design, since the main purpose is to investigate the possible impact of an intervention. Yet, the research design is also determined as mixed-method research and explanatory design, as the growing body of literature points out the importance of combination of qualitative and quantitative data collection would result in a more complete understanding of the progressive problem-solving abilities and processes which will lead us to investigate the whole process.

Participants
The participants of the study are n=207, 5th (n=78); 6th (n=54); and 7th (n=75) grade students (114 female, 93 male) selected from two public schools located in a small city of Turkey. To see the impact of complementary PBL & HOS design vs current curricula, students’ classes were assembled randomly with the assistance of the school’s science teacher, as treatment/intervention and controlled groups. The groups are consisting of:

- Treatment groups: 132 students (59 male / 73 female)
- Controlled groups: 75 students (34 male / 41 female).

Interventions
The interventions consist of the specifically designed lesson plans that are carefully combined with PBL & IBL approaches’ features, coherent with curricular content and HOS narratives, namely Complementary PBL&HOS approach. By these lesson plans, it is mainly aimed to assure meaningful content acquisition, lead them carry out investigations by practicing scientific practices (e.g. data collection, generating explanations, modelling, interpretation etc.) and to develop adequate views of SI on students and, ultimately to improve their problem-solving skills and creativity. The Complementary PBL&HOS approach was delivered to treatment groups as part of their middle school science class by the school science teacher with the assistance of the lead researcher. The interventions lasted for two semesters.

Data Collection & Analysis
In our study the one of the main quantitative data sources is designated as the Views about Scientific Inquiry -VASI (Lederman et.al, 2014) questionnaire. The instrument consists of 7 open-ended questions, where the questions corresponds one/two aspects of SI. Those aspects as Lederman et al. (2014) emphasized are as follows: (1) scientific investigations all begin with a question and do not necessarily test a hypothesis; (2) there is no single set of steps followed in all investigations (i.e. there is no single scientific method; (3) inquiry procedures are guided by the question asked; (4) all scientists performing the same procedures may not get the same results; (5) inquiry procedures
can influence results; (6) research conclusions must be consistent with the data collected; (7) scientific data are not the same as scientific evidence; and that (8) explanations are developed from a combination of collected data and what is already known. The instrument was administered as pre-test and post-test. Additionally, besides the post-test administrations all the students were interviewed, even though the recommended interview rate is about 20% due to the young age range of the students. The responses of the students were transcribed and used as complementary to their written responses. SI views of the students were categorized as informed, mixed, and naïve regarding to the procedure provided by Lederman et al. (2014). For instance, if the student provided a response consistent across the entire questionnaire that is wholly congruent with the target response for a given aspect of SI, they were labeled as “informed” And if the response is either only partially explicated, and thus not consistent with the targeted response, they were labeled as “mixed”. And if the student provides no evidence of congruence with accepted views of the specific aspect of SI under examination, was scored as “naïve.” After the coding procedures were completed, descriptive analysis results of the students were gathered via SPSS 25.0. Although only the descriptive analysis advised to be used by the instrument’s developers, basic inferential statistics are also used to compare the results’ significance regarding to interventions upon two groups.

**Preliminary Results & Discussion**

Due to limited space restrictions, only the small portion of preliminary results, which is the change on 7th graders’ SI views and the comparison among the groups could be provided. According to results, (please see Table 1, 2, 3), before the interventions of Complementary PBL&HOS approach, the SI states of the both treatment and controlled groups were mostly scattered on naïve category among the aspects, which is consistent with the relevant literature studies that descriptively investigate current SI understandings of 7th graders (Lederman et al., 2019; Dogan et al., in review; Hamed, Rivero & Jiménez, 2017). However, after the interventions substantial increases on informed category on both of treatment groups were observed, whereas almost no development occurred on controlled group’s informed category. Also, the change on treatment groups was found statistically significant across many SI aspects while only the change on one aspect (SI-8) was found significant of controlled group. In terms of SI views according to preliminary results the interventions were found effective to increase the number of informed students. Yet, the impact of the intervention on other groups and parts of the study are still being profoundly investigated concurrently as qualitative and quantitatively to support the arguments. The results -in progress- will be shared with the scientific community by the time study is completed.
### Table 1. Descriptive VASI results of groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Categories</th>
<th>SI 1 pre-test</th>
<th>SI 1 post-test</th>
<th>SI 2 pre-test</th>
<th>SI 2 post-test</th>
<th>SI 3 pre-test</th>
<th>SI 3 post-test</th>
<th>SI 4 pre-test</th>
<th>SI 4 post-test</th>
<th>SI 5 pre-test</th>
<th>SI 5 post-test</th>
<th>SI 6 pre-test</th>
<th>SI 6 post-test</th>
<th>SI 7 pre-test</th>
<th>SI 7 post-test</th>
<th>SI 8 pre-test</th>
<th>SI 8 post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>7C Controlled</td>
<td>naive</td>
<td>81.0</td>
<td>85.7</td>
<td>90.5</td>
<td>85.7</td>
<td>38.1</td>
<td>47.6</td>
<td>33.3</td>
<td>33.3</td>
<td>47.6</td>
<td>33.3</td>
<td>61.9</td>
<td>38.1</td>
<td>33.3</td>
<td>19</td>
<td>90.5</td>
<td>71.4</td>
</tr>
<tr>
<td></td>
<td>mixed</td>
<td>19.0</td>
<td>14.3</td>
<td>9.5</td>
<td>14.3</td>
<td>61.9</td>
<td>47.6</td>
<td>66.7</td>
<td>66.7</td>
<td>52.4</td>
<td>66.7</td>
<td>33.3</td>
<td>33.3</td>
<td>66.7</td>
<td>81</td>
<td>9.5</td>
<td>28.6</td>
</tr>
<tr>
<td></td>
<td>informed</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>4.8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<td>0.0</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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</tr>
<tr>
<td>7D Treatment</td>
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<td>64.3</td>
<td>89.29</td>
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<td>50</td>
<td>53.57</td>
<td>21.43</td>
<td>71.43</td>
<td>25</td>
<td>46.43</td>
<td>17.86</td>
<td>46.43</td>
<td>32.14</td>
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<tr>
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<td>35.7</td>
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<td>10.71</td>
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<td>35.71</td>
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<tr>
<td>7A Treatment</td>
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<td>65.4</td>
<td>69.2</td>
<td>53.8</td>
<td>76.9</td>
<td>38.5</td>
<td>61.5</td>
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</tr>
<tr>
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<td>46.2</td>
<td>50.0</td>
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<tr>
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<td>0.0</td>
<td>0.0</td>
<td>0</td>
<td>7.7</td>
<td>0</td>
<td>11.5</td>
<td>0</td>
<td>11.5</td>
<td>11.5</td>
<td>26.9</td>
<td>0</td>
<td>3.8</td>
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</table>

### Table 2. Inferential Wilcoxon Signed Ranks Test VASI Results of groups

<table>
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<th>Group</th>
<th>Z</th>
<th>Asymp. Sig. (2-tailed)*</th>
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</thead>
<tbody>
<tr>
<td>7C Controlled</td>
<td>-447*</td>
<td>.655</td>
</tr>
<tr>
<td>Group</td>
<td>-447*</td>
<td>.655</td>
</tr>
<tr>
<td>7D Treatment</td>
<td>-2.840*</td>
<td>.005</td>
</tr>
<tr>
<td>Group</td>
<td>-2.840*</td>
<td>.005</td>
</tr>
<tr>
<td>7A Treatment</td>
<td>-2.530*</td>
<td>.011</td>
</tr>
<tr>
<td>Group</td>
<td>-2.530*</td>
<td>.011</td>
</tr>
</tbody>
</table>

*p value: in the 95% confidence interval

### Table 3. Mann-Whitney U Comparison for Treatment & Controlled Groups

<table>
<thead>
<tr>
<th>Scientific Inquiry Aspect</th>
<th>P value</th>
<th>Asymp. Sig. (2-tailed)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post test</td>
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<tr>
<td>SI-1</td>
<td>.245</td>
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<td>SI-2</td>
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<td>SI-3</td>
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<td>.589</td>
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<td>SI-4</td>
<td>.099</td>
<td>.033</td>
</tr>
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<td>SI-5</td>
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</tr>
<tr>
<td>SI-6</td>
<td>.171</td>
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<tr>
<td>SI-8</td>
<td>.683</td>
<td>.036</td>
</tr>
</tbody>
</table>

*p value: in the 95% confidence interval
References
Dogan et al., (in review). Middle school students’ understanding of scientific inquiry: An investigation of gender, grade level and school Type. *PAU Journal of Education*
National Research Council (NRC). (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century*
Plants aren’t that boring...

Amélie Tessartz

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Introduction
Various studies show a lack of learners’ interest in plants (e.g. Elster 2007; Wandersee 1986). Wandersee & Schussler (1999) even introduced the term ‘plant blindness’, which describes the inability to see or notice plants in the environment, to recognise their importance for the biosphere and to appreciate their aesthetic and biological properties. If people are not interested in plants their willingness to preserve their biodiversity will be low (see Leske & Bögeholz 2008). Therefore, it is important to enhance student’s interest in plants, in order to make a contribution to environmental education. As it has been shown that out-of-school experiences support learners’ interest in nature (Kals, Schumacher & Montada 1999) the aim of this PhD project is to investigate how out-of-school learning environments should be concretely designed to foster learners’ estimation and enhance their interest in plants.

Theoretical background
Interest, as a motivational precondition for learning, plays an important role in education (Schiefele 2001). According to the Person-Object-Theory of Interest (POI; Krapp 1992), interest is conceptualised as a relation between a person and an object: this object is not necessarily a concrete object it can also be a topic or activity. Three different aspects are characterising this relation and thus the interest – knowledge, emotions, and value: An interested person wants to learn more about the object (knowledge), has positive feelings, e.g. fun, during the interaction with the object (emotion), and recognises its importance in a personal or social context (value). The more a person is interested, the more these three aspects are pronounced (Krapp 1992; Hidi & Renninger 2006).

We can differentiate two types of interest. Situational interest can arise as a result of an interaction between a person and an object and always depends on the specific situation. Through multiple interactions an individual interest can emerge. It is a strong and long-lasting form of interest and not linked to a specific situation anymore. In the educational context it is specifically important to enhance learners’ situational interest, as the development of an individual interest for every topic and every child is not possible (Krapp 1992; Hidi & Renninger 2006).

Research Question
How should out-of-school learning environments be designed to enhance students’ interest in plants? What kind of topics, activities, and contexts are appropriate?
Research design and methods
The project uses the Design-Based Research approach (DBR Collective, 2003), which has been specifically adapted for biological education research focusing on the development of learners’ interest (= PIB; Scheer (Scheersoi & Hense, 2015). This approach always starts with a perceived educational problem, in this case the learners’ lack of interest in plants. To investigate and solve this problem an extensive literature review about the emergence and promotion of interest was conducted, especially in connection with botanical topics. In addition, quantitative and qualitative methods were combined, in order to investigate students’ interest in plants: A questionnaire focusing on perceived interest-differences between specific types of plants (e. g. crop plants) was developed (see Urhahne, Jeschke, Krombaß & Harms, 2004). The gathered data (N=500, 10-18 yrs.) were analysed using the statistical software R (R Development Core Team, 2008). The Friedmann’s – ANOVA test with post-hoc analyses was executed in order to compare multiple groups of non-parametric depending data (Field, Miles & Field, 2012). In addition, qualitative data were collected through interviews (N=6) and participant observations (N>150) (Bortz & Döring, 2016) during educational programs (e. g. in a botanical garden) to find out about the reasons behind students’ interest or lack of interest. The transcription of the audio data was analysed through qualitative content analysis (Kuckartz, 2012) using the program MAXQDA. A self-developed coding scheme consisting of codes deductively derived from the theory and inductively derived from the data of the preliminary study itself was used. Based on the results, hypotheses were generated concerning the design of interest-enhancing learning environments.

In a second step, for formative evaluation, these design hypotheses will be tested on different groups of learners, by analysing the development of their situational interest during the specifically designed interventions (e. g. activity days; workshops, etc.). Similar to the preliminary study, qualitative data will be collected via participant observations during the interventions and subsequent interviews and analysed through qualitative content analysis. Based on this analysis, the design hypotheses will be gradually tested, refined or rejected in order to derive (i) research-based recommendations (i. e. design-principles) for the development of successful learning environments and (ii) to contribute to interest research regarding plant blindness and out-of-school learning.

Preliminary findings and Discussion
Although learners mentioned in several interviews that plants are “boring” and “not really interesting”, the questionnaire data show differences in interest between plant groups. For example, cherry trees, the Venus flytrap, and sunflowers are perceived as significantly more interesting than grass, lime trees or spruces (p<0,001). The qualitative data indicate reasons for these differences and the (lack of) interest in plants in general: Learners stated for example that plants are not interesting because “they don’t move” (interview; ♂ 12 yrs.), and “they all look the same” (observation during workshop; ♂ ~12
yrs.). However, plants “can be interesting if they have something special” (interview; ♀13 yrs.) and “if I don’t know them” (interview; ♂13 yrs.). The fascination with special features among plants has also been observed during several workshops e. g. in the botanical garden.

Moreover, plants that are used as food, for example cherries, spawn a great amount of interest (interview, ♂13 yrs.), as well as plants with aesthetic features, e. g. the colour of a sunflower: “They are so joyful” (interview; ♀13 yrs.) and “I like bright flowers” (interview; ♂13 yrs.).

Additionally, plants are regarded as interesting when they have perceived ecological or social relevance. Even “Boring trees” can turn into interesting plants as soon as their ecological context is perceived: “Actually, trees are so important! They are cleaning the air and especially they provide habitat for so many living beings” (interview, ♂12 yrs.). Plants with personal significance are also considered as interesting (interview; ♂13: “Grass is interesting because I ‘loove’ soccer and it’s played on grass.”).

Observations in science workshops have shown that the approach of inquiry-based learning is suitable for interest development in botanical topics. The interview data support this assumption: “I like to do practical work, I won’t fill out any worksheets” (interview, ♀13 yrs.) and “I would like to do some experiments with plants” (interview, ♂13 yrs.). Accordingly, the data indicate, that the level of interest can vary as a function of context and activity in which the topic is embedded. Based on the results of this preliminary study, about 20 design hypotheses for learning environments have been derived, for example: Out-of-school learning environments which are designed to support learners’ interest in plants should include practical activities (investigations; cultivating plants; usage of scientific and authentic equipment).

In the ongoing formative evaluation, this and numerous other hypotheses are currently tested. It has been shown for example, that cultivating plants, and the fact of having own plants, can enhance student’s interest: “Do we grow plants today?”; “Can I plant my own seeds?”; “Can I carry my plants home in the end?” (participant observations; ♂& ♀11 yrs.). But especially the scientific documentation during the cultivation-process (used seeds; sort of soil; dates of cultivation; dates of germination; amount of fruits etc.) was positively highlighted: “I liked the planting today. The soil was warm in my hands, that was nice. And I liked that we could do kind of an experiment within the planting. So we can find out what we can also plant at home. Because of my [documentation-] table I can see what kind of soil I can use and so on…” (interview;♀11 yrs.). We can presume that practical activities related to plants (e. g. cultivation) can stimulate students’ interest in plants but especially the scientific approach has an interest enhancing effect on learners.
Conclusion
Several reasons for interest and the lack of interest in plants could be singled out during the preliminary study. Special characteristics, contexts and activities which are more likely to enhance students’ interest in plants were identified. Based on these findings, different design-hypotheses for interest-enhancing out-of-school learning environments were formulated. These hypotheses are currently tested in specifically designed learning environments (activity days; workshops; etc.) in order to formulate concrete design principles which tent to enhance students’ interest in plants and which can easily be transferred into everyday practice.

To monitor the long-term effects of these out-of-school interventions, a group of learners (10-12 years old) will also be observed over a longer period of time (at least one year) as part of a longitudinal study.

References
Flipped Classroom – A research project between high hopes and lacking evidence

Lars-Frederik Weiß

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An overview – What is the project about?
Within the EU-project MEET-CINCH (Modular European Education and Training Concept in Nuclear and Radio Chemistry), novel education and training approaches are called into consideration to raise awareness for the field of physics and radio chemistry. The modern flipped classroom (FC) concept will complement the available tools for teaching and training in the nuclear and radiochemistry field. My research project regarding the FC consists of one theoretical and two empirical parts, as shown in table 1. In a first step an extensive literature review on the flipped classroom has been conducted. The review has not yet been fully completed, but already provides a deeper insight into the current state of research and allows first statements and implications for the empirical part. In a second step the lecture “Nuclei, particles, solids - Physics IV” at the Leibniz University of Hannover will be restructured and redesigned into a partially flipped classroom. As a third pillar, the flipped classroom approach will be implemented in physics classes in German high schools.

Figure 1: Structure of doctoral thesis

<table>
<thead>
<tr>
<th>Theoretical part</th>
<th>Empirical part</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensive literature research</td>
<td>Implementation and evaluation of the FC in a physics lecture in University</td>
</tr>
<tr>
<td></td>
<td>Implementation and evaluation of the FC in high school physics classes</td>
</tr>
</tbody>
</table>

Literature review
Most often, the flipped classroom approach consists of two different phases. Firstly, a self-studying phase in which students asynchronously work through materials provided by the lecturer or teacher. In most cases students work through video lectures provided by the lecturer/teacher. “The purpose of the before class activities is for students to increase their curiosity and motivation, and to highlight potential in-class difficulties or misconceptions in understanding the topic” (Limniou et al. 2017). Secondly, a so called presence phase in which students are engaged in active learning and solve problems requiring the use of higher order thinking skills (Bergmann und Sams 2013; DeLozier und Rhodes 2017; Bishop und Verleger 2013). Compared to passively received, traditional lectures, active learning forces the application of cognitively more demanding...
forms of learning and favors the development of critical and complex thought patterns (Prince 2004; Eichler und Peeples 2016).

“The flipped classroom method [...] has been very present in the discussion about modern forms of teaching for a number of years, also using digital media” (Werner et al. 2018). Subsequently the number publications on the flipped classroom approach is increasing rapidly, especially in the last two years (Talbert 2018). Even if at first glance the basic idea of the concept seems easy to understand – a shift of knowledge transfer into a phase before the actual classroom teaching and thus more time for active, pupil-centered learning in the actual classroom – a deeper look into the literature promotes an ambiguous situation with regard to a definition that makes it possible to distinguish the flipped classroom sharply from traditional teaching.

**Preliminary findings of the literature review**

On the one hand, there are definitions that define the flipped classroom via technology and video lessons and thus define the flipped classroom as new and innovative; on the other hand, however, there are more open definitions that allow teaching concepts to be understood as flipped classrooms, which have probably been practiced for several decades. Looking at the findings from the research of the Flipped Classroom approach so far, it can be seen that a theoretical framework for design and implementation is missing. This confirms that subject didactics are only involved in the planning, implementation and, above all, evaluation of the flipped classroom in exceptional cases. This is particularly evident in the didactic design of the self-learning and presence phase. Learning goals, methods chosen and material used remain unmentioned in a dominating majority of studies. Since the research is not based on a common framework and the implementation of the flipped classroom is not described in enough detail and varies widely, studies conducted so far are hardly comparable. Nevertheless, “[d]espite differences among studies, general reports of student perceptions were relatively consistent. Opinions tended to be positive, but there were invariably a few students who strongly disliked the change” (Bishop & Verleger 2013). Adding to this, common advantages and disadvantages found in a number of studies have been analyzed and elaborated. Despite the enormous growth of the abundance of literature, especially in the last two years “[...] the flipped classroom still has exotic status in the German higher
education system, but especially in the German school system" (Finkenberg 2018). Therefore, didactic research on the flipped classroom is the exception in Germany as well as in Europe, especially in schools. Further research needs to be done on how the FC can be implemented not only in universities but also in school settings. Subsequently, the following research questions arise:

1. What theoretical framework was used in former research about the flipped classroom approach? If none, what is lacking?
2. How do lecturers’ concerns and expectations change during the process of implementation?
3. How does the flipped classroom affect learners’ affective characteristics?
4. How does the implementation in university differ from the implementation in high schools?

Preparation for the empirical parts
Semi-structured interviews have been conducted with members (N=4) of the MEET-CINCH project responsible for “novel education and training methods” prior to the design and implementation of the FC in different lectures within the MEET-CINCH project. The interviews have been analyzed with a qualitative content analysis according to Mayring (1994) to serve as a starting point to see what ideas and expectations, but also considerations and obstacles the individual participants associate with the flipped classroom concept. More interviews during the process of implementation and post implementation are planned to dive deeper into the expectations and concerns of the lecturers regarding the FC approach. The analysis of qualitative data, e.g. interviews, provides information on how the attitude of lecturers towards the flipped classroom changes during the implementation process. As a result of the interviews conducted and the literature research shortly presented above our goal is to accompany the design and implementation process of the flipped classroom in order to create a clear theoretical and comprehensible basis for the didactic research. Interviews and surveys with students in university but also in high school will counteract the current lack of qualitative studies being conducted on the flipped approach (Giannakos et al. 2018) and will give a detailed insight in students’ perception and affective attributes. The Institute for Radioecology and Radiation Protection is currently producing video lectures which will function as a means of preparation for the presence phases. The planning of the presence phases is far advanced. After the completion of the videos and the planning of the presence phases, the lecture will be implemented in FC format starting this summer semester. The didactic planning of the presence phases and the close monitoring of the implementation will provide an insight into how certain components of the FC are influencing affective characteristics like motivation, interest, expectation of success etc. of the students. With the aid of a pre-and post-test survey, mainly based on a Likert scale design and an SPSS analysis, these characteristics can be compared to a regular, non-flipped lecturing approach. Furthermore, the implementation in university and in schools will allow us to compare the achieved results to a certain degree and is planned in summer/autumn
2019. The comparison will allow us to make statements about the extent to which the implementation of the FC approach differs between university and school.

**What I expect from attending the ESERA Summer School**

By participating in the ESERA Summer School, I hope to gain input on how I can sharpen my research questions and how I can improve the approach of my main study. Furthermore, I hope to get a deeper insight into different measuring instruments to record and evaluate qualitative data, which would be particularly suitable for my empirical studies. Adding to this, I would like to know more about data triangulation, since my study will include different methods to collect data. I hope to broaden my horizon by discussing other projects and to derive ideas for my own study from them and to contribute suggestions to other projects.

**References**


Democritus

Mentors: Annette Scheersoi, Martin Rusek
Investigating upper secondary students’ difficulties in evaluating experimental data

Steffen Brockmüller

University of Duisburg-Essen, Germany

Outline
Students’ ability to engage in scientific inquiry has become a major focus of science education ever since it was made a distinct domain in curricula (KMK, 2005; NRC, 2012). Inquiry learning, i.e. the involvement of students in practices and thinking employed in science, has been discussed as a possible approach to fostering the corresponding competences (Ronnebeck, Bernholt & Ropohl, 2016). Typically, the ways in which scientific inquiry proceeds are interpreted as unique processes of problem solving (Klahr, 2000). This scientific problem solving is often referenced as scientific reasoning (Opitz, Heene & Fischer, 2017). It can be divided into three components: generating hypotheses, planning and carrying out investigations to test these hypotheses, and evaluating the collected evidence (Klahr, 2000; Vorholzer, von Aufschnaiter & Boone, 2018). Scientific reasoning is characterised by the application of distinct bodies of knowledge which include procedural knowledge of strategies used for scientific investigations (e.g., identifying and controlling variables), and epistemic knowledge about the rationales and criteria of working scientifically (e.g., ensuring validity and reliability of an investigation) as well as content knowledge (Arnold, Kremer & Mayer, 2017; Roberts & Gott, 2004; Kind, 2013).

The project described here focuses on students’ scientific reasoning while they evaluate evidence gained from experiments. They document and process the experimental data and interpret them based on their prior knowledge. They draw conclusions in reference to preformulated hypotheses. Drawing on epistemic criteria, they assess the generalisability of the results of the experiment onto other phenomena and judge the quality of the experimental data as well as the validity of the experiment just conducted (Kind, 2013; Wellnitz & Mayer, 2011). These procedures are potentially difficult for students. The study’s aim lies in the identification of specific difficulties students face when evaluating data they generated in hands-on experiments. These difficulties will then be related to student characteristics in terms of their procedural, epistemic, and content knowledge. In that way, the study contributes to an elaboration of the current understanding about how these knowledge domains shape students’ performance when handling experimental data. By investigating students from upper secondary school, the study aims at expanding upon the currently limited state of research on this age group.

Review of literature
As empirical findings indicate, students show a variety of difficulties when evaluating evidence. They have problems with identifying trends in data (e.g. Sandoval & Millwood, 2005). When faced with anomalous data, i.e. data that contradicts their preconceptions,
students will often fail to deal with them appropriately, e.g. by validating them through repetition (e.g. Toplis, 2007). More generally, it has been shown that students fail to incorporate the concepts of reliability, validity and objectivity into their reasoning while evaluating data (e.g. Lubben & Millar, 1996). This manifests itself in their performance: many students have difficulties identifying experimental data which are appropriate for drawing conclusions about a certain phenomenon (McNeill & Krajcik, 2007), or fail to appreciate inaccuracy of measurement when handling data (Hogan & Maglienti, 2001).

The studies described above primarily focus on the abilities of middle school students. Consequently, the state of research only provides limited evidence which allows to assess what kind of support is required by students from higher class levels (Arnold et al., 2014, Vorholzer, et al., 2018). As a result, only few studies have so far presented possible approaches to supporting upper secondary students’ scientific reasoning when evaluating experimental data (e.g. van Rens, 2014). From the perspective of chemistry education research, it is equally salient that the above-mentioned studies investigated students’ either without reference to a domain of science or drawing on a neighbouring sciences, i.e. physics or biology.

Research questions
Against this background, the project described here aims at closing the gap in research by answering the following questions.

**FF1.** Which difficulties do upper secondary students show when evaluating evidence gained from chemical experiments?

**FF2.** How does the occurrence of these difficulties correlate with students’ procedural, epistemic, and content knowledge?

Design and method
To answer these research questions, a study will be conducted in which video and audio data of a sample of students ($N = 80$, age typically 16-18) from German upper secondary schools conducting experiments in groups of two will be gathered and analysed. The contents of the experiments are taken from North Rhine-Westphalian state-level curriculum for upper secondary chemistry courses and focus on the concept of chemical reaction. The focus of the experimental settings lies on the evaluation of data gathered in these experiments. To ensure that this focus expresses itself in scope and difficulty of the corresponding phases of the experiments, students’ generation of hypotheses as well as the planning and carrying out of the experiment itself will be guided, e.g. by specifying possible hypotheses and presenting details on how to test them. This way, errors during evidence evaluation which result from difficulties in other phases of the experiment (Wahser, 2007) can potentially be minimised. By involving students in this kind of structured inquiry, this study deviates from previously conducted similar studies (e.g. Baur, 2018) which employed less guided experimental settings. Dealing with quantitative and qualitative data sets different requirements for students (Wellnitz & Mayer, 2011). Hence, it seems plausible to expect distinct difficulties they face when
evaluating them. Consequently, the experimental settings will confront students with quantitative and qualitative data by necessitating the consideration of both to come to valid conclusions. A pilot study conducted with a smaller sample size ($N = 24$) will serve to validate the experimental settings in terms of being suitable to elicit students’ difficulties as well as with regard to being adequately solvable.

The video and audio data gathered in the main study will be analysed qualitatively. A content analysis aims at the inductive identification of categories that reflect the difficulties shown by students (e.g. Mayring, 2000). In a second step, their occurrence and frequency will be analysed statistically with regard to the students’ scores in tests for the different knowledge domains relevant when engaged in scientific reasoning. To this end, instruments measuring students’ content knowledge (Henke, 2007; Hülsmann, 2015), procedural knowledge (Henke, 2007), and epistemic knowledge (Roberts & Gott, 2004) are being adapted and developed. The quality of these tests will be ensured by conducting another pilot study evaluating them with the help of a sample of $N = 150$ students. Students’ cognitive abilities as well as their motivation, situational interest and self-concept will be measured as control variables.

**Expected outcomes**

The findings made in this study about the difficulties older students face while evaluating experimental data can prospectively inform the design of measures for supporting students’ scientific reasoning. Matching their contents and the actual need for support based on an expanded knowledge about student difficulties can contribute to ensuring a high validity of such measures.

**Literature**


Investigating teachers’ beliefs towards Inquiry-Based Learning in Science Education of the Primary school system of Trinidad and Tobago

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Introduction

Wellcome (2014) highlighted that if more pupils are enthused to study science, starting at the primary level, this will help secure our economic future and cause more students to continue to study science subjects beyond the statutory curriculum and move into related employment. Singapore, a country that continues to lead the world in science performance as recorded in the 2015 Trends in International Mathematics and Science Study (TIMSS) (Mullis and Martin, 2016), showed commitment to inquiry-based approaches to education, for example, their ‘teach less, learn more’ educational approach, has reduced the number of outcomes in the programs of studies so that teachers can focus on laying a strong foundation of knowledge and skills involving inquiry-based processes. (Ministry of Education Singapore, 2017).

This favour for inquiry-based learning (IBL) has seemingly transcended to Trinidad and Tobago, as researcher, Maharaj-Sharma (2012) proposed that it is time for science teachers, and particularly primary school teachers [in Trinidad and Tobago], to make concerted efforts to adopt classroom practices and institute instructional measures geared at improving the primary science experience of students. She proposed that if guided inquiry approaches are infused into science lessons, even the most critical and disinterested students are eager to engage in the learning because of the autonomy and the psycho-mental involvement this approach confers on the students.

However, despite the emphasis for the use of IBL in science, as mentioned in previous research (see Levy, Thomas, Drago, & Rex, 2013), Voet & De Wever (2018b) cited authors such as Loteer, Rushton & Singer, (2013) to highlight that even so, IBL is not yet a common practice in many classrooms. Gillies and Nichols (2014) pointed out that many teachers often times face challenges and shy away from using IBL, because of their belief, in that they believe that they lack sufficient content knowledge or pedagogical skills to do so. Capps et al., (2012), highlighted that only “very few studies have systematically assessed teacher beliefs” (p.304). As a result, there is little information about the way in which teachers’ beliefs influence their implementation of IBL even though these beliefs ultimately determine their classroom behaviour (Voet & De Wever, 2018a; 2018b). As for Trinidad and Tobago, James (2014) pointed out that literature on the development of education in the country is generally thin.

Purpose of the Study

This research aims to investigating the current beliefs of primary school teachers in T&T, towards their use of IBL approaches in science education, and how these beliefs
impact on their teaching practices. It will aid in better understanding the current reality of teacher practice of science instruction in the primary classroom, and also aid in starting informed discussions on teacher training needs as the Ministry of Education (2017) championed that it is vital to understand the importance for science, and scientific knowledge to be present in Trinidad and Tobago to “harness and release the innate dynamism, innovation and intellect of the 21st Century learner intent on building human resource capacity in pursuit of national sustainable development.”

Subsequently, this study aims to help in alleviating the issue of a very limited presence of published research in educational development in Trinidad and Tobago, with the potential to provide a foundation for further research to be developed, which in turn can aid in evaluating programmes and guiding policy and reform. (James, 2014; Ministry of Education, 2017). On a wider scope, the information that this research will present on the beliefs of teachers’ and its impact on their implementation of IBL in the context of Science Education, will address the issue of a worldwide deficit in studies systematically assessing teacher beliefs resulting in little know information about the aforementioned topic. (Capps, Crawford & Mark and Constas, 2012; Voet and De Wever, 2018). This, in turn, will facilitate data in which further studies, especially those of a cross-country comparative nature can be done.

**Literature Review**

Inquiry-based learning (IBL) has been receiving a lot of attention and consideration as a modern instructional method in education (Chowdhury, 2015). However, there seems to be a sense of complexity in determining a single standard definition for Inquiry Based Learning. (Murphy, 2016). For the purpose of this research, the definition of IBL has been adapted from Meehan, (2018) to refer to a pedagogy which begins with a challenge for learners, in which they are tasked with a question or a problem, which must be solved through investigation and research.

Research has demonstrated that teachers’ actions in the classroom are largely in line with their beliefs or tacit assumptions about their work in class (see, for example, the reviews by Kagan, 1992; Pajares, 1992). These beliefs act as filters that ultimately screen, define, distort, or reshape teachers’ decision-making (Pajares, 1992). In short, educational beliefs are propositions about schooling, teaching, learning, students, and subjects, which are held consciously or unconsciously (Pajares 1992). These propositions are evaluative, in the sense that they are accepted as true by the individual, and are therefore imbued with emotive commitment (Borg, 2001). Unlike knowledge, they are not necessarily based on evidence, and may very well defy logic (Richardson 1996). Voet & De Wever (2018) admonished that teachers’ decisions to organize IBL in class, is largely driven by their beliefs about knowledge goals and self-efficacy for organizing IBL.
Research Questions
1. What are the current beliefs of teachers towards the use of inquiry-based learning (IBL) approaches to teach science at the primary education level in Trinidad and Tobago?
   a. How does these beliefs impact the practice of the teachers in implementing IBL?

Research Design and Methodology
This study will implement a mixed method research design with a case study approach. It also utilizes the theoretical framework of Beliefs related to Inquiry-based learning, that has been developed by researchers Voet and Wever. Voet and Wever, (2018) explained that this framework builds on research on the nature and structure of beliefs by Op ‘t Eynde, De Corte, and Verschaffel (2002) which suggests that (1) the object (education), (2) self, and (3) context (class), forms the constitutive dimensions of teachers’ beliefs system. The framework however takes these three constitutive dimensions of teachers’ beliefs and categorizes them further into five variables.

Data gathering techniques will include: Semi-structured interviews, classroom observations and questionnaires. Collecting data from these three different methods will aid in the validation of the research findings by using Methodological Triangulation (Denzin 973, p.301) Stake (1995) advised that it is crucial to choose best persons, where best means those that best help us understand the case. Purposive sampling will therefore be utilized to obtain data from in-service teachers in primary schools in Trinidad and Tobago from the last four grade levels that students are cognitively able to effectively engage in IBL activities. Completed documentation of observations and transcription of interviews, will be imported into NVIVO qualitative data analysis software (or similar analysis software). Initial or open coding will be performed on the raw data, to derive specific categories in vivo from actual phrases/key words found in the data. This will allow the researcher to build ideas inductively while deterring him from imposing his own beliefs on the data (Chamaz, 2000). After the initial codes are identified, axial coding along with the constant comparison analysis technique will be utilized to identify patterns as well as paradoxes in the data (Glaser & Strauss as cited in Wellington, 2000, p. 136). Questionnaire responses will be collated using SPSS (Statistical Package for the Social Sciences) under Voet and De Wever ‘s headings of teachers’ beliefs, and further analysed.

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Incorporating the concept of Fields into Middle School Instruction on Energy

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Focus of the study
Science education policies all over the world require students to develop understanding regarding the energy concept (e.g. National Research Council [NRC], 2012). Science education research has repeatedly shown students problems in understanding energy, in particular the conservation of energy. Newer literature suggests that teaching students fields as a means to store energy may promote a more consistent and complete understanding of the energy concept and thus prepare students for future energy-related learning (PFL). Yet empirical evidence on the helpfulness of fields in introducing energy is currently largely lacking. Major aim of my research project is to investigate the extent to which a fields-based approach in comparison to a traditional approach to teaching energy is promoting students’ understanding of the energy concept as well as their PFL.

Review of relevant literature
Science education researchers agree that in order to understand the energy concept students need to learn five key aspects: 1) forms, 2) transformation, 3) transfer, 4) degradation, and 5) conservation of energy (for an overview see Chen et al., 2014). The most common way of introducing energy are Forms-based approaches that distinguish different forms of energy like kinetic and potential energy for different phenomena. Forms-based approaches, however have been criticized in the past (see Kaper & Goedhart, 2002). The criticism focuses mainly on two points:

1) Potential energy is difficult for students to locate as it is not a property of just an object but also of its location (Hecht, 2003). It is not associated with a single physical entity and becomes apparent only when transformed into kinetic energy (Swackhamer, 2005). Students also think that potential energy has the “potential to be energy” but is actually not existent until it is transformed into another form (Lindsey, 2014). Hence, for students, potential energy seems not to be real as it is not as easily observable as kinetic energy (Hecht, 2003).

2) Furthermore, research has shown that students struggle with energy conservation (Driver & Warrington, 1985) and even at the end of middle school only few students develop the ability to apply it in several contexts (Neumann, Viering, Boone, & Fischer, 2013). Students bring intuitive ideas about energy into science class that result from their everyday experiences (e.g. Chen et al., 2014). In everyday language energy is ‘used up’ (Solomon, 1983) or has to be ‘saved’. Students’ problems with conservation may possibly occur because of students’ misconceptions of potential energy.
Introducing fields in the context of energy has the potential to help address these problems and thus help students develop a deeper understanding of energy. A field surrounds objects that interact at a distance via the field between them. From a physics point of view, potential energy is the form of energy that is stored in a field between at least two objects. Depending on the configuration of the objects, the amount of energy stored in the field changes and with it the field’s shape. In case of magnetic and electric fields, this change in shape can be visualized so that potential energy becomes observable for students like they can observe kinetic energy in motion. Potential energy becomes every bit as real as kinetic energy – it manifests itself in the change of fields (Swackhamer, 2005). Understanding energy conservation is not possible without an idea about potential energy located in fields and energy transfer from and into fields. Introducing fields gives energy a location when it is not manifested in the motion of objects. Since it has to be somewhere and simply moves from one place to another, it is not ‘used up’. In this sense, introducing fields as location for potential energy makes energy conservation possible and more comprehensible for students.

Fields are, however, an abstract concept themselves that students struggle with (e.g. Bar, Zinn, & Rubin, 2007). Fields are therefore often only formally introduced in high school as a mathematical means to describe the distribution of a physics measure in space and time. This, in turn, may be the reason for students’ difficulties - that fields are not systematically developed as an idea and introduced only as a mathematical means. In the context of energy instruction in middle schools the field concept can be simplified as there is no need to introduce its’ mathematical character. A field can be introduced as a physical entity that can be visualized and that can simplify the reasoning about a range of energy-related phenomena (cf. Swackhamer, 2005). While fields may provide students with conceptual tools for developing a more robust understanding of energy, empirical evidence for this assumption is lacking so far. Specifically, it is presently not clear whether introducing fields at the beginning of energy instruction is helpful or rather whether inherent challenges in the fields-concept itself lead only to overtax students, thus leveling any potential positive effects.

**Research questions**

The present study addresses the lack of knowledge regarding whether and how the introduction of the concept of fields with eleven and twelve year old students may promote students’ understanding of energy. The respective research questions are:

1. …impact students’ learning about energy, in particular their understanding of potential energy forms?
2. …influence students’ preparation for continued learning about energy, in particular, their ability to further their understanding about energy conservation?
Research design and methods

In order to investigate the proposed research questions, a quasi-experimental pre-post-test study will be carried out. 10 middle school teachers in one state (Schleswig-Holstein) in Germany will be recruited with two of their 6th grade classes, so eleven or twelve year old students, resulting in a total of 20 classes (approx. total N = 500 students).

The study design is shown in Figure 1. Prior to the intervention, data on students’ prior knowledge about energy and fields as well as their abstract reasoning skills will be collected. Afterwards, classes will be assigned to either the experimental (fields-based approach) or control (non-fields-based approach) condition and receive 5 weeks (ten lessons) of instruction on the energy concept. Both instructional approaches will be based on an existing energy unit (Krajcik, Reiser, Sutherland, & Fortus, 2012), translated into German and adapted to the instructional schedule and requirements of schools. The second approach will be further adapted to include the teaching of fields. Following the instructional units, students complete a set of post instruction assessments to estimate their understanding of energy and fields and their respective self-efficacy. All written assessments will include a mixture of multiple-choice and open-ended items taken or adapted from existing assessments (e.g. Nordine, Krajcik, & Fortus, 2011). In addition, interviews will be carried out after instruction. Students will be presented with four phenomena and asked to describe the phenomena from an energy perspective. The goal is to obtain a richer and more detailed picture of students’ conceptualization of energy and fields than it is possible to obtain with written assessments. Later that year, it will be explored how students are prepared for future energy-related learning (PFL) in context of electric energy. Both groups receive two lessons about electric energy, again in two conditions, adding fields in the fields group. Written assessments enable us to compare how students in each instructional treatment were prepared to learn about the novel scenario of electric energy. Energy conservation was only introduced implicitly during the unit and will then be made explicit as part of the PFL.

Data analysis for research question 1 will be conducted using ANCOVA with post-instructional knowledge as well as self-efficacy after instruction as dependent variables.
and group as an independent variable with measures of pre-instructional knowledge and abstract reasoning skills as covariates. An analogous Repeated Measures Analysis of Variances (RM-ANOVA) will be conducted and multiple regression analysis for the control variables. Data analysis for research question 2 will be analyzed using an ANOVA with contrasts with the energy conservation task as dependent variable and post-instructional knowledge as well as self-efficacy and abstract reasoning skills as independent variables. For the interviews a qualitative inductive analysis will be conducted.

The PhD-project started in September 2017 and a small-scale pilot data collection (N=90 eleven and twelve year old students) takes place from October 2018 to May 2019. As part of the presentation at the ESERA summer school, I would like to present the project rationale, materials, study design and methods and discuss the results of the pilot data collection.

References


Investigation of the role of knowledge for decision-making processes in preventive health contexts

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Focus of the study
In the past, most people died because of infectious diseases. Nowadays the majority of people die because of non-communicable diseases (NCDs), such as diabetes mellitus. Type-2-diabetes (T2D) on the one hand is genetically determined. On the other hand, it occurs due to different lifestyle-factors, e.g., a nutrition that is high in sugar and saturated fats; physical inactivity and high stress levels (Renz-Polster & Krautzig, 2013; Falconnier Bendik & Donath, 2016). Globally, 415 million people suffer from T2D with an increasing tendency, so that the prevalence of this metabolic disease has become a serious public health issue (World Health Organization (WHO), 2016). School, and especially science subjects, can contribute to the prevention of NCDs, such as T2D, through the distribution of knowledge and competencies to make conscious and reflective decisions in health-related contexts (Zeyer & Dillon, 2014; Arnold, 2018). For this purpose, this study focusses on factors that influence people’s decision-making processes in health-related contexts using the example of the influence of sugar-consumption on the onset of T2D.

Theoretical framework and relevant literature
The project theoretically refers to the Integrated Model of Decision-Making in Health Contexts (Arnold, 2018). The author assumes different motivational constructs as well as different knowledge dimensions as important influence factors on decision-making processes in health related contexts.

Regarding the motivation level, four major constructs formulated as expectation-value constructs are mentioned (Arnold, 2018):

1) **Perceived Threat**: The belief that one is likely to suffer from health problems associated with high sugar intake (Perceived Susceptibility (PSU)) and the evaluation of these health problems as severe or threatening (Perceived Severity (PSE));

2) **Attitude Towards Health Action**: The belief that one can reduce the intake of sugar (Efficacy-Expectation (EE)) and the deem of this reduction (Value of Action (VA));

3) **Attitude Towards Health Outcome**: The belief that the reduction of sugar intake will lead to a reduction of health problems associated with sugar intake (Outcome-Expectation (OE)) and the evaluation of the reduction of health problems associated with high sugar (Value of Outcome (VO)) and
4) **Subjective Norm**: The belief how relevant people, e.g. parents or peers, will react (Social Outcome Expectation (SOE)) and the evaluation of this reaction (Value of Social Outcome (VSO)).

These are core concepts from leading theories in the field of behavioural psychology, such as Social Cognitive Theory (SCT; Bandura, 1977); Theory of Planned Behaviour (TPB; Ajzen, 1985; Fishbein & Ajzen, 1975); Health Belief Model (HBM; Rosenstock, 1974a, 1974b); Protection Motivation Theory (PMT; Rogers, 1983); Health Action Process Approach (HAPA; Schwarzer, 2008) and Framework Model of Health Literacy (FHL; Zeyer, 2012).

The Integrated Model uses intention as the dependent variable, because it is a proximal predictor for the actual behavior shown (Luszczynska & Schwarzer, 2005).

Besides the motivational constructs, three knowledge dimensions are mentioned (Arnold, 2018 following Kaiser & Fuhrer, 2003):

1) **System health knowledge (SK)**: Knowledge about health, the body and its (mal)functioning (e.g., knowledge about the use of carbohydrates; the metabolism of carbohydrates; the mechanisms and risk factors leading to insulin resistance and T2D; the impact of T2D on health).

2) **Action-related health knowledge (AK)**: Knowledge about possible actions to preserve functioning and prevent mal-functioning of body and health (e.g., knowledge about recommendations about sugar-intake; foods that contain carbohydrates and sugars; actions to reduce the intake of sugar). And finally,

3) **Effectiveness health knowledge (EK)**: Knowledge about the relative potential of actions to lead to the desired prevention of diseases (e.g., the ability to decide for foods that contain less sugar).

**Research question**

Most studies trying to clarify the influence of nutrition knowledge on actual eating behaviour fail to state reliable results about this relationship (Wardle, Parmenter, & Waller, 2000). A missing specify between knowledge (independent variable) and behavior (dependent variable) is a discussed reason for this lack of evidence (Worsley, 2002; “law of specificity”, Ajzen & Fishbein, 2005). Hence, the presented dissertation project tries to fill this desiderate in educational research by investigating the following research question:

*How do the three knowledge dimensions SK, AK and EK influence the intention for preventive health behavior?*

To examine the research question, we plan an experimental investigation study testing the following hypotheses:

1. A promotion in SK will lead to an increase in the Perceived Health Threat (H1),
2. a promotion in AK will lead to an increase in the Attitude Towards Health Action (H₂),
3. a promotion in EK will lead to an increase in the Attitude Towards Health Outcome (H₃) and
4. an increase in the motivation will lead to an overall increase in the intention (H₄) to act in a healthy way (Arnold, 2018).

Design and methods
To test our hypotheses, pupils will get a promotion in either SK (experimental group 1 (EG1)), AK (experimental group 2 (EG2)), EK (experimental group 3 (EG3)) or a basic intervention in all three knowledge types (control group (CG)). Before and after the intervention pupils will finish an online questionnaire consisting of knowledge-, motivation- and intention-items (see above). The diagnostic instrument has been developed, and pilot tested this year (preliminary findings see below). The knowledge dimensions were operationalized in Single-Choice-Items. The test for measuring SK consisted of 34 items. The test for measuring AK consisted of 17 items and finally, the test for measuring EK consisted of 21 items.

The intervention study will take place in the 9th grade of Swiss mandatory education. We plan a minimal sample size of N = 200 pupils so that we have at least 50 pupils per investigated factor (EG1-3 and CG). In total, the intervention will take four school lessons (180 min). In the first lesson, pupils will answer the online questionnaire and we will then allocate them due to their results to the different experimental-groups or the control group (randomization; Rost, 2007). The experiment will take two school lessons (90 min). Immediately after the promotion, all participants (EG1-3 and CG) will answer the online questionnaire once more. Thus, we want to find out if a promotion of the different knowledge dimensions actually influences the motivational factors and in this way, the intention for preventive health behavior as hypothesized (see above). Within the next months, we will develop teaching material for the intervention study. The data will be analyzed based on Item-Response-Theory (Rost, 2004). Structural equation models will research correlations between knowledge, motivation and intention, whereas causal relationships will be investigated through analysis of variance.

Preliminary Findings
Multidimensional Rasch analysis (software ACER ConQuest) was applied to analyse the dimensionality of the knowledge test. The model’s fitting parameters were compared to corresponding parameters of a one-dimensional model. The three- and one-dimensional models were compared using Akaike’s Information Criterion (AIC; Akaike, 1981) and Bayes’ Information Criterion (BIC; Wilson et al., 2008). To identify the model providing the best fit to the data we calculated deviance factors (inversely reflecting the degree to which the data fit underlying assumptions). To assess the significance of differences between the models’ deviance factors we applied χ²-tests (Bentler, 1990). On the one hand, Akaike’s Information Criterion is lower for the three-dimensional model
\(\text{AIC} = 7993.87\) then for the one-dimensional one \(\text{AIC} = 7997.48\). On the other hand, Bayes’ Information Criterion is higher for the three-dimensional model \(\text{BIC} = 8228.79\) then for the one-dimensional one \(\text{BIC} = 8217.25\). \(\chi^2\)-test shows that the three-dimensional model significantly outperforms the one-dimensional model \(\chi^2[5] = 13.61, p < .05\). These results are contradictory so that a correlation analysis between the three knowledge dimensions is needed to finally clarify which model fits better. Reliability analysis for the knowledge sub scales showed following results: SK, EAP/PV Reliability: .74; wMNSQ: 0.85-1.12; AK, EAP/PV Reliability: .63; wMNSQ: 0.83-1.16 and finally EK, EAP/PV Reliability: .31; wMNSQ: .93-1.02. Within the next weeks, we will optimize the test (especially EK subscale) and pilot test it again before beginning to plan the intervention.

References


Assessment of pre-service teachers’ scientific reasoning in the context of modeling and investigation tasks

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Abstract

Scientific reasoning is highlighted as a priority in worldwide education curricula and is also part of professional development programs for science teachers. We have sought to assess the reasoning of pre-service teachers in the context of modeling and investigation tasks. To achieve this, we used an existing instrument that presents structured tasks focusing on seven dimensions: aim of the research and investigative question; use of observations to formulate hypotheses; experimental investigation of hypotheses; interpretation of data; use of models to formulate hypotheses; testing the validity of a model; evaluating and revising a model.

Introduction

Scientific Reasoning

Scientific literacy is becoming more important for informal decision making (Heijnes, van Joolingen, & Leenaars, 2018; Deboer, 2000), due to the integration of science in daily life. Scientific reasoning has emerged as a key competency (Stiller et al., 2016) that is represented in educational standards worldwide (Krell, Redman, Mathesius, Krüger, & Driel, 2018; NRC, 2012). Scientific reasoning also reflects the general epistemic structure behind the competencies of modeling and investigation (Mathesius, Hartmann, Upmeier, & Krüger, 2014), which play an important role in scientific inquiry, by connecting the worlds of observation and theory (Klahr, 2000) and facilitating the construction of explanations of scientific phenomena, as well as evidence-based.

Conceptual understanding and the acquisition of scientific reasoning competencies are highly relevant for academic teacher training in biology, chemistry and physics (Krell et al., 2018; Mathesius et al., 2014; Namdar & Shen, 2015; Stiller et al., 2016). There have been numerous studies evaluating such competencies in secondary education. However, there is a lack of corresponding research in tertiary education (Krell et al., 2018; Stiller et al., 2016). Considering that previous research in this direction is scarce, there is a need to assess scientific reasoning competencies and further investigate in what ways learning opportunities and teaching scaffolds affect on the development of pre-service teachers’ scientific reasoning.

Though this collaborative research with Freie University of Berlin and Humboldt University we aim to address this challenge, foremost with assessing investigation and modeling competences as fundamental parts of scientific reasoning and subsequently to explore ways of facilitating the development of these competencies. In this study, we
report on an effort to assess the scientific reasoning of pre-service teachers and to identify teaching scaffolds with potential to improve these competencies.

Research Questions

Considering the above, the main research questions which this study aims to address are the following:

1. To what extent does a structured set of modeling and investigation tasks provide a valid assessment of scientific reasoning?
2. Which strategies could enhance the competence of scientific reasoning in the context of modeling and investigation tasks for pre-service teachers?

Methodology

Students of primary education participated in this study. The students were guaranteed anonymity and they worked in groups of three (home groups) throughout most parts of the intervention, as an analogy of small scientific communities in which scientific knowledge is produced (Bell, Urhahne, Schanze, & Ploetzner, 2010). However, students worked on an individual basis when they answered the assessment questionnaires.

The pre-existing questionnaires were translated from German into Greek through the TRAPD approach (Krell et al., 2018). The same questionnaires are in use in on other three countries. The ultimate goal is to develop a framework with good practices for training teachers based on a variety of data, concurrently with the validation of the assessment instruments. The 21 tasks measure seven abilities of the two competencies, modeling and investigation, which are: aim of the research and investigative question; use of observations to formulate hypotheses; experimental investigation of hypotheses; interpretation of data; use of models to formulate hypotheses; testing the validity of a model; evaluating and revising a model.

Expected results

From the theoretical assumptions we derived a hypothesis that anticipates evolving competencies of scientific reasoning by undergraduate students. We expect to find that students who participate in scaffoldings with reflection strategies about the processes of modeling and investigation, and on the nature of science, will demonstrate improved abilities for scientific reasoning. We also expect that reflection strategies on epistemological aspects of science will affect these competencies.

The collection of data will be implemented in two phases: The first phase took place in January 2019, at the start of university courses. In this way, we will obtain insights on the students’ scientific reasoning competencies before and after the teaching scaffolds in epistemological awareness. Additionally, we will follow-up data from the same students in the next fall semester in order to explore retention and subsequent evolution of these.
competencies. The second phase will take place towards the end of the spring semester and will yield into motion on the outcomes.

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Bibliography
Teachers’ pedagogical practices in integrated contexts of education: the case of school visits to science museums

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Abstract
With this PhD, we aim to understand the impact of teachers’ pedagogical practices related to school visits to science museums and student learning.

School visits to science museums play an important role in the current educational landscape since they provide a promising avenue to articulate formal and non-formal education contexts. Consequently, it is necessary that teachers’ plan visits in order to integrate them into the school curriculum and the work done in the classroom (Rodrigues & Martins, 2005; Remmen & Frøyland, 2015).

In this research, we will characterize teachers’ pedagogical practices and student learning will be evaluated immediately after the visit and six months later in order to recover students and teachers' memories.

Our research shows that despite the numerous studies analysing the impact of science museum visits on students learning few investigations examine, in detail, the role of teachers in the process (Souza, Bonifácio & Rodrigues, 2017) and that research guidelines have not yet percolated into teachers’ practice.

Our preliminary results show that despite teachers’ acknowledgment of the importance of planning school visits considering the stages of pre, during and post-visit, there is still a gap between their strategies and the impact in students’ learning. At the moment, student data analysis is approaching completion as we intend to conclude the PhD before August 2019.

Theoretical Context
School visits to science museums have become popular in recent years. School groups make out the larger visitor group (Morentin, 2010). For example, the 20 Portuguese Centros de Ciência Viva (Living Science Centers) received 226,877 school visitors in 2015 (Garcia, Silva, & Ramalho, 2016).

The need to articulate formal and non-formal education contexts stated by international guidelines for Science Education (International Council for Science, 2011; National Research Council, 2009); the recognition of the educational value of school visits in promoting motivation, skills and positive attitudes and values towards science (Falk & Dierking, 2000); the validation of science museums as a potential recreational and didactic resource (Morentin & Guisasola, 2014); and the teachers’ understanding of the learning opportunities provided by the school visits (DeWitt & Osborne, 2007) are examples of the importance attributed to this learning resource.
Years of research have resulted in recommendations on how teachers can conduct school visits to science museums in order to integrate the visit with the classroom program. Theoretical models, structures and guidelines suggest teachers should guide their visits supported by careful planning of the pre, during and post visit (for example, Allard, 1999; Morentin & Guisasola, 2013; Oost, De Vries, & Van Der Schee, 2011; Rennie & McClafferty, 1995; Remmen & Froylend, 2015). To fully explore the educational potential of school visits teachers are advised to plan student-centered activities aligned with curriculum guidelines. These activities should be integrated into the classroom either before, during visit preparation or after it (DeWitt & Storksdieck, 2008; Rodrigues et al., 2015). However, our literature review shows that almost no studies of teacher-led school visits to science museums examined their practices (Souza, Bonifácio & Rodrigues, submitted).

Since it is expectable that teachers’ school visit pre-planning would affect the student experience and learning, identifying their strategies may provide a better understanding of teachers’ perspectives and of the overall experience. Studies that analyse the role played, in this context, by teachers need to be interpret, in a holistic view, due to the complexity of the factors involved in student learning.

Research question and methodology

This study presents the following research question and sub-questions:

What is the impact of teachers’ pedagogical practices before, during and after the visit to a science museum upon student learning?

i. What strategies teachers use in the pre, during and post-study visits to a science centre?

ii. Are teacher’s strategies in accordance with literature recommendations?

iii. What is the learning was identified in the students during the pre, during and post-study visit?

iv. What is the relationship between teacher strategies and student learning in a study visit?

As a case study this research follows an interpretative paradigm and a qualitative perspective (Yin, 2015). Five professors and their third-grade primary school students (n = 87) visited the same science museum. They were accompanied during the pre, during and post visit steps. It is important to mention that this work proposal consists in understanding how teachers independently plan and implement study visits. The researcher assumed the role of passive observer.

Data collection occurred in two phases. Phase 1 was structured in three stages. At the pre-visit stage, classes were observed, teachers interviewed and, questionnaires applied to the students. In the next stage, during the visit, teachers and students were accompanied during the science museum visit. Visual and video observations were made and field notes were taken. At the last Phase 1 stage, the post-visit, classes were observed, teachers interviewed and questionnaires applied to students. In Phase 2,
executed six months after each visit to the science museum, teachers and students were interviewed and questionnaires and group interviews with the students were carried out. In addition, we collected materials and resources produced by teachers and students between the start of phase 1 until the end of phase 2.

In order to answer questions i) and ii) and to characterize teachers' practices, we analysed class and visit observations, teachers’ interviews and the material collected. In order to answer question iii) and identify student’s learning, the questionnaires and the student interviews will be used. We understand learning as the acquisition of scientific knowledge, skills and a positive attitude towards science. In order to answer question iv), the results obtained in questions i) and ii) will be combined with those of question iii).

Data is analysed with Bardin’s content analysis technique (2009).

**Preliminary results**

Our research revealed not only that there is a lack of knowledge concerning how teachers actually plan the visits, either in terms of the activities carried out or in relation to the practices adopted for the integration of the formal and non-formal education contexts, as it indicates a low exploitation of the pre and post-visit stages in the classroom (Souza et al., 2017). Moreover, teachers’ do not seem to be always aware of the importance of preparing school visits, according to the three steps model, for student learning.

Partial results, obtained through the application of an instrument that evaluates the quality of teachers study visits planning (Rodrigues, 2011), in a scale of 1 to 5 (1 - insufficient, 2 - regular, 3 - good, 4 - very good, 5 - excellent), revealed that four of the five teachers efforts obtained a classification of regular (level 2). Teachers focused mainly on preparing the “pre” stages (three teachers at level 3 and two teachers at level 2) and “during the visit” (two teachers at level 3 and three teachers at level 2) compared to step “post-visit” (two teachers at level 2 and three teachers at level 1). Several studies argue the need to carry out classroom activities with students before and after the visit to the science museum (Falk & Dierking, 1997; Remmen & Frøyland, 2015). Contrary to these recommendations, teachers reported that they did not follow students’ learning upon returning to the classroom. This result confirms other researches (Anderson et al., 2006; Morentin & Guisasola, 2015; Tal & Steiner, 2006).

The non-existent articulation of the visit with the school curriculum reveals the need to include this topic in teachers initial training and continuous programs. At the moment student data is under analysis in order to evaluate student learning during the pre, during and post-study visit stages and establish possible connections with teachers’ pedagogical practices. Final results are expected before August 2019.

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Designing and evaluating a teaching-learning sequence about electromagnetic radiation for grade eight

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University of Vienna, Austria

Outline of the focus of the study
Electromagnetic radiation has an important role in our everyday life. Microwaves, mobile phones, lightbulbs, the sun and the dentist’s X-Ray generator are just a few examples of common sources. Despite its importance, it is not part of the Austrian curriculum for middle school. In the presented project, a teaching-learning sequence (TLS) is developed to introduce the topic in grade 8. The aim is to enable students to develop conceptual understanding of electromagnetic radiation.

The body of literature on learning about electromagnetic radiation is quite small. Therefore, a design-based research approach is used to enhance our knowledge on learning processes and adapt the TLS accordingly. As a first step, design guidelines based on the respective body of literature are formulated. Next, central ideas of the content are formulated as compact explanations (key ideas). Student’s approval and understanding of these key ideas are investigated. Subsequently, a TLS is developed based on these key ideas, implemented in physics classrooms, evaluated and refined in continuous cycles.

Review of relevant literature
For the development of the TLS, the model of educational reconstruction is applied (Duit et al. 2012). Following this model, the development and evaluation of the TLS goes hand in hand with the analysis of the scientific content as well as the assessing and consideration of students’ perspectives.

There are some studies that investigate students’ conceptions on radiation, but most of them focus on radiation in terms of radioactivity. Only a few papers address electromagnetic radiation explicitly. However, there are some results that have to be considered. Students are often not able to distinguish between ionizing and nonionizing radiation (Rego and Peralta 2006). They categorize radiation as “bad” or “good” (Rego and Peralta 2006) as well as “artificial” or “natural”, “dangerous” or “harmless” (Plotz and Hopf 2016; Neumann and Hopf 2012). Another conception is that an object that was exposed to radiation becomes radioactive (Prather and Harrington 2001). The lack of knowledge on student’s learning motivates the design-based research approach – it is aspired to contribute to the respective body of literature.

Looking into other domains helps to build the theoretical framework. It proofed useful to look into the work of Haagen-Schützenhöfer (2016) on teaching and learning geometric optics. Given that light is a type of electromagnetic radiation, the models she used for her TLS might be transferable to electromagnetic radiation.
Research questions
The project aims to answer the following research questions:
(1) Do students approve of the introduced key ideas and are they able to transfer the knowledge to new tasks?
(2) Do teachers approve of the learning effects and the practicability of the TLS after implementing it in their classroom?
(3) Which learning gains can be reached through the TLS?

To answer these three questions, the project consist of three phases of research. In the second and third study, the TLS is implemented in classrooms. These abstract focusses on the first study.

Research Designs and Methods
To answer the first research question, teaching experiments are conducted. The method of probing acceptance described by Jung (1992) is used for this purpose, with a sample size of overall 20 students. Using this method, explanations are presented to students. The students are asked what they think of these explanations and to rephrase them. Afterwards they are instructed to solve a problem. The teaching experiments are recorded and transcribed. The transcripts are analysed with the method of evaluative qualitative text analyses (Kuckartz 2014), using a coding manual. For every part of the teaching experiment, it is coded if the student’s performance was good, satisfactory or insufficient. The results are depicted in a profile matrix to enable to look at the date in a case-oriented as well as an topic-oriented perspective (Kuckartz 2014). The transformations the students make in their rephrasing as well as the difficulties that arise are extracted from the transcripts. The results are discussed with experts with an emphasis on what works and what doesn’t.

Design guidelines
As part of the design-based research framework, domain-specific design guidelines were formulated based on the existing literature. The guidelines are as follows:

(1) The basic concepts recommended by Plotz (2017), are used as construction principles. These include the order of the different types of electromagnetic radiation in the spectrum, its propagation, its omnipresence as well as the transportation of energy and the interaction with matter. A special focus is set on the interaction with the human body.
(2) Following the work of Haagen-Schützenhöfer (2016), electromagnetic radiation is represented as cone-shaped radiation beams. It is neither introduced as waves nor as particles. Instead, electromagnetic radiation is characterised by its properties.
(3) To explain the various effects of electromagnetic radiation on matter, the concept of energy is used. Afterwards, the spectrum is introduced as a map in which the different types of radiations are classified by the energy they transport.
Key Ideas
Based on the design guidelines, three key ideas were formulated. The first idea is the distinction between matter and radiation and is rooted in the work of Wiener et al. (2015) on particle physics. The second idea describes the interaction of electromagnetic radiation with matter by looking at the transmission, absorption and reflection of the radiation. The third idea explains that sources of radiation emit energy. The radiation carries energy – if something absorbs radiation, the energy is transferred to the object.

Preliminary findings
The key ideas described in the section above were evaluated through teaching experiments. Five eighth grade students and one seventh grade student participated in the trial. The results of the content analysis were depicted in a profile matrix (see Fig. 1). The results show that adapting concepts of optics for the development of the TLS is a promising approach: The students approve of the presented explanations and were able to solve most tasks. The aim of the first key idea, to present students an explanation of the term “electromagnetic radiation” they find plausible, was archived in a satisfactory way.

The context of radio waves often triggered preconceptions that don’t align with the intended physical concept. It was decided to implement the context of mobile communication instead. Additionally, connecting the concepts of energy and radiation proofed to be difficult for students. The key idea was revised to be more linguistic accurate. The term “heat” will be avoided in future developments, as students got confused with the concepts of heat and energy. A special focus of future investigations will be set on this aspect. Teaching experiments to evaluate the revised key ideas are currently conducted.

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<th>Introduction of the term EMR</th>
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<td>Rephrasing the explanation about the transfer of energy from the sun to our planet</td>
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<td>Connecting the impact of EMR on the human body and the transferred energy</td>
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Fig. 1: The results of the first teaching experiments depicted in a profile matrix (EMR = electromagnetic radiation).
Publication bibliography


Aristarchus

Mentors: Sevil Akaygun, Koos Kortland
Study Culture and Study Practices of First-year University Students

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Focus of the project

The transition from upper secondary school to higher education can be experienced as a challenging process by first-year students (Holmegaard, Madsen, & Ulriksen, 2014; Trotter, Roberts, & Development, 2006). Not only do they enter a new institutional context where they meet new teaching formats, curriculum and expectations (Yorke & Longden, 2007), they must also cope with meeting the cultural aspects of the study programme; in particular how to fit into what they experience as viable ways of navigating in terms of reaching a sense of belonging (Holmegaard et al., 2014; Kith & Love, 2000). In the literature on first-year in higher education there have been a strong focus on retention (Ulriksen, Madsen, & Holmegaard, 2010). However the problem with drop-out is not the only reason why the first year is an interesting field of research. It is within the first year that the students establish their study practice, build their academic identity and learn how to become a student (Ulriksen et al., 2010). The meeting of first year can be described as an integration process with two dimensions; academic and social (Tinto, 1993). In this project, academic integration processes are approached through a focus on students’ meeting with the teaching and learning regimes (Bager-Elshborg, 2017; Trowler & Cooper, 2002) and the “ways of thinking and practicing” (Hounsell & Hounsell, 2007) within the discipline and the study culture. The students must learn to “decode” the new culture, and to act according to the existing, but often implicit assumptions and discursive repertoires (Trowler & Cooper, 2002). This means learning how to talk, navigate, participate, and learning how to practice ‘student’ in ways that are accepted as the legitimate ways within the discipline. Turning to understand the social integration process, Tinto points to the part of the integration that takes place outside the classroom, including more subtle social processes. Integration processes should be perceived as dynamically interacting rather than two separate dimensions. The aim in my Ph.D.-project is to investigate the study cultures and study practices of first-year university students. I am interested in the meeting between the students and the study programmes they are entering. In the project I follow the first year-students of three different study programmes (bachelor level) at the University of Copenhagen: Biology-Biotechnology, Philosophy and Film and Media studies (cohorts of 2018 and 2019).

Research question: How are study culture and study practices developed and negotiated among first year students in the encounter with the study programme and during the first semester in three BA programmes at University of Copenhagen?
Sub-questions: (a) Which study practices are recognized as respectively legitimate and illegitimate to be acknowledged as ‘an appropriate student’ with in the three different study programmes? (b) How is traditions and ‘the ways of practicing and thinking’ in the study cultures transmitted and maintained? (c) Which possibilities does the first-year students have on the way they can resist, redefine and negotiate the study culture – and where are the limits?

**Research design and methodology**

The project draws on a combination of different qualitative methods to gain access to a more nuanced and complex understanding of the study culture and study practices of first year students. The study programmes are selected to ensure a variation in the student populations, in the weighting of theory, experimental and practical elements and a spreading in the scientific area. The programmes are all a part of the University of Copenhagen and they enroll 60-80 students each per year. To get insight into the practices and “ways of doing” participant observations is done in the introduction week, lectures, lab exercises, group work, extracurricular activities such as Friday bar and ‘movie night’. Group interviews were conducted with tutors to gain knowledge about the traditions and conveyed by in the introduction week. To gain access to the students’ expectations and first impressions of the study programme, they were invited to a workshop in the second week of the semester. The workshop included both an individual part with questions about choices, expectations and a group part where the differences between upper secondary school and university were discussed. To gain access to the personal experiences and the processes of integration, 20 students volunteered to do a short video diaries five times during the first semester (Noer, 2014). The students are selected based on their responses in the workshop and on criteria of diversity in their expectations and attitudes towards the study programme and themselves as students (Flyvbjerg, 2006). The videos are recorded by the students themselves in their home setting, and they are invited to share their experiences with both social and academic aspects of the study and about the challenges, doubts and joys they encounter. After the final diary in-depths individual interviews will be conducted with the students, here they will be presented to sequences from their videos and asked to elaborate about their experiences, thoughts etc. In the beginning of second semester I will organize a “mapping your university” workshop, where the students are invited to make a visual map of the university and discuss the practices and the norms within their study programme. In analyzing the data a thematic analytic approach will be applied (Clarke & Braun, 2014). The analysis will search for themes across and within the three study programmes. Data will be coded in Nvivo. The selection of three study programmes both within and without of science will enable the analytical benefit of contrasting and comparing between the study cultures. In analyzing the data the more personal accounts from video diaries and interviews will be related to the practices and interactions in the study culture observed during the academic and social activities.
Preliminary findings Traditions as a way to maintain and promote a study culture: The fake mathematical lecture

In the workshop the new students are asked about their expectations and first impressions of the study programme. When asked what they expect to be challenging several of the students answer the level in math and how fast it goes; “math has always been a challenge”, “I’m surprised of how fast everything goes”, “In math there are a very high speed...”. The responses to what they look forward to is much dominated by “laboratory work”: “I am looking much forward to going in laboratory”, “lab exercises”, “lab” etc. and one student explicitly writes: “when the math course is done”. The workshop data indicates that a lot of the students find math difficult, have troubles following the speed of the lectures, and look forward to go into lab and to the more biotechnology specific parts of curriculum.

In the study programme Biology-Biotechnology the students are welcomed the very first day of the introduction week with a tour of the campus. The tour ends in a huge auditorium where the students are told to start calculating mathematical exercises. After 10 minutes of calculating the teacher starts lecturing about differential equations referring to the content as high school knowledge, they should all know very well. The students do not know, that the curriculum they are being presented for is actually not what they are expected to know by the start, but instead by the end of the semester. Every year for 30 years the students are exposed to this chock of “the fake lecture” as the first encounter with academic content of their study programme. In the group interview the older students describe it as a rough and frightening start, yet being a part of upholding the tradition. With this knowledge about the students’ expectations and experiences “the chock math lecture” might risk to enlarge the fear for the mathematics instead of reassure them, that it will be fine. When the introduction to this part of curriculum is made solely as a prank to chock it risks to have a negative effect on the students’ encounter with the study programme. Research about transitions into STEM Higher Education shows that students meet a gap between what they expect and what they meet (Ulriksen, Holmegaard, & Madsen, 2013) and that the ‘toolbox courses’ like mathematics can be experienced by the students as not explicitly connected to the specific discipline they chose (Ulriksen, Holmegaard, & Madsen, 2016). In light of this it can be discussed whether ‘the fake math lecture’ is productive or counterproductive in giving the new students a fruitful first experience with their study programme. New students are often in doubt whether they have chosen the right programme (Herrmann, Troelsen, & Bager-Elsborg, 2015) and seek to be confirmed that they are on “the right track”. They are in a vulnerable position as wanting to fit in and with the possible doubts the students have about whether their choice is right or not the math lecture might enlarge the doubts.

I am currently investigating the meanings and consequences of these traditions and the implications for the study cultures and the initial impressions the first year student get.
By the time of the ESERA Summer School 2019 I have produced the majority of the data and are in the phase of analyzing and writing the first publication.

**Literature:**


Well, that shouldn’t have happened – What to do when school experiments don’t work out as intended?

Christoph Holz

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Introduction

Physics experiments are critical elements of physics teaching in more than one way: Critical in a sense of understanding physics (e.g. Harlen, 1999; Tesch & Duit 2002), but also in a sense of being risky and potentially distressing as experiments do not necessarily work out as planned. Especially quantitative experiments can be emphasized in this matter since theoretically expected values often are not and cannot be found. Dealt with appropriately, this can give way to address physics methodologies and the uncertainty of measurements resulting in promising situations for teaching the nature of physics (Heinicke, Glomski, Priemer & Rieß, 2010).

In an on action view of dealing with uncertain data, a lack of a firm understanding of the uncertainty of measurements can already be seen in university practicals (Seré, M.-G.; Journeaux, R.; Larcher, C. ,1993; Heinicke & Riess, 2009). Moreover, a lack of competencies to address uncertain data in teaching settings has been found even in experienced teachers using video vignettes (Rührig & Hötting, 2015).

Dealing with uncertain data in actual teaching situations (in action) adds difficulties to already challenging situations. It puts a high strain on physics teachers since they quickly either have to “fix the problem” or think of some effective way to remedy the situation (a methodological approach to such a situation is seldomly seen). Pressure due to limited time and the need to act leads to stress (e.g. Wahl, 1991). As a result, some physics teachers might decide to replace real experiments with videos, simulations or applets - thereby reducing opportunities for learning experimental or evaluation competencies that are central in scientific literacy. Research of actual teaching situations (in action) dealing with uncertain data seems to be lacking.

In the presented study, we analyse these experimental situations with a multi-method approach including in action as well as on action aspects to create a foothold in this research field. This basis can be used for further research and to design learning environments for training preservice teachers to deal uncertain data more effectively and appropriately.

Review of relevant literature and theoretical framework

Stressful teaching situations in general have been moderately well-researched (e.g. McIntyre, McIntyre & Francis, 2017; Brenner, Wallius, 1985; Wahl 1991), but respective studies usually focus on classroom management and pedagogical difficulties as causes of stressful situations or general occupational stress and burnout. Since physics (or more generally science classes) stand out in the inclusion of practical work and
experiments, which as described above can also be possible causes of stress, this direction should also be addressed in research. On this topic, however, little is yet known.

As a theoretical framework, the model of general acting and decision-making that precede stress by LAZARUS (1991) was adapted for this study. This model has also been previously used in the context of teachers’ acting (see e.g. WAHL, 1991). Essence of these approaches is the subjective and implicit nature of decisions which have several key specifications for a learning environment targeting said situations as well as for further research. Self-efficacy and subjective perception of a situation will deeply impact the actions in these (LAZARUS, 1991; BANDURA, 1997). This can be expected to be one of the causes for the discrepancy of reasoning in versus on action since especially in stressful situations explicitly learned contents, strategies etc. seem to often be neglected in favour of implicit theories (WAHL, 1991).

A similar effect is also found outside of teaching contexts in students reasoning in and on experimental situations where experimental data is handled (HEINICKE & RIESS, 2012).

To successfully create a base for further research both in action and on action aspects as well as the connection of both should be included.

**Resulting research questions**

The research and thereby the research questions are split in two: The first part concerns the empirical research of preservice teachers’ dealing with uncertain data. In a second part a classification of teaching types via a broad spectrum of methods and characteristics is performed.

*First research question:*

How do preservice physics teachers deal with encounters of uncertain experimental data in teaching situations and which problems arise in doing so?

*Second research question:*

Which types of preservice teachers can be pointed out in dealing with uncertain data and which factors can this be ascribed to?

**Research design and methods**

*First research question:*

The categorization of possible ways of dealing with uncertain data is realised via qualitative content analysis of videos of preservice teachers in situations of physics experiments. Complementary to these videos, written self-reflections directly after the interventions as well as after watching the videotapes are surveyed to take into account the personal experience of each participant. To ensure a valid categorization, the analyses are both validated in terms of standard interrater processes as well as interrated by each respective proband.

The videotaped teaching sequences are obtained during a specific existing university course in which preservice physics teachers gain practical teaching experience in complexity-reduced microteaching events.
Second research question:
This research question is approached using a broad spectrum of methods. The expected discrepancy between actions in teaching situations and the reasoning on them makes up the basis for the study design. To successfully open up this research field both sides need to be addressed. The aforementioned videos are used to realize the in action part of dealing with uncertain data. The on action side is surveyed by testing the knowledge of physics methods in dealing with (HEINICKE, 2012) and the attitude towards uncertain data (HOLZ & HEINICKE, 2018).
Exploring both sides in itself is not enough to paint a complete picture of this research field. The connection of both sides is included via interviews of the students in which excerpts of their videos are discussed. Moreover, a fixed unit is taught (in action) which can be directly compared with a written vignette (on action) of it. Additional attributes are surveyed to give a broad grounding for the typification: Self-efficacy towards the use of experiments (MEINHARDT, 2018), Intolerance of Uncertainty (CARLETON, NORTON & ASMUNDSON, 2007) and further self-assessments.
This broad set of data is used to discern different types of dealing with these experimental situations. Since the data acquisition happens during a single university course. Each student can be traced through all sets of data, thereby allowing an in-depth qualitative typification.

Primary findings
A first set of about 80 videos of preservice teachers in micro-teachings – teaching with quantitative experiments - was generated which after analysis led to general categories of underlying problems to be addressed in a designed learning environment or specific modules. These categories include insufficient or inadequate preparation of experiments or lessons, insufficient theoretical knowledge (regarding content, nature of measurements, possible perturbations), suboptimal didactical decisions (choice of experimental materials, structure), no clear definition or awareness of teaching goals and no anticipatory moderation. Students also significantly tend to deal with uncertain data fairly late during a given unit. Handling it will be in many cases postponed to the interpretation of said data. In such cases a strictly argumentative approach is used to deal with the uncertain data, while physics methodologies are rarely used.
Towards a typification a primary set of data has also been generated but has yet to be evaluated fully. Since the extent of differing types and sets of data is large the bundling of these types is challenging. One possible approach is to follow and analyse single students answers and characteristics throughout big parts of the given set to discern “extreme” and indicative types.

Prospects
At the summer school, results of the first cycle of the main study will be presented concerning both the categories of causes and underlying problems as well as first
experiences about the subsequent learning environment by means of students’ feedback. First approaches to the large set of differing data as well as findings of specific parts can be presented. Insights and feedback towards further evaluation of said big set off data, specifically concerning the planned typification throughout it could help the progress of the study.

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Interpretation and utilization of written feedback by elementary students working on science investigation tasks

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Introduction
Assessment is a primary emphasis of policy makers and is mentioned in educational policy documents of science (National Research Council, 2012). It has an important role in education and learning (Black & Wiliam, 2009). There are different types of educational assessment, such as formative assessment which occurs during teaching and influences teaching (Black, 2010). Formative assessment has been recognized as a powerful teaching practice for teaching Natural Sciences and essential for reaching NRC stakeholders (Kloser, 2014). The present study will focus on formative assessment and particularly on written feedback method provided by the teacher to the students.

Problem
During the last five decades, a wealth of studies has been conducted that revolve around feedback and its role in learning (Brookhart, 2008). The effectiveness of feedback as a means of formative assessment is contingent on two conditions. The first pertains to the content of feedback per se and its potential to provide students with appropriate support and guidance as to how to move toward the learning goals (Nicol, 2011). The second condition relates to the need for the students to actually and genuinely engage with the process of interpreting, and acting on, the feedback (Jonsson, 2013). Many studies were conducted to investigate the first condition. Nevertheless, significantly less attention was paid to investigating parameters regarding productive utilization of feedback by students (Ruiz-Primo&Li, 2013). Consequently therefore, further research is needed to investigate the use of teachers' feedback by students.

Literature review
Formative assessment is an emphasis on educational policy documents and programs of professional development (Bell & Cowie, 2001). This teaching practice results from the collection of information on the progress of students (elicit information), i.e. their current learning approach in relation to the learning objectives, the difficulties they encounter, their educational needs, etc. Then, this information is interpreted (making inferences) and utilized by teachers to adapt the process of teaching and learning in order to meet the students’ needs (Black & Wiliam, 2009). Formative assessment can take place through a range of forms, including, for instance, written-feedback by the teacher, peer-feedback among students, self-assessment. This research focuses on written feedback method. One of the many actions that can occur in the methods of formative assessment is to provide feedback to students (Brookhart, 2008). Ramaprasad (1983) defined
feedback as the information about the discrepancy between what is understood by the learner and what is expected by him to understand.

The feedback is effective under certain conditions. One important condition is the quality of feedback (Nicol, 2011). Apart from the feedback’s quality, the extent to which it will serve to facilitate learning is strongly influenced by the extent to which students will act on it (Jonsson, 2013). During the last decade, research on written feedback has been approached from different perspectives. One perspective is focused on the feedback of the teacher (Nicol, 2011). Research has been concentrated on teacher and specifically on the content of feedback comments (Ajjawi & Boud, 2017). Many researchers have sought to delineate the characteristics of effective feedback and this has led to important insights (Hattie & Timperley, 2007). There are researchers who studied teachers’ challenges while writing comments on the basis of the characteristics of effective feedback (Holmeier, Grob, Nielsen, Ronnebeck, & Ropohl, 2018). The second condition concerns the use of feedback by the students. This latter condition has not received consistent or extensive attention so far (Ajjawi & Boud, 2017). Also, the studies examine solely college students (Evans, 2013). The few studies that have been published so far have mainly focused on learners’ self-reporting on the utility of the feedback they receive (Ruiz-Primo & Li, 2013).

Purpose and research questions
The purpose of the present study lies in examining the use of teacher’s written feedback comments by elementary students during the process of designing and conducting science investigations with authentic data. This study aims to answer the following research questions:

1) Are elementary students able to decode and interpret written feedback comments?
   -What kind of difficulties do they face while decoding and interpreting written feedback comments that may impede a productive utilization of comments?

2) What factors facilitate or impede the productive utilization of written feedback (e.g. insistence to improve the initial answer, ability to decode and interpret written feedback comments)?

Participants
A pilot study was conducted and involved 11 elementary students attending a public school in Cyprus. The school was selected by convenience sampling. The teacher was selected through purposive sampling, based on the following criterion: the teacher teaches in upper-elementary grades (4th - 6th) as this group age of students can study descriptive feedback comments. More data will be collected to enrich the existing one.
Instructional setting
The students worked in groups (3-4) with investigation tasks on the topic of heat and temperature and friction. Students were asked to design a valid experiment where one variable is changed, one other is measured and all the other variables that may influence the outcome of the experiment are kept constant. The students’ work was collected and the teacher provided descriptive written feedback by taking into account three dimensions documented in the literature: a) what the students have achieved, b) what they have yet to achieve and c) how to proceed (Holmeier et al., 2018). Then, the students were given time to discuss and decode the feedback (color coding), revise their initial response accordingly and noting the changes they have made in their work.

Data sources
The data of the study were collected through a variety of sources, namely: a) students’ decoding of written feedback comments (underlining with different color the three dimensions described above) b) students’ initial and revised artefacts, c) video recordings of students’ discussions while decoding/interpreting and using teacher’s feedback in groups, d) students’ noting of the changes made in the artifact and e) individual semi-structured interviews with students. For answering the first research question we used the sources a, c and e and for the second one the b, c and d.

Data analysis
To ensure that the given written feedback comments were effective and considered the characteristics of effective feedback were coded by the researcher based on the three dimensions mentioned above. Students’ decoding written feedback comments were compared with researcher’s coding of written feedback comments (descriptive statistics). To analyse students’ initial and revised artefacts applied phenomenography analysis. Video recordings of students’ group discussions were analysed qualitatively. Firstly, the unit of analysis was the whole discussion in order to identify the episodes where students discussed each different feedback comment. Secondly, the unit of analysis was the sentence. We used constant comparative method both for the video episodes and for the student interviews. Students’ noting of the changes made in the artifact were analysed qualitatively.

Preliminary findings
The findings revealed that students had difficulties in decoding and interpreting teacher’s feedback comments. Many of teacher’s comments were decoded in an erroneous manner (27/70). Those comments concerned what they had not made entirely correct and how to proceed to improve their answer. In contrast, they did not face difficulties to decode comments that identified aspects of good work. Based on the video discussions, the students faced difficulties regarding feedback comment, procedural and substantial difficulties regarding decoding. These difficulties were in line with students’ self-reports. Table 1 provides an overview of the codes for each category. We present code 1.1 in
Students reject the usefulness of written feedback comments. The following expert from interviews is indicative:

*This comment was not useful because we knew it. It did not tell us something that it was useful to improve our answer.* [S7, line. 19]

Table 1. Students’ Difficulties while Decoding and Interpreting Written Feedback Comments

<table>
<thead>
<tr>
<th>Difficulties regarding Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reject the usefulness of written feedback comments</td>
</tr>
<tr>
<td>2. Do not understand the context of initial artefact and feedback comments given (for this reason do not understand feedback comment)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Logistic Difficulties regarding Decoding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Difficult to use colors to decode feedback comments:</td>
</tr>
<tr>
<td>1.1. Misunderstand the colors for decoding</td>
</tr>
<tr>
<td>1.2. Forget the colors for decoding</td>
</tr>
<tr>
<td>1.3. Do not understand the different function of the colors</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Substantial Difficulties regarding Decoding</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1. Focus on superficial elements like words or syntax instead of essential elements</td>
</tr>
<tr>
<td>3.2. Do not distinguish the comments which provide suggestion about how to proceed and the comments which concern errors or omissions</td>
</tr>
</tbody>
</table>

References


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Exploring the experiences of children in science leadership teams

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Outline

This study is a narrative inquiry, with the aim of exploring the experiences of children aged nine to eleven from low-income families in London, England, as they take part in Child Science Leadership Teams (CSLTs). Of particular interest to this study are how these experiences affect the way the children perceive science, scientists, and themselves in relation to science.

The disparities in university attendance according to family income in England are striking. Only 22% of pupils eligible for Free School Meals (abbreviated as FSM, a measure used in the UK as a proxy for low family income) attend university, compared with 39% of those who are not eligible for FSM (DfE, 2016). When it comes to science, the current picture looks particularly bad - the most recent national standardised data on children’s science attainment at age eleven found that only one in ten children eligible for FSM met the Department for Education’s science expectations for their age group (DfE, 2017). This compares with one in four of children not eligible for FSM, which in itself is a figure so low that it should be a cause for concern.

I currently work a primary school, with pupils aged four to eleven, as a Scientist in Residence. As part of this role I develop, support and facilitate teams of children to investigate their own scientific questions, carry out authentic scientific research, and lead science enrichment across the school. I call these teams of children ‘Child Science Leadership Teams’, or CSLTs. Attitudinal surveys that I have given children in CSLTs over the past four years have informed my practice, but also made me think more deeply about how children’s experiences in and out of school shape their perceptions of science, scientists, and whether they themselves could one day be scientists – their science identity - and which of these experiences can be orchestrated, or facilitated, by teachers. A desire to examine this rigorously, with a focus on children who are eligible for FSM, is what motivated me to begin my doctoral studies.

Brief review of relevant literature

A number of relevant areas of literature – science aspirations, identity, capital, and self-concept - overlap, and can provide different perspectives, or what I think of as “lenses”, from which to consider my research area.

In particular, two recent large-scale UK-based projects, ASPIRES (UCL, 2019) and UPMAP (UCL, 2018), have provided helpful starting points for thinking about why some
pupils choose to pursue science subjects when they become optional - and why others do not. The ASPIRES research team have built on Bourdieu’s work to develop the idea of ‘science capital’, whereas UPMAP surveyed pupils to find out about the relative effects of intrinsic and extrinsic motivational factors.

Mujtaba and Reiss (2014) found, as part of the UPMAP study, that encouragement from teachers was a key driver in pupils choosing to pursue physics to post-compulsory level, whilst DeWitt and Archer (2015) of the ASPIRES team highlighted that “parental attitudes to science and attitudes to school science had the strongest relationships with aspirations in science, followed by the association between aspirations and self-concept in science.”

It is worth noting that there is a significant gender imbalance among the pupils who pursue physics beyond compulsory level (IOP, 2018). Whilst this is not the focus of my research, I recognise that it is very possible that it will emerge as a theme once I conduct my analysis.

Informed by my understanding of the literature, in addition to my experience as a practitioner, I have developed an analogy to simply illustrate how a range of internal, external, personal and structural factors inform a pupil’s post-compulsory subject choices, and eventual career choices. I see this analogy as a conceptual framework, or tool, to identify where teachers might be able to make change happen. Based on this framework, I consider it possible that the experiences that pupils have in child science leadership teams might change the way they think of science and scientists, and their science identity. This tool is also one that I will use in interviews with children to help me understand the extent to which the literature fits with their experiences.

**Research questions**

How do children’s experiences in CSLTs affect (1) their perceptions of science, (2) their perceptions of scientists, (3) their science identity?

**Outline research design and methods**

In seeking to understand children’s experiences, I determined early on that a qualitative approach would be most appropriate. Whilst quantitative methods can be incredibly useful in identifying patterns and correlations on a large scale, they are less relevant when addressing research questions about causality, understanding experience and mechanisms. The focus of my research questions on experience and identity, and the consequent need for rich data with room for complexity, led me to narrative inquiry. Throughout the process of designing my research I have been guided by Clandinin and Connelly’s assertion that “the narrative inquirer does not prescribe general applications and uses but rather creates texts that, when well done, offer readers a place to imagine their own uses and applications” (2000: 43). Unfamiliar as it has been to me, with my background in physics, I have come to recognise that it would be unreasonable to expect this study to lead to generalisable or reliable findings. Instead I am interested in the trustworthiness of my field texts and the verisimilitude of the stories I compose from them.
– in the words of Amsterdam and Bruner, “they will be true enough if they ring true.” (2007: 30).

My field texts will consist of interviews with participants as well as scrapbooks, my pre-existing work records pertaining to participants, and a research diary. From these I will compose research texts telling the stories of up to five participants.

My participants are children who are currently, or have in the past been, in CSLTs that I have facilitated, as well as their family members. They will be aged between nine and fifteen. Children who are eligible for FSM will be invited to be a part of the main study group. Participants will be interviewed, the children singly or in pairs according to their requests. The interview questions will be piloted through the use of focus groups involving pupils and parents / carers who meet most but not all of the criteria for the main study group (children who were part of the child leadership teams, but who are not eligible for FSM). Participants in these focus groups will be invited to suggest changes to the final questions and improve the research design.

The interview will consist of several parts, each designed to address the research questions relevant to each interviewee from different angles. The bulk of the interview will consist of the interviewees being asked to tell a story – either their story, about their experience of being in the CSLT, or their child’s story. To support this, there will be a scrapbook with pictures and texts relevant to the year they spent in the science leadership team. One part of the interview will include a card sort activity to find out how interviewees think of scientists, and to what degree they think of themselves in a similar / different way. After preliminary analysis, follow-up interviews may be requested to clarify or validate findings. I received ethical approval to begin my study in December 2018, upon which I carried out pilot interviews, the data from which is being analysed during spring and summer 2019.

**Preliminary findings**

I carried out pilot interviews during December 2018, analysis of which will inform interview questions and plans. I will carry out interviews with main study participants during June and July 2019, so will have preliminary findings by August 2019.

**References**


Characterization of secondary school STEM projects from scientific practices framework

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Introduction
Throughout the last decades, in the Catalan region there has been a bottom up innovation movement scaling up from primary education to secondary education (https://www.escolanova21.cat/english). This movement is mainly triggered by the recognition of many schools and teachers of the growing necessity to engage learners into active methodologies from a competence-based framework.

In many Catalan secondary schools, the introduction of innovative active methodologies results in the adoption of the Project-Based Learning (PBL) approach. Being a widespread methodological choice, there is a wide diversity of PBL approaches being used, showing strong differences in managerial and pedagogical aspects such as time intensity and structure, degree of interdisciplinary, etc.

Within this context, from the Science Education point of view there are concerns about how science teaching and learning unfolds in these innovative PBL environments. Whether in educational research conferences, teacher education events or informal teachers meetings, many questions arise regarding the benefits but also limitations of the PBL introduction for Science education in our schools.

Our research is devoted to exploring this situation from two standpoints. First, that PBL was introduced with the aim to shift schools towards competence-based learning, so it would be necessary to explore how scientific competences are taken into account in the innovative scenarios. Second, that in science education research and literature there is a certain consensus regarding useful frameworks for understanding scientific teaching and learning, such as the scientific practices framework (NRC, 2012), which could be or not part of the innovative effort.

Theoretical Framework
Understanding that everybody should be given the chance to learn science fostered a shift towards scientific literacy in the 70s and 80s. Science-Technology-Society and Science in Context are examples of how this shift was materialised. These movements supposed a settlement to further develop a global definition for scientific literacy as the one given by the competence-based PISA Framework (OECD, 2016). As such, we can understand scientific competences as an operational learning goal of any science education effort that aims to achieve scientific literacy. The competence definition unfolds in 3 key scientific competences that can clearly connect to the different dimensions of the scientific practices framework (Crujeiras, 2014), which has received
special attention in the Science Education field, by encompassing three spheres of school scientific activity: modelling, inquiry and argumentation (Osborne 2014).

As a consequence, in our viewpoint developing scientific competence is tightly connected with the participation in (school) scientific practices. The framework is based on the idea that the cognitive, social and discursive activity that takes place in the science classroom should resemble the cognitive, social and discursive processes of real science (NRC, 2012). As such, the scientific practices framework implies a change in the curricular focus from the products (facts, concepts, ...) to the processes (develop investigations, modelling phenomena, ...) of science (Grandy & Duschl, 2012), focusing in the epistemic dimension of science education (Jiménez-Aleixandre, 2012). This change is justified both in terms of the socio-cultural theories of learning and the aim for epistemic coherence with new ideas on the Nature of Science (NOS) (Osborne 2014).

In the last curricular proposal of USA, where this framework is used, scientific practices are combined with core ideas in Science as learning objectives, following the line of reasoning of Harlem and colleagues when proposing a scientific education centred on key or big ideas of and about science (Harlem, 2010).

Promoting scientific practices in PBL environments, also known as Project-Based Science (PBS), has also been under study for some researches (Krajcik & Shin, 2014) which outline the importance of having well defined learning goals that blend the selection of core ideas and scientific practices as content focus.

In a wider perspective, PBS has been widely characterized by several well-defined elements: a) an inquiry process, triggered by a b) driving question and c) a culminating final product or action (Hasni, 2016). Research on PBL outlines the necessity to scaffold knowledge construction (Kanter, 2010), discussion supports (Alozie, Moje & Krajcik, 2010) and self-learning regulation (English & Kitsantas, 2013). In many cases PBS are integrated into a STEM (Science, Technology, Engineering and Mathematics) approach (Capraro & Slough, 2013), which can mislead the content focus (Edmunds, 2017).

**Research Questions**

In order to explore the PBL introduction in the Science classroom in our context, this thesis is structured in two main studies. The first study aims to understand which remarkable elements (referred as aspects) are present in current STEM projects and how these different aspects may vary through teachers reported views. The following research questions are posed from the perspective of the scientific practices framework to achieve scientific competence: 1) Which are the key aspects that characterise current STEM projects for secondary school? 2) What different teacher views can be identified for each key aspect characterising current STEM projects? and 3) How can these different views on key aspects characterising current STEM projects be organised in levels according to their coherence with the scientific practices framework?
The second study will narrow the investigation scope to centre the attention on the evolution process of a particular secondary school which is moving from a traditional perspective of teaching and learning towards a PBL approach within a mentoring programme. Therefore, a fourth research question is: 4) In which ways can expert school mentoring improve STEM projects design?

In the following, we will refer only to study 1 methodology and initial results, as we are yet to carefully precise and develop this second study to its fullest.

**Methods**

For this study we considered two qualitative data sources. To answer the first and second research question, we chose 6 leading STEM teachers who actively participate in PBL design and enactment and could demonstrate expertise by long PBL experience as practitioners, participating in teacher training events and even publishing in the field. For the third research question, a sample of 16 STEM projects were chosen from a network of newly founded secondary schools. 4 STEM project sequences were chosen from each of the 4 secondary schools working on PBL at random (4x4).

**Data Collection**

The participants were interviewed following a semi-structured protocol to gather their views on different aspects regarding science teaching and learning with PBL approach, such as level of (inter)disciplinarity, content, contextualization, authenticity, final action, assessment and classroom management. Interviews were audio recorded and transcribed.

The project sample was obtained through the schools’ website downloading and virtual sharing of the available teaching materials (regarding teaching programs, specific project activities, evaluation activities, etc). Information from each project was summarised for a global project overview.

**Data Analysis**

An interpretative approach to analysing both sets of qualitative data was adopted based on the constant comparative method that combines both inductive and deductive analysis (Miles, Huberman, & Saldana, 2014). In the first study, data was reduced and interpreted following both a bottom-up and theoretical-based strategy, consisting on fragmentising, conceptualising and reassembling participants’ and literature ideas to identify convergence and divergence of views, an relate them to different aspects.

To answer the third research question, the construction of a rubric that organises the coherence between emerging teacher views and our theoretical perspective was proposed. Four quality levels were developed ranging from those views closer to the scientific practices framework to those more distant in meaning.
The emerging categories, views and levels where then validated in a 3-step group
discussion with science education research experts and experienced teachers where half
of the interviewed participants were also present.

**Preliminary Results**

Regarding the first and second research question, participants reflected on different aspects that could be rearranged from theory in 7 dimensions: learning goals, content, context, action, classroom practices, assessment and collaboration.

Participants showed agreement on the benefits of PBL methodology for developing 21st century skills. Most of them stressed creativity as a key competence associated with PBL but they showed distinctive visions on where learners could be creative. Some of them stressed creativity referring to the final product creation in a general sense (P2 said: *In many creative moments they had to decide which Leonardo Da Vinci invent they would like to robotise*), while others focused on creativity within science, for instance on experimental design (P5 describes a teaching scene where learners design their own research questions as a key point to use their imagination).

Regarding the content dimension, participants showed disagreement to select contents. Some teachers focused on key Science ideas (P5: *It’s like selecting contents... we’ve tried to work several key things...*) while others focused on ideas merged from the context to bring authenticity to the project (P6: *I first teach some contents about the context*).

Referring to the context dimension, all participants acknowledged its importance to connect with students’ daily lives and foster motivation. Even though, some of them went further on its applicability considering its learning uses. As an example, P4 outlined “the important thing [talking about context] is that they [learners] become aware that some ideas can only appear when you hold some specific knowledge”.

Regarding the third research question, the different achievement levels from the aspects presented above are being organised in a rubric document that can be consulted on the following link: https://sites.google.com/view/stem-pbl-rubic/stem-pbl-rubic

**References**


Teachers’ Beliefs on Learning and Teaching Science Content and Scientific Inquiry

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Focus of the Study
The German standards for science education as well as the standards and curricula of many other countries stress the importance of fostering not only students’ understanding of science content (SC) but also their ability to engage in scientific inquiry (SI; e.g., KMK, 2005; NRC, 1996). It is often assumed that engaging students’ in inquiry activities (inquiry-based instruction) is a suitable teaching strategy to achieve these goals (e.g., NRC, 1996). In fact, inquiry-based instruction plays an important role in German classrooms (e.g., Börlin & Labbude, 2014; Duit & Tesch, 2010). However, findings from video-studies suggest that the focus of inquiry-based instruction is often exclusively on content learning goals, whereas a focus on fostering students’ knowledge and abilities of SI (e.g., control-of-variables strategy) seems to be rare (e.g., Duit & Tesch, 2010). A potential reason for the relatively small focus on knowledge and abilities of SI in teachers’ instructional practices could be their beliefs on learning and teaching of SC and SI (e.g., Pajares, 1992). For instance, most teachers agree that it is important to explicate and explain rules and concepts (e.g., physical laws) at some point during the instruction while teaching SC. In contrast, with respect to SI, teachers seem to assume that students learn corresponding rules (e.g., control-of-variables strategy) without such explanations by merely working on inquiry tasks (Abd-El-Khalick et al., 1998).

Theoretical Framework and Research Questions
Beliefs may be defined as “psychologically-held understandings, premises, or propositions about the world that are felt to be true” (Richardson, 1996, p. 103, emphasis added). In contrast to knowledge, beliefs may be intraindividually contradictory and do not require interindividually consensus (e.g., Richardson, 1996). With respect to teachers’ instructional practice, two specific domains of beliefs are assumed to be of particular importance: (1) teachers’ content-specific beliefs which include beliefs on “appropriate instructional activities, goals, forms of evaluation, and the nature of student learning” (Kagan, 1992, p. 67), (2) teachers’ self-referential beliefs which include “beliefs concerning his or her own ability to perform certain professional tasks” (Kagan, 1992, p. 67). In addition, while teachers’ beliefs on inquiry-based instruction in general are examined in some studies (e.g., Crawford, 2007; Engeln et al., 2013), evidence on their beliefs about fostering SC and SI through inquiry-based instruction is rather rare (e.g. Crawford, 2007). In particular only little is known about how content-specific and self-referential beliefs of teachers differ with respect to whether the aim of instruction is to
foster students’ knowledge and abilities of SC or SI. Research presented in this synopsis aims to address this gap in the literature; the first research question (RQ) is:

RQ1: What are the content-specific and self-referential beliefs of (pre-service) physics teachers about learning and teaching SC and SI?

To investigate to what extent teachers’ beliefs are a potential cause for the difference in their classroom practice, it is important to investigate not only whether beliefs regarding learning and teaching SC and SI differ, but also how that (in)difference relates to their actual performance. While the assumption that the beliefs of teachers influence their actions is frequently made in the literature (e.g., Bandura, 1997; Pajares, 1992; Richardson, 1996), empirical investigations of that assumption have led to mixed results (see overview in, e.g., Fang, 1996; Kagan, 1992; Mansour, 2009). Thus, the question arises whether and how the teachers’ beliefs regarding learning and teaching of SC and SI (RQ1) are related to their actions and their reasoning as they, for instance, plan or analyze instruction.

RQ2: a) What actions and corresponding reasoning are demonstrated by physics teachers while planning and analyzing instruction on SC / SI and b) how do their actions and reasoning differ regarding these two goals?

RQ3: What is the relationship between physics teachers’ beliefs on learning and teaching SC / SI and their actions and reasoning?

Research Design and Methods

The main study consists of two consecutive steps (see Fig. 1): In the first step, teachers’ beliefs on learning and teaching SC and SI are assessed (RQ1). The aim of the second step is to capture the teachers’ actions and reasoning (RQ2) and thereafter to investigate the relationship between beliefs and performance (RQ3). Prior to the main study, a pilot study will be conducted (with approximately $N = 70$ German pre-service teachers) to test, revise, and validate the instruments (see Fig. 1).

Figure 2. Research design and timeline of the project

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1 While the focus of the main study is on in-service teachers, the data from a planned pilot study (see Fig. 1) may be used for analyses as well, as it allows investigating RQ1 for pre-service teachers. The findings on pre-service teachers’ beliefs will be presented at the Summer School.
Step 1: Assessment of (Pre-Service) Teachers’ Beliefs

The teachers’ beliefs regarding the learning and teaching of SC and SI (RQ1) are assessed with an online questionnaire, which is an established and “extremely useful” (Schraw & Olafson, 2015, p. 91) methodological approach in belief research. The questionnaire consists of multiple Likert scales that address teachers’ beliefs on, for instance, the importance of student activity for learning and teaching of SC or SI (see Tab. 1). The items used in the questionnaire are in part adapted from existing instruments (e.g., Seidel et al., 2005), but also comprise a number of self-developed items. Items on SC were formulated as similar as possible to items on SI in all scales to allow for comparative analyses of teachers’ beliefs regarding both learning goals (see examples in Tab. 1).

<table>
<thead>
<tr>
<th>Scale</th>
<th>Example item on science content / scientific inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content-specific</td>
<td>For good teaching of physics content / scientific inquiry, it is important that ...</td>
</tr>
<tr>
<td>Student activity</td>
<td>... the students carry out investigations by themselves.</td>
</tr>
<tr>
<td>Student orientation</td>
<td>... the students’ prior experiences on physics content / scientific inquiry are taken into account.</td>
</tr>
<tr>
<td>Explicit instruction</td>
<td>... physical concepts (e.g., Ohm’s law) / rules for conducting inquiry (e.g., control-of-variables strategy) are elicited and explained to the students.</td>
</tr>
<tr>
<td>Self-referential</td>
<td>I am able to plan lessons on physics content / scientific inquiry that are neither too easy nor too difficult for the majority of students.</td>
</tr>
</tbody>
</table>

Statistical investigation (e.g., t-tests) of similarities and differences between teachers’ beliefs on SC and SI will be conducted on the level of individual items as well as entire scales. In addition, open questions are used to gain an insight into the beliefs teachers express by themselves and without being prompted by the statements in the Likert items. In addition to the questionnaire, a guided interview is conducted with a partial sample. The interview data will be analyzed with a category-based approach (e.g., qualitative content analysis; Mayring, 2014) to triangulate, validate, and complement the results with regard to the addressed beliefs in the questionnaire.

Step 2: Capturing Teachers’ Actions and Reasoning

In the second step, a combination of planning and analyzing tasks will be combined with a guided interview to investigate the extent to which the assessed beliefs correspond with the actions and reasoning of teachers (RQ2 and RQ3). The tasks will be used as a means to analyze teachers’ actions, whereas the interview is supposed to elicit their
reasoning. First, the teachers have to plan a lesson for a specific SC or SI learning goal. Second, they will be asked to analyze a vignette of a hypothetical lesson that targets either SC or SI. After the tasks, teachers will be asked to elicit the reasoning behind their planning decisions and the results of their analyses in a guided interview (e.g., “Why would you proceed like this?”). The vignettes will be developed based on the different teaching strategies, which are addressed in the questionnaire (see Tab. 1), and thus allow a systematic variation of the strategies over the vignettes. As an initial approach to investigate the interview data, a category-based analysis will be conducted that combines categories deduced from the literature (e.g., importance of different strategies for learning and teaching SC / SI like student activity, based on Seidel et al., 2005) as well as categories induced by the data (e.g., Mayring, 2014). Next, the results will be linked to the teachers’ beliefs assessed in step 1 of the study (see above).

Current State and Outlook
So far, the online questionnaire has been developed, field tested with 10 physics teachers, and revised. In addition, multiple qualitative studies (e.g., think-aloud) have been conducted to assess the cognitive validity of the items, scales, and vignettes (Messick, 1995). In a pilot study that will be conducted in January and March 2019 the questionnaire will be administered to approximately $N = 70$ German pre-service physics teachers. Data from the pilot study will be used to develop data analysis techniques as well as to validate and revise the questionnaire (e.g., by investigating the internal structure and reliability of the scales; Messick, 1995). The data from the pilot study will also be analyzed to get insights in pre-service physics teachers beliefs’ on learning and teaching SC and SI (RQ1). Results of the validation and the analyses of pre-service teachers’ beliefs will be presented and discussed at the ESERA Summer School 2019. Furthermore, the Summer School will be used to present and discuss the methodological approach for addressing the assessment of teachers’ actions and their reasoning (RQ2 and RQ3).

References


Improving biology and chemistry pre-service teachers’ use of external representations through feedback

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Introduction
Planning lessons is one of the most common tasks of teachers. Thus, designing instructional materials and representations is part of their daily work (Nerdel, 2017). From a science learner’s perspective, it is necessary to work with representations and to extract information that is relevant for the learning process. As findings from science education research indicate, working with representations represents a great challenge for learners. This does not only apply to students who start to learn science in school but also to university students (Taskin, Bernholt, & Parchmann, 2015a). Especially undergraduate students have persistent difficulties with representations during their whole teacher education. Consequently, there is a need to improve prospective science teachers’ representational competences. This need faces two challenges: (1) On the one hand, the necessary theoretical knowledge is quite complex and expansive as it includes knowledge from cognitive psychology, science education, and the natural sciences. (2) On the other hand, preparing instructional materials is of great practical importance. Therefore, both requirements will be combined in the in-service teacher training for pre-service teachers (PSTs). The following abstract describes an intervention study for in-service teacher training and aims to improve PSTs’ use of representations by means of feedback.

Theoretical background
No matter whether the phenomenon is the evolution of the species or a chemical reaction, representations are an essential communication tool to deliver knowledge about phenomena to students. The use of representations in science is not only characterised by high specialised forms – such as reaction equations – but also by the application of several different representations combined in one material (Kozma & Russell, 1997). These are summed up as “multiple external representations” (MERs; Ainsworth, 2006). Cognitive psychology gives reasons why the use of MERs is important for effective learning. For example, a liquid thermometer can be illustrated on a worksheet with a combination of a text and picture. Students can infer the structure and magnitude of the thermometer through the picture and the description of the function through the text. During reading, the MERs are converted into mental models. At the same time, the elements of the text-based mental model are mapped on the picture-based model, and vice versa. So, the content is embedded twice in students’ working memory (Schnotz & Bannert, 2003).

If the representations are poorly illustrated or if the single representations are not linked, as a result, learning processes are inhibited. Thus, teachers’ representational competences for
preparing instructional materials are indispensable for teaching science effectively (Kozma & Russell, 1997; Nitz, Ainsworth, Nerdel, & Prechtl, 2014). However, studies point out that PSTs have low representational competences and difficulties representing facts and phenomena (Taskin, Bernholt, & Parchmann, 2015b). Especially teaching and illustrating the four levels of representations in biology and chemistry (macro, micro, sub-microscopic and symbolic level) are big challenges (Bucat & Mocerino, 2009). Nevertheless, the use of representations is rarely part of in-service teacher training programs and should be promoted (McElvany et al., 2009).

In Germany, teacher education encompasses two phases; the first phase at university (theory-based) and the second phase as an in-service teacher training (practice-based). After the first phase, having studied two subjects and general pedagogy for 10 semesters, PSTs must pass an in-service teacher training for 18 months. During this period, the PSTs teach under the supervision of a mentor at school. Accompanying, they have seminars in both subjects once a week (MSB NRW, 2016).

Empirical findings confirm the high potential of feedback for educating and training teachers, especially the combination of externally and internally provided performance feedback (Butler & Winne, 1995; Scheeler, Ruhl, & McAfee, 2004). Internal feedback is information that results from the reflection of one’s own performance (e.g. a PST gives feedback to his own). In comparison, external feedback is information that is provided by someone else (e.g. a supervisor gives feedback to a PST). By receiving both forms of feedback, the PSTs can increase the quality of their self-assessment and self-regulation (Butler & Winne, 1995), such as for designing instructional materials.

In addition to the mentioned cognitive dimension of teachers’ professional knowledge about representations, the dimension of beliefs and attitudes is part of professional competence (Baumert & Kunter, 2011). Unlike knowledge, beliefs are considered as being difficult to change because they are developed over a long period of time (Pajares, 1992). However, beliefs have a significant impact on the design of teaching and learning materials (Dubberke, Kunter, McElvany, Brunner, & Baumert, 2008).

**Aim of the study and research questions**

So far, most of the studies on learning with representations have focused on the investigation of students’ problems. The study presented here focuses on the difficulties that PSTs’ have when designing instructional materials. Based on the given theoretical background, an intervention aiming at the improvement of PSTs’ representational competences will be developed and its impact on PSTs’ competences and beliefs will be analysed. The main research questions are:

What are the effects of external and/or internal feedback on

1) the professional and pedagogical content knowledge and

2) the beliefs of PSTs about external representations?
Method and Design
The intervention study will be carried out with a pre-post-follow-up design (cf. Table 1). Dependent variables are professional knowledge about representations and their beliefs about the importance of representations for learning biology and chemistry. Both tests for both subjects will be adapted from already existing test instruments (Kleickmann et al., 2014; Nitz, 2012; Taskin et al., 2015a). In order to analyse the effect of the independent variable, the external and the internal feedback, the sample of $N = 120$ PSTs will be divided into 2x2 subgroups (cf. Table 1). Thus, there is a systematic variation of all feedback types. The external and internal feedback will be provided by an evaluation sheet that was already developed. This sheet contains quality criteria about representations in instructional materials and is applicable for both forms of feedback (Tonyali, 2018). Furthermore, the evaluation sheet helps measuring the quality of the edited MER as another dependent variable in this study.

In the intervention, the PSTs get an input about MER from the perspective of cognitive psychology, science education and natural sciences. Each of the three phases is structured by three stages. First, the PSTs get a short impulse; second, they get a task to edit their worksheet, and finally, they receive the corresponding feedback. This cycle of input, task and feedback will be conducted three times (cf. Table 1). The whole intervention will be implemented in the regular in-service teacher training program of PSTs.

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<tbody>
<tr>
<td>1 Intervention with internal and external feedback $(n = 30)$</td>
<td>Tests of control variables, pre-tests</td>
<td>Phase I</td>
<td>Phase II</td>
<td>Phase III</td>
</tr>
<tr>
<td>2 Intervention with external feedback $(n = 30)$</td>
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<td>3 Intervention with internal feedback $(n = 30)$</td>
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<td></td>
<td></td>
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<tr>
<td>4 Intervention without feedback $(n = 30)$</td>
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</tbody>
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Preliminary findings
The evaluation sheet for internal and external feedback was piloted with PSTs that are about to achieve their master’s degree $(N = 12)$. The sample designed a worksheet for a
default topic whereupon the feedback was provided. On a scale of 1 (low) to 4 (high), the quality of the used MERs was analysed before providing the feedback, $M_{pre} = 2.62$ ($SD = 1.15$) as well as after providing feedback and revising the worksheets based on the feedback, $M_{post} = 3.16$ ($SD = .99$). Even the quality of the internal feedback increased in comparison to the external feedback, $ICC_{pre} = .42-.89$, $ICC_{post} = .72-.97$. Furthermore, the PSTs stated in stimulated recall interviews that they felt more qualified designing and evaluating MER for teaching and learning biology and chemistry (Tonyali, 2018).

These results show first positive impacts of feedback on PSTs’ use of representations. Now, it is necessary to analyse interaction effects between internal and external feedback more precisely as described above for the main study.

**Status and outlook**

The dissertation project started in autumn 2018. Currently, the test instruments for the dependent variables as well as the instructional materials for the intervention are being developed. The instruments and materials will be ready by early 2019, so that the pilot study can follow and the results of this pilot study can be presented at the ESERA Summer School. Furthermore, suggestions for optimizing the main study are desirable which is planned for end 2019.

**References**


Gesetz über die Ausbildung für Lehrämter an öffentlichen Schulen (Lehrerausbildungsgesetz), Ministerium für Schule und Bildung des Landes Nordrhein-Westfalen/(MSB NRW) 04.06.2016.


Heraclitus

Mentors: Renee Schwartz, Andreas Vorholzer
Exploring the nature of creativity in relation to teaching and learning in primary science with consideration of potential insights from arts disciplines

Polly Bell

Oxford Brookes University, UK

Focus of the study

As a qualified primary teacher, I have an interest in understanding how teachers can support and develop creativity (i.e. imaginative activity producing outcomes that are original and relevant in the context in which they emerge). What creativity means in science may starkly contrast to traditional arts (defined as subject areas of art and design, drama, music and dance) where creativity can often be identified through observable, tangible outcomes. Kind and Kind (2007) expounded the benefits of imaginativeness in science while debating this, furthermore they proposed that integrating art into science teaching could be of benefit. When focus shifts from expression in performance to cognitive processes it becomes impossible to directly ‘see’ or isolate creativity, however thinking skills can provide indirect evidence. As Wegerif (2011) asserts, thinking is reflected in language and develops through interactions, justifying the observation of creativity through classroom dialogue and behaviour.

This research examines the nature of similarities and differences in primary science and arts classes in the related but distinct processes of creative teaching and learning. The study intends to scrutinise data with different theories of creativity in mind to discern how creative teaching practices could potentially be incorporated within a trans-disciplinary approach. Moreover, this study investigates how teachers’ expertise and experience in arts or science differs and consequently suggests ways that each could incorporate strategies from the other to thereby strengthen STEAM teaching.

Review of relevant literature

Systematic research is needed relating to how or whether creative teaching approaches are being applied in practice in primary school science. Mullet et al’s (2016) review of the literature revealed that teachers often equate creativity with the arts or performance of some kind and do not feel they are sufficiently prepared to support creativity in their teaching. Even if science is perceived as creative this belief may not be reflected in classroom teaching (Meyer and Lederman, 2013). In science great value can be placed on assimilating knowledge and understanding whereas arts tend to emphasise self-expression. Despite this, Kind and Kind (2007) assert that science is creative despite being rational, and a change in the perspective of teachers may be required to acknowledge this. Researchers including Davies and McGregor (2016) detail
inspirational approaches to the teaching of primary science such as ‘making the ordinary fascinating’, ‘developing a sense of wonder’ and ‘relating science to everyday life’. Additionally, a pan-European research study unearthed key features of play and exploration, motivation and affect, dialogue and collaboration, problem solving and agency, questioning and curiosity, reflection and reasoning, and teacher scaffolding and involvement in early years creativity (Cremin et al, 2015).

Creative teaching may differ between curriculum subjects (Jones and Wyse, 2013) due to curriculum content. For example, Glaveanu (2018) contends that artistic approaches to creativity lend themselves to spontaneity and expressiveness, whereas inventive approaches (often associated with science) more to conscientiousness and practicality, and craft approaches to collaboration. Paradoxically, he stipulates that although artistic and scientific creativity are opposites in some ways, they have commonalities and teachers should remain open to these. Many suggestions for creative teaching in arts subjects and science appear to echo common principles (Sawyer 2012: p.400) which makes logical sense if stages of the creative process are essentially universal (Cropley and Cropley, 2008). Despite this, differences between individual predictors of creative achievement have been found in arts and science (Kaufman et al, 2016). Therefore, it appears likely that subject knowledge and expertise are required (Baer, 2015) as well as domain and task-specific skills (Barbot, Besancon and Lubart, 2016).

The notion that the simple inclusion of arts in science lessons will foster pupil creativity should be questioned. To this end a variety of perspectives will be examined through a questionnaire, observations and interviews to help clarify the complexities and consider whether generalised principles may apply. Exploring the ways that teaching and learning unfold in creative arts and science classrooms may ultimately increase understanding of how they can effectively be integrated to foster learner creativity in a STEAM approach (Colucci-Gray et al, 2017).

**Research questions**

- How do primary teachers employ creative teaching practices in science and the arts?
- What commonalities and differences can be seen in creativity in primary science classes compared to the arts?
- How does having a subject specialism influence creativity in teaching and learning within and beyond this subject?

**Outline of the research design and methods**

This research fits within an interpretivist paradigm, adopting a mixed method approach involving the triangulation of qualitative and quantitative data. A questionnaire relating to creativity in science distributed to science and arts award-winning teachers contained open questions to elicit rich descriptions of experiences of creative teaching and learning
in arts and science. Additionally, Likert scale questions measured the frequency of reported use of specific teaching practices within these subjects. Quantitative data from the questionnaire survey will be analysed with SPSS and qualitative data examined deductively and inductively to ascertain if any patterns are evident that should be focused on in case studies. The questionnaire also presented the opportunity for teachers to volunteer for further involvement.

A successful pilot study has been completed and in spring 2019 three science and three arts key stage 2 curriculum lead teachers will participate in case studies to represent a range of individual approaches, while restricting numbers for manageable data analysis. Participants will have a science and an arts lesson video and audio recorded to witness episodes of teacher-pupil and pupil-pupil dialogue or interactions that appear to illustrate creativity of pupils in primary school lessons (science and arts) through external expressions in dialogue and action. Teacher-pupil relationships are complex and bi-directional with each influencing the other, consequently all teaching as well as dialogue, behaviour and actions of one group of pupil participants in each lesson will be video and audio recorded, noted and transcribed. Transcript analysis will be based on several relevant researcher’s analytical frameworks (to establish how the data fits these), my own adapted from a review of the literature that synthesised findings from the research area and finally, inductively to allow any further insights to emerge.

Additionally, following each observation semi-structured teacher and pupil focus-group interviews will be undertaken. Participants will be presented with question prompts designed to elicit in-depth ‘insider’ reflections on each lesson and creative teaching and learning to assimilate a range of individual perspectives. Interviews will be recorded, transcribed and analysed using category coding techniques utilising the same analytical frameworks as lesson observations, as well as inductively analysed.

**Preliminary findings**

Data collection is currently taking place. Initial analysis of award-winning science teachers’ questionnaire responses demonstrated that they regularly adopt a range of creative teaching practices, although with more frequency in science.

<table>
<thead>
<tr>
<th>Teaching Practice</th>
<th>Science Mean</th>
<th>Std. Dev.</th>
<th>Arts Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taking risks in your teaching</td>
<td>3.96</td>
<td>0.75</td>
<td>3.43</td>
<td>0.94</td>
</tr>
<tr>
<td>Thinking time to develop ideas</td>
<td>4.13</td>
<td>0.77</td>
<td>3.86</td>
<td>0.87</td>
</tr>
<tr>
<td>Including hands-on tasks</td>
<td>4.48</td>
<td>0.54</td>
<td>4.29</td>
<td>0.82</td>
</tr>
<tr>
<td>Variety of activities to explore</td>
<td>3.29</td>
<td>0.85</td>
<td>2.69</td>
<td>0.92</td>
</tr>
<tr>
<td>Time for play</td>
<td>3.58</td>
<td>0.96</td>
<td>3.10</td>
<td>1.12</td>
</tr>
</tbody>
</table>
Further analysis will determine whether these results are statistically significant and how they compare with findings from arts teachers. Case study data should establish how this may be reflected in science and arts classrooms.

References


Exploring the impacts of localizing socioscientific environmental messages through aquarium exhibits

Jennifer Idema
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Outline of Focus
A pillar for the world’s economies, the marine resources provided by oceans support over three billion people globally as a food source. Additionally, over 40% of the world’s populations live within 63 miles of an ocean coastline (NOAA, 2018). As human populations continue to grow, anthropogenic pressures like climate change, pollution, and over-fishing, intensify the burden placed on these marine resources (Clayton et al., 2014). Because each culture and their responses to these types of socioscientific environmental issues are unique, a one-size-fits-all, top-down approach to handling the conservation of natural resources is challenging. Therefore, examining how different communities approach these topics, and how those messages are received and interpreted by the members of those communities, is crucial if humans are to reverse their growing footprint on the planet (Clayton et al., 2014). Using a socioscientific issues framework (Zeidler, 2014), I will examine how aquariums facilitate learning about socioscientific environmental issues through exhibit design and how these messages are interpreted by visitors. I hope to gain insight into how localizing socioscientific environmental issues through exhibits influences perceptions about these issues and marine conservation.

Key terms. Intergenerational family group (IFG). Because the family groups of today can be made of a parent(s) and child(ren), grandparent(s) and child(ren), same-sex parents and child(ren), etc., with ages of members spanning different generations, for the purpose of this study an intergenerational family group is defined as being made up of at least one adult and one child (who appears to be under age 18). Localized socioscientific environmental issues (LSSEI). Messages designed to connect visitors with environmental issues by: linking these issues to a local location, showing visitors the relevancy of these issues in their everyday life, creating awareness on impacts visitors have on these issues, and/or how visitors can take action to change these issues. Socioscientific issues (SSI). Social issues of a controversial nature that are related to science. These issues are generally complex and open ended, with multiple solutions and no right answers (Zeidler, 2014). Exhibits to be studied will contain these types of issues (e.g., impacts of climate change, over-fishing, pollution, illegal wildlife trade, invasive species, etc.).

Literature Review
People have to care about an issue before they are willing to act. However, before people can care, they first need to be informed. Informal Science Institutions (ISI) like zoos & aquariums, are places people visit where they can learn science information in formats they feel are approachable and non-threatening, thus allowing them to engage with science at
levels they feel comfortable with (Bell et al., 2009). One of the largest populations of visitors to these institutions is IFG (Falk & Dierking, 2000). These groups also play a large role in shaping a person’s thoughts and perceptions of science and the world around them (Uzick & Patrick, 2017). If zoos and aquariums are to be considered more than places to view animals, and instead seen as places for conservation and learning (Patrick & Tunnicliffe, 2013), then attention must be brought to these growing environmental issues. Many people feel far removed from these environmental issues, failing to understand how their actions and the actions of the communities in which they live impact (Clayton et al., 2014) marine ecosystems regardless of their distance from an ocean. Consequently, ISI attempt to inform and engage visitors through exhibits that localize environmental issues, in an effort to bring visitors and these issues closer together. With more than 600 million people worldwide visiting zoos and aquariums every year, these places are in a unique position to teach and provide visitors with opportunities to connect with the natural world (Packer & Ballantyne, 2010). Zoos and aquariums can direct the experiences of their visitors through, “...real objects, people, places, or animals; learning is voluntary and is stimulated by the needs and interests of the learner; and they provide a very learner-centered experience which involves exploring and examining, making choices, making personal connections, developing one’s own way of understanding, and controlling one’s own learning environment” (Packer & Ballantyne, 2010, p. 25). The challenge for zoos and aquariums then becomes designing meaningful opportunities for visitor engagement. By localizing socioscientific issues through exhibits, these ISI can potentially increase the relevancy of environmental issues in the lives of visitors. The research questions that guide my study are illustrated in a data matrix (Table 1) to show how each question will be answered with corresponding data collection method.

Table 1. Data matrix: Research questions organized by data sources

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Data Sources</th>
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</thead>
<tbody>
<tr>
<td>RQ1. In what ways do aquariums present SSEI to visitors through exhibits?</td>
<td>Staff Interview</td>
</tr>
<tr>
<td>a. What rationalizations are considered when choosing the socioscientific issue(s) to be featured in the exhibit?</td>
<td>P</td>
</tr>
<tr>
<td>b. What is the intended take-home message of the exhibit?</td>
<td>P</td>
</tr>
<tr>
<td>c. What (if any) trends exist in exhibit design and messaging for SSEI exhibits?</td>
<td>P</td>
</tr>
<tr>
<td>RQ2. How do visitor interpretations of LSSEI exhibits compare to the aquarium’s intended message?</td>
<td>P</td>
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<td>-------------------------------------------------</td>
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<tr>
<td>RQ3. On which aspects of the exhibits do visitors focus?</td>
<td>P</td>
</tr>
<tr>
<td>RQ4. How do intergenerational family groups communicate and interact with one another while engaging with a LSSEI exhibit?</td>
<td></td>
</tr>
<tr>
<td>a. What discourse occurs between group members as they experience the exhibit?</td>
<td>P</td>
</tr>
<tr>
<td>b. What are the cognitive levels of questioning that occur while they experience the exhibit?</td>
<td>P</td>
</tr>
<tr>
<td>c. What roles do group members take on as they interact with each other and the exhibit?</td>
<td>P</td>
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</tbody>
</table>

P= Primary data source, S= Secondary data source.

**Research Design and Methods**

The use of qualitative research methods allows a researcher to obtain rich descriptions about beliefs, values, and motivations that can be used to gain insight into perceptions and behaviors of the those studied (Berkwits & Inui, 1998). Case studies allow the researcher to capture complexities of an issue through the examination of an individual or group’s experiences (Idema, 2015). A multi-site collective case study links multiple case studies, across multiple sites through the study of categorically bound data present at each site (Stake, 1995). This approach provides validity to a study through cross-site synthesis and replication of research methods (Berkwits & Inui, 1998). My study uses a qualitative, multi-site collective case study approach to examine the presentation of LSSEI through exhibits and how IFG interpret these messages. Because IFG make up one of the largest populations of visitors to ISI (Falk & Dierking, 2000), I am focusing on the interactions that occur amongst these groups as they experience the exhibit.

**Data collection methods & participants.**

*Exhibit observations.* I will document photographic evidence of signage, manipulatives, species choice, and makeup of the exhibit at aquariums that are accredited by the Association of Zoos and Aquariums (AZA) and/or the World Association of Zoos and
Aquariums (WAZA) and contain at least one exhibit that highlights a LSSEI. Collecting observations at these accredited sites contributes to the validity of my study, as each facility must meet rigorous criteria regarding: animal care and management; involvement in conservation and research programs; educational programming through exhibits and interpretation staff; safety policies and procedures; security; physical facilities; guest services; and quality of staff. Photographic evidence provided through these observations will help me develop a criterion for aquarium exhibits that feature a LSSEI. I will then use this criterion to select five AZA/WAZA accredited aquariums across North America at which data will be collected for answering RQ2 – RQ4.

Aquarium Representatives, semi-structured interviews. At each of the observation sites, I will conduct semi-structured interviews with the aquarium staff member(s) who played a role in design of the exhibit. I will transcribe each interview verbatim before using a deductive approach to code responses in terms of intended messaging, exhibit design choice, and target audience.

Intergenerational Family Groups. I will observe five IFG from each of the AZA/WAZA accredited aquariums as they visit the targeted exhibit. I will collect video and audio recordings of their interactions while visiting the exhibit using a front facing camera attached to glasses each participant will wear. I will also take field notes as participants interact with the exhibit on group communication and observable engagement. After participants have concluded their time at the exhibit, I will conduct a short, semi-structured group interview to gather data on interpretations of the LSSEI. I will use a comparative coding approach to identify similarities and differences in intended versus interpreted messages across exhibits.

Eye-tracking video recordings. I will collect eye-tracking data extracted from the Tobii eye-tracking glasses worn by IFG. I will superimpose these data over the front facing video data and calculate most common areas of interest fixated upon using frequency counts.

Preliminary Findings
I conducted a pilot study that focused on the presentation of a particular LSSEI (environmental impacts associated with climate change) to answer RQ1. I collected data from 30 AZA/WAZA accredited facilities. Preliminary findings show that few aquariums incorporate the LSSEI of climate change into their exhibits. Those that do (n=7), share similar characteristics across aquariums by focusing on climate change impacts on coral reefs. These exhibits contain no reference of how climate change could impact local communities. Amongst the facilities surveyed, the lack of the presentation of climate change and its impacts on marine/aquatic ecosystems in exhibits is concerning, especially when prior studies about delivering difficult messages and engaging in climate change dialogue suggest that visitors are willing to reflect thoughtfully on content and engage in dialogue (Esson & Moss, 2010; Clayton et al., 2014). These findings also show that the exhibits that do incorporate climate change into their design did not reference local communities. Lack of local connection could possibly play a role in limiting visitor perceptions about climate
change and their willingness to take action (Moser, 2010). Trends in aquarium exhibit messaging and presentation instead focused on SSI like plastics, over-fishing, invasive species, and illegal wildlife trade. While these issues are no less important, perhaps the reason aquariums choose to engage visitors through exhibit design in these lesser SSI is because they are much more visible and less controversial in everyday life.

References


Developing learners’ interest in insects as a way of countering the biodiversity crisis

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Theoretical background and focus of the study

In the context of the global biodiversity crisis (e.g. CARDINALE ET AL., 2012) the decline in insect populations and insect diversity poses a major challenge, especially because of their high ecological importance (HALLMANN ET AL., 2017; WEISSER & SIEMANN, 2008). This problem is further complicated by dwindling public knowledge about many species (e.g. BRÄMER, KOLL & SCHILD, 2016). Lack of knowledge and the “extinction of experience” (SOGA & GASTON, 2016) – people’s decreasing interaction with nature in their everyday life – is creating a disconnect from nature and biodiversity. However, knowledge about and connection to nature and biodiversity is highly important, not only for ecologists and biodiversity scientists but also for politicians and the public. There is a need for broader and deeper public understanding of nature to address the biodiversity crisis (COSQUER, RAYMOND & PREVOT-JULLIARD, 2012).

Interest is regarded as a critical learning prerequisite both in and out-of-school settings. Several studies show that interest can influence learning processes positively (KRAPP, SCHIEFELE & SCHREYER, 1993). Moreover, interest can be regarded as a central motivational precondition for the appreciation of nature and the readiness to protect biodiversity (KALS, SCHUMACHER & MONTADA, 1999). However, studies reveal a waning interest in natural sciences during early secondary school (e.g. POTVIN & HASNI, 2014). These years are of a great significance for the formation of the students’ individual interests, which affect their decision-making concerning their studies and their future careers (KANG, HENSE, SCHEERSOI & KEINONEN, 2018). Therefore, approaches that focus on peoples’ interest in nature are critical for informed citizens and for future scientists.

According to the “Person-Object Theory of Interest” (POI) (KRAPP, 1999; SCHIEFELE, 1991), interest is defined as a specific relationship between a person and an object (KRAPP, 1999). This object can either refer to concrete things, to a topic, a subject-matter, or even an abstract idea. The specific relationship between person and object is characterised by three basic components:

1. A person who is interested in a certain object wants to learn more about it (cognitive component).
2. Activities related to the object of interest are accompanied by positive emotions (emotional component).
3. The object of interest is regarded as personally valuable and meaningful in a way that the person is ready to invest time or other resources in object-related activities (value-related component).
Two types of interest can be distinguished: situational and individual interest. While situational interest is an emotional state brought about by situational stimuli, individual interest is defined as a relatively enduring preference for certain topics, subject areas, or activities (SCHIEFELE, 1991). Under certain circumstances, situational interest can serve as the basis for the emergence of individual interest (KRAPP, HIDI & RENNINGER, 1992).

My PhD-project aims to identify factors for positively developing interest in insects and biodiversity among students aged 12-16. Out-of-school settings not only enable direct interaction with nature but also show a high potential for the development of interest in previous studies (e.g. UITTO, JUUTI, LAVONEN & MEISALO 2006). Hence, this project focuses on learning in out-of-school settings.

Research question
To address the above-mentioned challenges, the main research question of this study is: How should out-of-school learning settings be designed to inspire and maintain the secondary school students’ interest in local insects and phenomena of biodiversity?

Methods
This study is based on the Design-Based-Research (DBR) approach (DESIGN-BASED-RESEARCH COLLECTIVE, 2003). Following the adaptation of the DBR-approach for biology education (PIB, SCHEERSOI & HENSE, 2015), a mixed-method-approach (KUCKARTZ, 2014) for measuring interest and interest development is used.

A preliminary investigation was conducted to formulate design-hypotheses for educational settings which give strategies to address the problem. After a broad literature review on interest in animals and out-of-school learning opportunities, I conducted a questionnaire survey (N=294, 11–18 years) to address basic questions of the preliminary investigation such as students’ degree of interest in insects in general and in different groups of insects specifically. This questionnaire was based on the studies of LINNENBRINCK-GARCIA (2010) and WENZEL (2016). The validated questionnaire used a five-point Likert scale. To compare multiple groups of non-parametric dependent data from the questionnaire, the Friedmann’s-ANOVA test with post-hoc analysis was executed using R (R DEVELOPMENT CORE TEAM, 2008). The quantitative data gleaned from the questionnaire was combined with qualitative methods (half-standardised interviews (N=8) and participant observations during the evaluation of existing programs (N=9)) to investigate the reasons for interest and preferences. In doing so, data from a variety of perspectives, such as entomologists, educators, students and research assistants were included to obtain an extensive prospect of the object of investigation. Data of the transliterated interviews was analysed using MAXQDA 2018 (VERBI SOFTWARE, 2017).

For testing the design-hypothesis during the formative evaluation, a first intervention in the form of a five-day summer camp was planned and conducted with 12 to 14-year-old students (August 2018): a mobile field station for the camp was developed including e. g. binoculars, magnifying glasses, nets for catching insects and identification keys. This mobile field station can be transported with a bike-trailer and be used upon nearly every terrain. The program included a day-trip to a local natural history museum, where participants...
learned basic identification skills and explored the entomological collection. On the other four days field-trips to different places (a meadow with neighbouring forest edges, a watercourse, and a sand habitat) were organised. Interest development was measured using participant observations and half-standardised interviews (N=7). Data of the transliterated interviews was analysed using MAXQDA 2018 (VERBI SOFTWARE, 2017). Results of the first intervention are used for refining the design-hypotheses, which will be tested and refined cyclically during the next steps of the formative evaluation. In doing so, the DBR-/PIB-approach provides an empirical contribution to the research in interest as well as design-principles for the educational practice.

At this juncture in time (03/2019), after having concluded the preliminary investigation (10/2017–06/2018), the project currently is in its formative evaluation with the next interventions being planned for summer 2019.

**Preliminary findings**

The evaluation of existing educational programs showed that there are hardly any educational programs on insects for secondary school students in our region (the Rhineland). The questionnaire survey showed that interest in insects is generally low (M=2.19, SD=1.26), although students regarded the value of insects for society as quite high (M=3.06, SD=1.44). Analysing the half-standardised interviews, it emerged that this is because students understood the role of insects as pollinators and decomposers. Nevertheless, the questionnaire data show significant differences between various groups of insects (χ²(15)=1189; p<0.001): Butterflies were regarded as quite interesting (M=3.59, SD=1.34) while bugs were passed-off as totally uninteresting (M=1.59, SD=0.97) (p<0.001). The differences between students’ interest in the itemised insect groups can be explained by i) aesthetic properties, such as perceived beauty in butterflies, ii) ethological characteristics, such as the flying ability in dragonflies or iii) personal encounters with insects, such as personally perceived unpleasant smell in bugs.

Hypotheses for the design of own educational programs were derived from the data of the preliminary investigation. Essential design-hypotheses are for example, that programs which aim at fostering students’ interest in insects should provide

- authentic contexts (e. g. museums, laboratories, field trips)
- a high degree of self-directed activities
- direct contact with nature
- typical biological working methods and skills (e.g. collecting and identifying insects)
- safe handling of living insects

The evaluation of the first intervention (the summer camp) shows that i. a.

- the diversity of places visited (natural history museum, meadow, watercourse, etc.),
- self-directed activities (collecting, identifying),
- technical aspects of biological working methods (set-up of the field station, methods of collecting with nets and working with binoculars),
- the diversity of insect groups observed,
safe handling of living insects,
and eye-catching, extraordinary or rare species
were particularly beneficial for the interest development of the participants. Furthermore, the data indicates growth in the perceived value of insects during the intervention. Currently, further programs with improved educational design are being planned. I aim to develop recommendations for the design of educational programs concerning the interest in insects as well as making empirical contributions to the theory of interest.

References


Understanding models and modeling processes by students of compulsory education

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Focus of the study
In this research, we attempt to enhance the epistemological beliefs of high school students about the nature, purpose, multiplicity and change of models before and after the implementation of a properly designed Teaching Learning Sequence (TLS) integrating Information and Communication Technologies (ICT). We theorize that the latter can actually improve students' epistemological beliefs and help them distinguish science models illustrated from images portraying non-science models e.g. technological devices.

Research questions
• What are the changes on students’ conceptual understanding of optics phenomena after their engagement with modelling pedagogies embedded in an exploratory oriented model-based TLS in the field of optics?
• What are the changes on students’ epistemological beliefs about the nature, purposes, multiplicity and change of models after their engagement with modelling pedagogies embedded in an exploratory oriented model-based TLS in the field of optics?
• Is there any relation between the students' conceptual understanding and their epistemological beliefs concerning the nature, purpose and change of models after their engagement with modelling pedagogies embedded in an exploratory oriented model-based TLS in the field of optics?
• What are the changes on student's ability to recognize and distinguish images depicting non-models from images representing obvious and non-obvious models after their engagement with modelling pedagogies embedded in an exploratory oriented model-based TLS in the field of optics?
• What are the criteria by which students recognize and distinguish images depicting non-models from images representing obvious and non-obvious models after their engagement with modelling pedagogies embedded in an exploratory oriented model-based TLS in the field of optics?

Literature review
Numerous researches point out that the use of models and modeling practices contribute to the increase of students' epistemological awareness regarding the nature, purpose, multiplicity and change of models (Petridou et al., 2009; Soulios & Psillos, 2016; Soulios, 2012). A precondition for achieving the above objectives is the development of modeling...
skills, which in turn presupposes the development of a proper framework for the support of these activities (Quintana, Zhang, & Krajcik, 2005). However, it is found that students' perceptions of scientific models differ significantly from scientifically acceptable ones (Treagust, Chittleborough, & Mamiala, 2002).

**Methodology**

The TLS used in this research is a product of modification and evolution of an earlier one (Lombardi et al., 2010; Testa et al., 2011). The original sequence was modified in order to become aligned with the Greek curriculum and redesigned to provide an appropriate supportive framework for developing students' epistemological beliefs about models by incorporating a plethora of modeling practices (Soulios, 2012). In specific, it includes expressive modeling practices in which students construct and use their own models. In addition, it consists of exploratory modeling practices in which students use pre-existing models. Furthermore, inquiry modeling practices are adopted i.e. models are used to make predictions which later on will be submitted to tests for validation. Additionally, cyclic modeling is also incorporated as a continuous process of designing, testing and revising the models created. The revised TLS includes a number of metacognitive episodes which aim to provide feedback to students. The notion of a science model is introduced in an explicit way by introducing the optical ray model for light phenomena. Finally, ICT's role is to act as a cognitive bridge between the real world and the virtual one, thus supporting the framework of modeling activities.

For the purposes of this investigation, the TLS is further modified in terms of both expression and content. Regarding the latter, the basic conversion includes adding more reflection questions and integrating the "Bending Light" application from Phet Website, supported by the University of Colorado, USA (Bending Light, 2016). The integration of this application into the TLS provides a user-friendly virtual interacting environment in which light is represented as a ray. This application allows also for the visualization simultaneous of the incident, reflected and refracted light beam as well as the manipulation and progressive change of their angle in real time. Furthermore, it provides the necessary virtual tools for the measurements of the previous mentioned angles. Regarding our sample, it consists of 60 second grade junior high school students (8th grade) of a public school in the prefecture of Thessaloniki, who worked in small groups. The intervention lasted 8 weeks in a total of 12 teaching hours.

In order to investigate their epistemological beliefs about models two questionnaires were introduced both before and after the implementation of the TLS. The first one is a closed-ended questionnaire which consists of 18 images in total. Below each image students choose between "yes" and "no" as to whether the image depicted represents a model or not. The pictures of the questionnaire are categorized into three clusters. The first cluster consists of images that do not represent a model. The second one comprises of images that represent models which are easily accepted as ones while the third cluster consists of images that although they represent models, they are hardly accepted as ones by the students. Such classifications is based on students' responses during earlier
investigations (Grosslight et al., 1991; Windschitl & Thompson, 2006) which showed that there are many interpretations of a model by students such as human models of clothing, role models, exact copies in scale (cluster 1). Other students’ replies refer to models as images, drawings, engineering plans and maps (cluster 2) or regard models as an idea, a representation, a mathematical or theoretical model (cluster 3). After completing the first questionnaire, students proceed to the second one which is open-ended and consists of seven epistemological questions regarding the nature, purpose, multiplicity and change of a model. The questionnaire was developed by I. Soulios (Soulios & Psillos, 2016) and it is based on questionnaires from earlier surveys (Crawford & Cullin, 2005; Grosslight et al., 1991). The classification of students' beliefs is based on the hierarchical three-level classification framework, developed in the abovementioned investigations. Students' beliefs are classified into three levels. The first one includes answers that deviate from the scientifically acceptable ones whereas the second level consists of intuitive answers that tend to approach the scientifically correct ones without being totally identical. Third level's answers are those that are identical with the scientific ones. Furthermore, a subset of 22 students was randomly selected to participate in semi-structured informal interviews, before and after the implementation of the TLS. During these interviews students are encouraged to elaborate their answers on both questionnaires.

Results
Preliminary analysis of students' answers on the first questionnaire shows that the percentage of positive answers regarding the first image cluster is significantly decreased. At the same time, a notable increase of positive answers regarding the second image cluster is recorded which means that after the completion of the TLS students do realize that the images of cluster 2 represent models. Regarding the answers on the third image cluster, only a slight increase is documented which implies that students' perceptions do not change. This indicates that students have more difficulty in accepting cluster 3 images as science models. The results of the open-ended questionnaire regarding students' epistemological beliefs about models are promising since all aspects of models i.e. their nature, purpose, multiplicity and ability to change, are improved after the implementation of the TLS. Students' transcribed interview analysis unveils certain criteria (axes) according to which students recognize and sort images into obvious science models, non-obvious ones and non science models. To begin with, the first axis deals with a model's purpose meaning that students categorize images into models according to what models are supposed to do. Another criterion is the nature of a model (axis 2). Finally, a third criterion is identified as combination of the first two axes and the notion of evolution meaning that students attribute to models the ability to change. The abovementioned results will be cross-referenced with the results from the second implementation of the TLS on a different student sample.
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Beyond the Bachelor’s Degree – Legitimate Choices
and Imagined Futures

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Introduction
Since 2005, students at Danish universities have had to apply to enter a master programme after completion of a bachelor’s degree. Previously, students enrolled for a full five-year master’s degree. This change marks the full implementation of the Bologna 3+2 structure in Denmark and it has introduced a new decision point for Danish students. The 3+2 structure was introduced through the Bologna Declaration with the aim to form a coherent European higher education structure. As a consequence students can no longer continue without doing anything. They must make a choice whether that lead to a master’s program or entering the job market. In recent years, this new decision point has gained political interest, not least due to the increasing number of students commonly referred to as ‘the mass university’ (Trow 2010), but also a growing focus on the need for more students within STEM. The decision point is hence not only new, it is also considered increasingly important. This means, that while students face a range of possible master’s programmes, not all of these might be conveyed and experienced as legitimate and accessible choices (cf. Holmegaard, Ulriksen, and Madsen 2014). Therefore, this research project focus on the interaction between students and their study programmes and how different choices and trajectories are presented, shared, considered and discussed as desirable and legitimate. The empirical offset is three bachelor’s programmes, at the University of Copenhagen (KU): Chemistry, Computer Science (CS) and Natural Resources (NR). The aim of this project is to contribute to the understanding of educational choices within science education and explore how anthropological methods can contribute to the research field of science education. Denmark is an interesting case as it distinguishes itself in terms of transition patterns and tuition fee. Most students continue directly to a master’s degree after their bachelor’s, and they do not pay a tuition fee, as university in Denmark is state funded.

A Short Review of Relevant Literature
Research on this topic is virtually non-existent and most of the scarce existing literature concerned with students’ considerations of a master’s degree is of quantitative nature, based on questionnaires (Heine 2012; Jepsen and Neumann 2010; Sarcletti 2015; Stuart et al. 2008). Contrary to the lack of research concerning the choice of a master’s degree, there has been a substantial amount of research on students’ choice of higher education. This research shows that many diverse and complex factors influence the choice and whether or not students choose science. Socioeconomic factors play a role as well as students extended social network containing both parents, friends, and peers (Brooks
Also students perceptions of science and how that relates to their own identity work play a role in their choice (Archer et al. 2015; Holmegaard, Madsen, and Ulriksen 2014a, 2014b). In my analytical framework, I thus focus on the interaction between students and their study programme to understand how legitimate and desirable choices are presented and negotiated. I am especially inspired by the above-cited work by Henriette Holmegaard et. al. and her approach to understand choice as a process and a negotiation of belonging. I further apply a concept that I term imagined futures, inspired by Ann Mische (2009). This concept draws attention to the way in which the students imagine their future and how they understand their own possibilities within this future.

Research Questions
How are students’ educational choices and imagined futures constructed as desirable and legitimate in the institutional setting of three specific science bachelor programmes? Sub-questions: (a) How do students conceive of and experience belonging to their discipline and study programme? (b) How does the process of choosing a master’s programme unfold for the students? (c) What is expressed as desirable and legitimate future student trajectories by students and university staff (and non-desirable and non-legitimate) and which elements are expressed as important in relation to this? (d) How are the legitimacy of different choices negotiated among students and university staff?

Research Design and Methods
The main method in this project is ethnographic fieldwork. This entails taking part in the daily activities, rituals, interactions and events of a group of people. By participating in daily activities, the aim is to gain insights into both explicit and tacit aspects of people’s practices (Musante 2015, 251). I am carrying out the fieldwork throughout the academic year of 2018-19, by following the cohort of second-year students in their daily activities.

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= Interviews

This means following courses with the students and being part of both lectures and laboratory work. It also includes engaging in academic and social activities outside the classroom, such as field excursions, information meetings and the students Friday bar. The academic year at science, KU is divided into four blocks. For practical reasons I follow only two courses at a time (figure 1), and I hence follow two study programmes.
more intense in each block. Ethnographic fieldwork is followed up by semi-structured interviews with eight students from each study programme, selected teachers, student counsellors and the head of each study programme.

During and in between activities, I make jottings in order to recall situations. These are afterwards written out as fieldnotes containing descriptions of the setting, interactions and conversations (Emerson, Fretz, and Shaw 1995). Fieldnotes and transcribed interviews are coded using the qualitative data analysis software Nvivo. First through an initial open coding, allowing new themes to emerge from the data. Second through a closed coding, narrowing in on selected themes in correspondence with the emerging themes and the analytical approach (Emerson, Fretz, and Shaw 1995, 150–61). The three bachelor’s programmes have been selected to represent variation. They differ in tradition and structure. At Chemistry, there is a tradition for students to continue directly to the master’s programme at the same department. As a contrast to this, NR does not have one single designated master’s programme. CS has a strong labour market orientation, resulting in an actual possibility for students to leave university after finishing just a bachelor’s degree². The second year has been selected, as this is a point where the initial induction process has been completed, but before the choice of what to do after the bachelor’s degree formally has to be made.

**Preliminary Findings**

I am currently in the final phase of data production and have hence not begun the final coding of the material. From an initial coding of data from Chemistry and NR, some contours are however already forming. The two programmes have shown to be very different in regard to among other things, the choices that students express as important at this point of their studies and the way they imagine the future.

At Chemistry the choice of specialization that students had to make in the end of their first year, was a topic of discussion all the way through the first half of the second year, as some students considered changing. The choice of a master’s programme however, has not been brought up by the students themselves so far. Despite this, there seems to be a tacit understanding, that everyone will continue to the master’s programme at the same department. This became explicit during interviews, as I asked the students about their thoughts on the future. They described the programme at Chemistry as a five-year programme, where the choice about which direction to pursue, hence was a choice of a quite distant future. When asked about the possibilities after completing a bachelor in Chemistry, one student even illustrated it as a highway – leading directly from the bachelor’s to the master’s programme in Chemistry at the department.

² For the majority of disciplines a labor market for bachelor students is virtually non-existing in Denmark. This in not counting what is termed ‘professionsbachelor’ educations. These are bachelor’s degrees that are directed toward a specific profession such as physiotherapist, nurse or teacher. In Denmark, these are based at the university colleges and last three and a half year.
As a contrast, the specialisations at NR soon became what students define themselves in relation to, more so than the programme in itself. They would for example refer to what they were studying by the name of the specialisation rather than by the name of the overall programme. The issue of choosing a master’s programme also came up at several discussions, already during the first weeks of the second year. It is not that the NR students, whom I have talked to, have a clear or narrow image of a desired future trajectory, but they are very aware that they have to make a choice within a relative close future. Both at informal conversations and during interviews the NR students emphasize that NR is a broad discipline with a lot of choices. Something that is both appreciated and sometimes causes frustration and doubts. Several of my informants have already changed their mind, once or more times, about which master they imagine themselves to pursue. Like other educational choices described in the literature, this choice seems to be a continuous process.

Following the preliminary insights, it is relevant to discuss how different academic and social settings influence students’ choices and ideas about the future. The norms within a study programme can shape which choices appear as possible and legitimate for students. The data indicate that students, who do not relate to the majority norm, can struggle to feel that they belong in the programme or at science in general. At the time of the summer school, I will have completed my data production and I consider it an opportunity to discuss and obtain feedback on my findings and the following analytical work.

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Exploring real-life problems with students: towards multi-perspective reasoning within and between disciplines in secondary science education

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Focus of the study
In order to make learning meaningful and representative for problems that occur in real life, students need to develop understanding of the different ways of thinking or perspectives that define the disciplines within natural sciences (Boer et al., 2014). Current secondary science education generally offers students knowledge in an unambiguous and highly categorized manner. What it does not teach students is how to reason, ask the right questions and devise a plan of action when faced with problems or situations that are not as clear-cut as the average exam assignment. Scientific reasoning is being elaborated in a most general manner, missing an explicit conceptualization on the meaning of, among others, biological and chemical reasoning (Hmelo-Silver, 2004; Janssen, et al., in press). Furthermore, courses in natural sciences offer knowledge in a fragmented way, causing a lack in the conception of the coherence between disciplines and domains within one discipline (Gilbert, 2006). The first step in tackling these problems, is to teach students what domain-specific reasoning is and how it can be used as a thinking tool (Hmelo-Silver, 2004; Janssen et al., in press).

The focus of this project is to investigate scientific perspectivism as a framework for a didactical approach to secondary biology education. The aim is to enable teachers to design lessons in which students develop scientific reasoning in mono- and multidisciplinary real-life contexts. We will focus on identifying biological perspectives (defined as ways of thinking) and developing practical design heuristics for creating lessons in which scientific reasoning is promoted by way of guided multi-perspective reasoning. Tools will be developed for the assessment of student domain-specific reasoning skills.

Review of relevant literature
Scientific perspectivism
Scientific perspectivism is an approach to understand and represent knowledge development. Scientific perspectivism can be understood as an attempt to escape from absolute forms of objectivism as well as relativism (Giere, 2010). Representatives of scientific perspectivism assume that there is a reality that is independent from human knowledge construction. Though perspectives are not empirically testable themselves, models based on perspectives are (Giere, 2010). Complex situations always need to be viewed from multiple perspectives. Important scientific perspectives are for instance an
evolutionary perspective, a classical mechanical perspective, a thermodynamical perspective et cetera.

Scientific perspectivism can provide useful orientation and thinking tools to offer students more structure for tackling ill-structured problems. Viewing such a problem from a particular perspective generates specific concept-related questions or ‘question-agendas’ (Love & Lugar, 2013), promoting content-specific scientific reasoning. For this study, we developed Perspective REasoning SchemeS (PRESS) aimed at exploring and reducing the students’ problem space gradually and effectuate multi-perspective thinking (see fig. 1).

Fig 1: An example of a PRESS scheme for the functional perspective in biology

Practicality
In order to be practicable to implement, a new teaching approach must provide teachers with concrete procedures for e.g. designing and implementing issues (instrumental); the result must not deviate too much from the methods that are already being applied and must not undermine important goals (congruent); the profits must outweigh the estimated costs (low-cost) (Doyle & Ponder, 1978; Janssen et al., 2013). Practicality is accomplished when teachers estimate that the expected value (desirability x feasibility) of the new repertoire is higher than the expected value of the current one. Expected values are based on motivational beliefs, which are linked to estimated benefits and drawbacks of an innovative proposal (Fishbein & Ajzen, 2010; Janssen et al., 2014).

A big perceived difference between their regular practice and the methods of multi-perspective teaching can reduce the estimated practicality of the target practice for teachers. We aim to minimize this effect by developing comprehensive design heuristics and a bridging framework (Janssen et al., 2014) for shifting the regular practice of teachers to multi-perspective lessons.

Research questions
The main question of this research project is: What is a practical-didactic approach for implementing multi-perspective teaching into regular teaching practice?

Research question 1: How can student multi-perspective reasoning be developed in high school ecology lessons?
1.1 Which perspectives can be identified for the domain of ecology and how can they best be represented?

1.2 What are the key design characteristics of practicable multi-perspective lesson series using PRESS questioning schemes?

1.3 To what extent do students develop multi-perspective reasoning in a multi-perspective lesson series in the context of ecology?

Research question 2: What are practical design heuristics that enable biology teachers to design multi-perspective lesson series?

2.1 What heuristics do biology teachers use in their regular teaching practice?

2.2 What heuristics do biology teachers use while designing PRESS schemes?

2.3 What heuristics do biology teachers use in the process of shifting from their regular practice to developing a multi-perspective lesson series?

2.4 What will be a good practical-didactical method for multi-perspective and teaching that accounts for the heuristics teachers use to switch to the target practice?

Research question 3: Does multi-perspective teaching promote student learning and domain-specific reasoning skills?

3.1 Does multi-perspective teaching promote domain-specific questioning and reasoning skills in students?

3.2 Does multi-perspective teaching promote general student learning (as measured by scores on standardized final exam questions)?

Research design and methods

Study 1 (research question 1; will be completed in April/May 2019)
The focus of study 1 is on designing lessons that incorporate multiple perspective reasoning. The yield of study 1 is: 1) an exemplary case of a multi-perspective lesson series, 2) a first draft for design heuristics for the development of multi-perspective lesson series, 3) insight of a more theoretical nature regarding characteristics that make such a lesson series work and 4) a rubric for assessing multi-perspective reasoning. This will be input for study 2.

A lesson series was designed (eight lessons of 45 minutes) with the aim of promoting student multi-perspective reasoning in an ecological context. Design heuristics for the development of similar lesson series were developed simultaneously. Multi-perspective reasoning is introduced gradually in the lesson series by providing students with basic versions of PRESS as a learning tool that are expanded as the lesson series progresses.

The lessons were implemented in two research cycles in 10th grade pre-university classes containing 41 students in total. Data was collected on learning processes and two types of
learning outcomes: 1) student ecological reasoning skills, 2) student scores on an assignment with standardized final exam questions. The lesson design and design heuristics were adjusted based on the findings. In April-May 2019 the lesson series will be tested in another 10th grade pre-university class. Data collection will be similar to the first phase.

Preliminary findings
Using qualitative data from the first two research cycles (an assessment of the lesson materials and student interviews), we adjusted the lesson series in a few key points. For example, we concluded that 1) multi-perspective lessons have to integrate ill-structured problem solving (to enable student reasoning) and 2) PRESS schemes should be used as a thinking tool that students actively elaborate on during the course of the lessons. Subsequently, we reframed these adjustments to the lesson series as general heuristics for designing multi-perspective lesson series.

To assess progress in student reasoning, we developed a rubric for assessing domain-specific reasoning skills. Exploratory analysis of the student data using this rubric shows that student reasoning skills improved in the course of the lesson series. Analysis of student scores on the test containing standardized final exam questions shows that participating student scores did not significantly differ from student scores of last year’s 10th graders (the control group). More thorough analysis will be done in the next months to further investigate these preliminary findings.

Study 2 (research question 2)
The focus of study 2 will be on gaining insight in the practical application by high school teachers of the design heuristics that were developed in study 1. The yield of study 2 will be: 1) a refinement of the design heuristics, 2) insight of a more theoretical nature in practical application of the design heuristics and 3) a bridging framework that describes a gradual shift from a general teaching practice to the practice of multi-perspective lessons. This will be input for study 3.

In this study ten biology teachers will design PRESS schemes and multi-perspective lessons for a biological domain of their choosing using design heuristics that were developed in study 1. Data will be gathered concerning the practical application of the design heuristics by teachers while designing PRESS schemes and lessons (thinking aloud interviews, lesson designs, videotaped lessons and pre- and post-interviews). For students, data will be collected on ecological reasoning skills and scores on standardized final exam questions.

Study 3 (research question 3)
The focus of study 3 will be on more thoroughly measuring the effects on student learning and domain-specific reasoning of multi-perspective lesson series that were created by the biology teachers in study 2. The yield of study 3 will be: 1) a quantitative analysis of data on student domain-specific reasoning skills (measured and graded with tools that were developed in the preceding studies), 2) a quantitative analysis of data on general student learning (measured with standardized final exam questions). At least 150 pre-
university students (10th grade or higher) will be included in both the test group (multi-perspective lesson series) and control group (general practice of the teacher).

References


Development and evaluation of a teaching unit in Particle Physics to promote students’ critical thinking

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Study Focus

For the challenges of our modern society we need citizens who have the necessary critical-thinking (CT) skills. It is a goal of education researchers and teachers to design a learning environment to teach students, as part of citizenship, to think critically in everyday life. In order to verify if students have achieved CT skills, establishing an appropriate CT evaluation method is necessary.

In this study we define CT as a use of thinking strategies that increases the probability of desirable outcomes (Halpern, 1998, 2009). Halpern (2009) classifies these thinking strategies as Reasoning, Thinking as Hypothesis Testing, Argument Analysis, Likelihood and Uncertainty Analysis, and Decision Making and Problem Solving. It is also important to distinguish between general CT skills, which require knowledge of everyday life (Ennis, 1989), and domain-specific CT skills, which require content-specific expertise (McPeck, 1990), e.g. in particular domains of physics. Furthermore, embedding CT skills within a content-specific instruction is expected to result in the development of both general and domain-specific CT skills (Tiruneh et al., 2015).

In our study, we are designing a content-specific instruction in the domain of particle physics to improve both general and domain-specific CT skills. Furthermore, we design a Particle Physics Critical Thinking test (PPCT) to measure the extent to what students gain domain-specific CT skills.

Particle physics is an abstract topic. Despite the students’ interest in some topics in particle physics like antimatter (Gedigk, Kobel, & Pospiech, 2017) there are no concrete guidelines and principles for designing a high-quality intervention in this abstract area to solve complex educational problems like teaching CT skills. Considering these we chose Design-Based Research (DBR) methodology to develop and optimize our content-specific instruction in an iterative cycle of design-enactment-analysis-redesign (Collins, Joseph, & Bielaczyc, 2004; Nieven, 2010; Puntambekar, 2018). As a result, we will identify guidelines for designing a content-specific instruction. These guidelines should be transferable to the other areas of physics e.g. energy or mechanics for designing a content-specific instruction to improve CT skills.

Literature Review

Unfortunately, there is widespread disagreement among educators and researchers regarding the definition of CT (Norris & Ennis, 1989; Lipman, 2010; Halpern, 1998, 2009). Some consider CT as a mental process (Norris & Ennis, 1989), but others define it as criterion-based thinking skills (Lipman, 2010).
For the purpose of this study we found that Halpern’s definition (2009) captures the essence of other definitions and is based on the skills that can be tested using Halpern Critical Thinking Assessment (HCTA) (Halpern, 2016) in terms of the observable outcomes of applying CT strategies, which are unobservable. Furthermore, studies on the evaluation of the ability concerning CT showed that both general CT skills (Ennis, 1989) and domain-specific CT skills (McPeck, 1990) should be taken into account.

In addition, fostering the development of students’ CT skills needs a well-designed subject matter instruction (McPeck, 1990). Embedding CT within subject-matter domains has been placed theoretically in the focus of some studies (Ennis, 1989; Halpern, 1998, 2009). However, theoretical limitations (regarding instructional design models which develop students’ general and domain-specific CT skills) and lacking empirical evidence (regarding the effectiveness of these models) are still a challenge. Searching for instructional design models that enhance students’ CT skills, we chose to focus on the “First Principles of Instruction” model. It offers guidelines for designing learning environments for higher-order learning outcomes (Merrill, 2013). Being a synthesis of numerous instructional design models, this model has a strong theoretical foundation and five clear principles for designing content-specific instruction: problem-centered, activation, demonstration, application, and integration. These principles can provide students with the opportunity to acquire knowledge and skills that are necessary to complete complex real-world tasks (Merrill, 2013). This model has already been applied in designing a content-specific instruction in Electricity & Magnetism for general and domain-specific CT skills, resulting in the development of domain-specific CT skills (Tiruneh et al., 2015). In that study, the HCTA was administered to measure the acquisition of general CT skills. Moreover, it was applied as a framework for designing a CT test in Electricity and Magnetism (Tiruneh, De Cock, Weldeslassie, Elen, & Janssen, 2016).

To the best of our knowledge, there has been no research on designing instruction in particle physics where CT skills are trained, nor is there any content-specific CT test in this field.

Research Questions
To fill this gap our main research goal is to design, implement and evaluate a particle physics course for high school students that improves their general and domain-specific CT skills.

To reach this goal, we have posed the following research questions:

1. How can a teaching-learning strategy in antimatter focusing on the “First Principles of Instruction” model and Critical Thinking skills improve general and domain-specific Critical Thinking skills of high school students of grades 11 & 12?
2. How do the students’ general and domain-specific Critical Thinking skills develop during the course?
Research Design and Methods
The purpose of this study is to design an instruction in particle physics that enhances students’ general and domain-specific CT skills. The specific topic of learning modules is antimatter (10 lessons) and the target group comprises German high school students grades 11 and 12.

To design the content-specific instruction, the “First Principles of Instruction” model (Merrill, 2013; cf. Tiruneh et al., 2015) was combined with our domain-specific interpretation of Halpern’s general definition of CT skills (Halpern, 2009). We used Halpern’s classification of thinking strategies and defined some content-related skills in each category and corresponding tasks and worksheets to make these skills domain-specific. Furthermore, explicit teaching of general CT skills was designed by defining and illustrating general CT skills and planned to implement within the first course session (Sadidi & Pospiech, 2018).

To evaluate the quality of our instructional design, we considered the criteria of Nieveen (2010): relevance, consistency, practicality (expected, actual), and effectiveness (expected, actual). To evaluate the relevance and consistency of the instructional design, we used screening, expert appraisal, and walkthrough methods in the design stage (Nieveen, 2010). To fulfill the expected effectiveness criterion, we developed a Hypothetical Learning Trajectory (HLT) that is made of 3 components: the learning goal, the learning activities and hypothetical learning process (Simon, 1995; Bakker & Van Eerde, 2015). That gave us a clear picture of what we should look for to assess the actual effectiveness of our instructional design in the implementation stage. To evaluate the actual practicality of the instruction, we defined criteria such as time, level of difficulty and students’ level to collect meaningful data during the implementation.

To develop and optimize our instruction, we use Design-Based Research cycle (Collins et al., 2004; Nieven, 2010; Puntambekar, 2018). We implement the instruction and document video-recording of teaching sequences, audio-recording of students’ discussions, and students’ answers on the worksheets during the course. We analyze the students’ answers on the worksheets by comparing them with the HLT (Bakker & Van Eerde, 2015). The findings will be triangulated by video and audio data. From the results we derive appropriate changes in the design of the instruction to improve its effectiveness and practicality and prepare it for the next planned implementations.

To evaluate students’ general CT skills, we use the HCTA as a pre- and post-test. To evaluate domain-specific CT skills we needed to design a Particle Physics Critical Thinking test (PPCT), implementing it as a post-test. We used the structure of HCTA items as a framework for designing the PPCT and validated its content and practicality using expert reviews, small-scale paper-pencil administration, and a cognitive interview with high school students (Adams & Wieman, 2010; cf. Tiruneh et al., 2016).

Preliminary Findings
We have already designed the instruction and implemented the first pilot study as a 4-day workshop at the university with 4 high school students. The HCTA was administered
as a pre- and post-test. Instead of running PPCT as a post-test, we decided to run a
cognitive interview with the 4 high school students at the end of the workshop to validate
the PPCT test. Furthermore, video-recording of teaching sequences, audio-recording of
students’ discussions and students’ answers on the worksheets were collected during the
lessons. Results of the data analysis of the first pilot study led to redesign of the
worksheets and improvement of teaching sequences. In addition, we gained an insight
into students’ false perception in particle physics. Now we are implementing the second
pilot study with 25 students grade 12 in a high school.

Acknowledgment
This project is funded by the European Social Fund (ESF) and the Free State of Saxony
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Eratosthenes

Mentors: Robert Evans, Lukas Rokos
Young Children’s Conceptions of Energy
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Background and Focus of the Study
Energy is considered a core and crosscutting concept in science and has substantial social and economic relevance. Consequently, “energy” as a topic of instruction already for young learners has gained attention and has been included in primary school curricula of many countries, e.g., U.S., Germany, and Switzerland. Swiss “Lehrplan 21” stipulates teaching and learning of the concept of energy by way of a spiral approach starting in K-2 education (D-EDK, 2016).

According to the theory of “conceptual change”, students’ prior knowledge is a key factor for successful learning. Most studies about students’ conceptions of energy and conceptual development (learning progressions), however, relate to secondary school students, while a few focus on grade 3-5 primary school students (c.f. Chen et al., 2014). To my knowledge, children at kindergarten and lower primary school age have not yet been assessed systematically.

The Ph.D. project addresses the question of grade 1-2 children’s conceptual understanding of energy. On the one hand, I am interested in children’s ideas about different aspects of the concept of energy. On the other hand, children’s understanding of energy-related phenomena, e.g., plants, nutrition, or movements, shall be assessed. Generally, this work shall make a contribution to the discussion about the early introduction of the concept of energy, to the development of conceptual understanding in primary school, and to methods for assessing young children’s conceptions.

Review of Relevant Literature
Teaching and learning of energy. The scientific concept of energy comprises the following interrelated core aspects: a) nature and manifestations/forms of energy, b) transfer and transformation, c) degradation and dissipation, and d) conservation; corresponding learning progressions, some starting from grade 3, have been proposed and partially investigated empirically (Herrmann-Abell & DeBoer, 2018; Lacy, Tobin, Wiser, & Crissman, 2014; Liu & McKeough, 2005). Though a general learning progression along these core aspects is found, the concept of energy is generally difficult to learn, and aspects like conservation of energy are often not applied even by high school and university students (Herrmann-Abell & DeBoer, 2018). Therefore, several authors endorse the early introduction of the concept of energy (Opitz, Harms, Neumann, Kowalzik, & Frank, 2015).

Primary school children’s conceptions of energy. A few intervention studies on energy learning have been conducted with a small number of kindergarten or primary school...
students, these studies reporting also the participating children’s pre-instructional conceptions, e.g., the study of Van Hook & Huziak-Clark (2008) for kindergarten, and the study of Lacy et al. (2014) for 3rd grade. A common finding is that the term “energy” is known by many youngsters, even at kindergarten age (appr. 50% of the kindergarteners). In the Anglo-Saxon language area children associate energy primarily with living or moving things, while German studies suggest a strong association with electricity. Though these studies give valuable insight in children’s thinking, there is still a lack of systematic assessment of pre-instructional conceptions of grade 1 and 2 primary school children.

Understanding of energy and understanding of phenomena. In most studies on energy conceptions or learning progressions the scientific term “energy” is used in the items or interview questions. Young children, however, might know more about the concept of energy than they are able to express in terms of “energy language”, especially since investigating phenomena without using the word “energy” is considered a starting point for energy learning in K-2 education (Next Generation Science Standards, 2013). Van Hook & Huziak-Clark (2008) attribute the children’s limited ability to articulate correct answers not only to language but also to “limited prior experience and knowledge of how things work”. If and how children’s ideas about energy are linked to their understanding of phenomena, has, to my knowledge, not yet been assessed.

Research Objectives and Questions

The aim of this study is to provide insights in young children’s conceptions of energy and about their understanding of exemplary energy-related phenomena or situations, in order to support development of suitable teaching designs and/or quantitative diagnostic instruments. To this end, a qualitative assessment instrument for energy concept understanding of grade 1 and 2 primary school students will be developed.

Research question: Which conceptions of energy do children in grade 1 and 2 hold?

a) Explicit approach: What do children of that age associate with the term “energy”, and which properties and characteristics does the entity “energy” have in children’s understanding, in particular, which aspects of the scientific concept of energy and what alternative ideas can be identified?

b) Implicit approach: What understanding of exemplary energy-related phenomena do children in grade 1 and 2 exhibit, in particular, which aspects of the scientific concept of energy and what alternative ideas can be identified?

c) Is there a relationship between the understanding of energy (question a) and the understanding of phenomena (question b)?

Research design and methods

Pre-study. A video study in one Swiss kindergarten (n=20, ages 4-6 years) and one Swiss 1st-3rd grade primary school class (n=16, ages 6-10 years) has been conducted using semi-structured interviews including sorting and drawing tasks, material prompts
and hands-on activities with single children or in groups of 2-4. With the kindergarten 
students, only the implicit approach was used within five exemplary contexts (nutrition, 
plants, electricity, heat, and movements). In the context of plants, for example, a 
conversation about a plant’s needs was triggered with pictures and objects with the 
purpose of gaining insight into children’s understanding of the role of sunlight. The 
explicit approach was pursued with the primary school students: They were asked to 
write or draw their associations with the term “energy”, to explain the drawing, to sort 
pictures (has to do with energy: yes, no, don’t know), and to explain their choice. The 
interviews were videotaped and are currently evaluated in a qualitative way by content 
analysis (Mayring, 2015), assisted by the computer program MaxQDA. In addition, a 
coding scheme for the drawings is being developed.

Main Study: Design. An assessment instrument for energy concept understanding of 
grade 1 and 2 children will be developed. The instrument will combine the explicit (via 
the term energy) and implicit approach (via phenomena). As recommended by 
Greenfield (2015), it is intended to combine multiple methods of data collection, i.e. 
drawings, sorting/mapping techniques, and interview. It is planned to assess the children 
individually in two sessions of 20 minutes each at maximum. Revised coding manuals 
from the pre-study will be used for evaluation. The instrument will be piloted in one 
grade 1 class in Switzerland in spring 2019; the main study will take place from 
September to December 2019.

Main Study: Items/tasks. The assessment instrument as whole should match the 
complexity of the concept of energy, not only with respect to the contexts but also with 
respect to the different aspects of energy. Therefore, in the design of items (tasks, 
questions) of the assessment instrument as well as in the development of the coding 
manuals, existing models for the structure and development of the concept of energy as 
proposed by science curricula and/or empirical studies (see above) together with known 
pre-instructional conceptions will be taken into account.

Preliminary Findings
An analysis of the pre-study, the assessment instrument and first results of the pilot study 
will be available in summer 2019. The ESERA summerschool will provide an excellent 
opportunity for me to discuss and refine the instrument before starting the main study in 
September 2019.

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Enhancing students’ interest in science and STEM careers: The role of career-based scenarios

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Introduction: the problem

There is an alarming decline in youth’s interest in science that predicts a future shortage between supply and demand in Science, Engineering, Technology and Engineering (STEM) labor market (OECD, 2018). In more than half of the OECD and partner countries the share of STEM tertiary education graduates is comparatively lower (24%) than the share of graduates in social sciences, business, administration and law (34%) (OECD, 2018). Although a number of initiatives have been implemented in Europe to confront this issue the trend remains unchanged since 2005 (Science Education-Horizon 2020-European Commission, 2018). Interest in science has been considered a fundamental aspect in making science-related study and career choices (Potvin & Hasni, 2014). Science Education reform efforts urge a call to enhance youth's interest in science and equip them with scientific skills and scientific thinking in order to cultivate scientifically literate citizens able to take over responsible research and innovation (Horizon 2020 - Work Programme 2018-2020 Science with and for Society, 2018).

In Cyprus, where the proposed study is situated, students’ score near the bottom line in the international science competitions (i.e. PISA, TIMSS). Moreover, the share of STEM bachelor and master’s level graduates in Cyprus remains the lowest across the European Union (9.8 % and 2.4% respectively) (Country Report Cyprus 2018). Even though Cyprus shares a high percentage of PhD graduates in natural sciences, mathematics and statistics (26.7 %) followed by engineering, manufacturing and construction (18.9 %), this corresponds to only 3% of all students enrolled in PhD programmes in 2014/2015.

Purpose of the study

The question then becomes one of why do students do not choose STEM studies and STEM careers? A review of the literature shows that middle school students’ knowledge of STEM careers (defined as student’s familiarity with any career or occupation that requires a high degree of knowledge in at least one STEM discipline) is limited and this
might impact their intentions of pursuing a STEM career (Blotnicky, Franz-Odendaal, French, & Joy, 2018). Hence, there is an imperative need to raise awareness of STEM careers and foster interest in science. In an endeavour to contribute to this effort, this longitudinal study focuses on an empirical classroom-based study (grades 7-10, 13-16 years) that aims to investigate the implementation of science-career-oriented scenarios and their impact on students’ interest in science and STEM-career aspirations and choices.

Theoretical Framework
The study draws on three particular theoretical areas: the Social Cognitive Career Theory (SCCT) model, Situational Interest (SI) and Problem-based Learning (PBL). SCCT model suggests that interest is seen as a predictor of career goals and choice and can be developed in a learning environment (Brown & Lent, 1996). SI is defined as a short-term form of motivation elicited by aspects in a specific situation that stimulate focused attention. As per Hidi and Renninger’s interest development model (2006), the first phase refers to Triggered SI (catch phase) and the second to Maintained SI (hold phase) consisting of affect and value components which depend heavily on environmental stimuli. Thus, PBL was considered an environment that could provide the stimuli to trigger and sustain SI. Further, the SCCT model emphasizes on the interaction between personal input (i.e. predispositions) and contextual affordances (i.e. support in particular academic activities) that can impact the learning experiences and eventually student’s self-view that emerges from the participation in certain activities and self-categorization in a particular community (Stets & Burke, 2000). Thus, given that the focus here is on interest in science and STEM careers, this study draws upon Stets, Brenner, Burke and Serpe’s (2017) conceptualization of a science student’s self-view as a student who has interest in science, tenacity in a science discipline and an intention to pursue a scientific career or enter a science graduate program.

Research Questions
Grounded within the assumption that students’ aspiration to pursue STEM careers is highly related to their interest in science, and given that regular experiences of SI can be the starting point for individual interest that may impact students’ current and/or future selves, this study aims to answer the following research questions:
How does the integration of career-based scenarios in science class:

(a) generate students’ Situational Interest in science and,
(b) raise students’ knowledge of STEM careers?
(c) impact students’ current and future selves related to science?

Methods

The first part of this study includes the empirical classroom-based study that was conducted in the context of a European funded project (MultiCO) and involved 17 student participants attending a private English school in Nicosia. The study includes five classroom interventions that the students participated in grades 8 and 9 (13-15 years) and were extended over 3-13 teaching periods (35-50’). In particular, the study evolved in three phases: (a) the design of the learning environment (the development of the teaching material referred to as career-based scenarios and the teaching sequence) and the development of evaluation tools; (b) the scenario implementation in science class; and (c) the data collection and analysis. The career-based scenarios are stories referred to socio-scientific issues that include career-oriented aspects.

The primary data collection methods included (a) two questionnaires consisting of Likert scale items and open-ended questions and, (b) interviews with 7 students and the teacher reflecting on the scenario implementation and the added value in terms of triggering and sustaining interest and also providing awareness of STEM careers. In addition, a collection of data from other sources (i.e. field notes, STEM career test) served in both facilitating the triangulation of the primary data and supplementing interpretation. Quantitative data will be analyzed using descriptive statistics and qualitative data were coded based on SI sources emerged from the literature corresponding to affect and value components of SI (RQ1a) and the operational definition of ‘knowledge of STEM careers’ (RQ1b). The second part of the study focuses on students’ self-view as science students (Stets et al., 2017). More specifically, following the initial findings from the qualitative and quantitative data collected during the first part of the study, individual interviews will be conducted to track students’ subject choices and career aspirations and explore the extent to which the interventions had an impact on students’ current selves and how these relate to possible future selves in STEM fields.
**Preliminary findings**

The preliminary findings from the classroom-based study showed that the use of career-based scenarios as an introduction to science teaching units can serve as a mechanism to generate students’ SI and enhance their knowledge of STEM careers under some conditions. What vividly stands out in triggering and sustaining students’ interest throughout the scenario implementation relates to specific features of the scenario and how these are supported in the teaching sequence. These features pertain to primarily (a) promoting students’ active engagement and self-regulated learning using PBL and novelty aspects, (b) establishing connections between theory and practice by transferring science concepts to a real-life-personally-relevant context and, (c) carefully integrating the career aspect by promoting the interaction with experts in an informal setting to gain a more nuanced understanding of its practical aspect and the theory behind it.

**Significance**

The perspective outcomes of my on-going research have implications for theory, practice and methodology in designing and evaluating interventions in science class both in local and global context. Initially, this study is considered unique for Cyprus context since it is the first research that explores youth’s interest in science and STEM career aspirations. Considering the low students’ scores in international science competitions and the low share of STEM bachelor and master’s level graduates in Cyprus, this study may contribute to the understanding of young people’s declined interest in pursuing STEM careers with the potential to suggest mechanisms that will enable to make informed career-related decisions.

Nevertheless, in an effort to impact on students’ interest in science and increase their knowledge of STEM careers, this study seeks to shed light onto the intricacies with respect to curriculum design in global context. More specifically, it exemplifies the way career-oriented instructional material can impact students’ interest in science and shares some interesting findings in terms of the conditions under which career-based scenarios in science subjects can enhance interest in science and STEM careers. These upcoming findings allow educators to refine their teaching in science class by designing or adjusting and integrating such scenarios in local context. Lastly, this research offers useful insights into evaluating science education interventions, suggesting a set of tools
used to collect data regarding students’ interest in science, knowledge of STEM careers and related aspirations. This study could set a fertile ground for future research to examine the long-term impact of science-career-oriented curriculum design in the development of science identity as a critical factor influencing STEM career choices (Carlone & Johnson, 2007).

References


Critical thinking and reflective participation on scientific practices in the early childhood classroom

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Outline
This study addresses the preliminary findings of a PhD research which seeks to improve the knowledge about students’ enactment on scientific practices and critical thinking (CT) skills. There is an emphasis in research and policy documents on the importance of engaging learners in scientific practices since early years (Cabe Trundle, 2015; Campbell & Jobling, 2012). Moreover, there is some consensus among researchers about the need to include CT as a core skill that should be taught in schools and included in the curriculum (Binkley et al., 2012). Preliminary results of this study revealed that when children engaged in inquiry-based tasks, they were able to mobilize theoretical and practical knowledge and used them to reason about data. Despite this context, research on scientific practices and CT remains scarce, particularly in early childhood education, being this aspect the main contribution of the project.

Framework
A key component of science learning is to engage student in scientific practices. Scientific practices are used to described behaviours that scientist engage in as they investigate and build models about the natural world, what implies that scientific investigation requires skills and knowledge (NRC, 2012). Research shows that involving learners in scientific practices leads to a more sophisticated understanding of key ideas and scientific models and of the nature of science (Lehrer & Schauble, 2015). For the purpose of this study, we draw Reiser, Berland and Kenyon’s (2012) view of scientific practices that not only involves building the knowledge and understanding the reason of it, but also the social interactions that accompany this process. We define the operational definitions of inquiry from Eshach and Fried (2005) consisting of observing, asking questions, hypothesizing, representing data (tables, diagrams, etc.), interpreting data and formulating models. Modelling operational definitions involves students’ participations on the development, use and assessment of models (Schwarz et al., 2009) and, regarding the scientific practice of argumentation, we concur with Berland and Reiser (2011) that it implies learners’ engagement in a dialogic process in which they socially construct, critique and revise claims about the natural world, basing them on evidence (Sandoval, Sodian, Koerber, & Wong, 2014). The assessment and justification of claims is connected with scientific reasoning, since the justification shows why the data count as evidence to support the claim, including appropriate scientific principles (McNeill & Krajcik, 2012).
In the recent years, scientific practices have gained more presence in international and national curricular documents (NRC, 2018; OECD, 2013) and there is a large part of the community scientific community accept the metaphor of children as little scientists (Legare, 2012). However, the misconception about how their skills for inquiry, creativity and CT are simple still stands (Siry, 2013). Moreover, scarce studies had been carried out about scientific practices in early childhood and even fewer address scientific reasoning at this age.

Critical thinking, understood as a self-regulatory judgement (e.g., explanation, interpretation, analysis) based on different kinds of considerations (e.g., evidential, methodological, contextual) (Facione, 1990), is closely related to scientific practices. Specifically, there is an overlap among CT skills such as inference, analysis, evaluation and/or communication (Facione & Facione, 1992) and the inquiry and argumentation skills in terms of the analysis of reliable information, the test of hypothesis and the assessment of scientific evidence, among others (Jiménez-Aleixandre & Puig, 2012; Zohar, Weinberger, & Tamir, 1994). Research findings suggest that engaging students in reflective discussions might help them to develop their understanding of scientific knowledge and a critical mindset as future citizens (Jiménez-Aleixandre & Puig, 2012; Yacoubian & Khishfe, 2018), although very little research has been done about CT in early childhood and how to promote it while engaging in science learning activities at this educational level, which is the main contribution of the thesis.

Research questions
This research aims to contribute to an existing gap in the knowledge base on the development of scientific practices and CT in the context of early-childhood education. The research questions that guide my project are:

1. What is the nature of students’ discourse when they engage in scientific practices?
2. How scientific practices promote critical thinking skills in early childhood students?

Research design and methods
As stated earlier, this study seeks to shed light to the underexplored research area of children’s enactment of scientific practices when engaging in an inquiry-based task. For the design of this study, we chose to employ a qualitative single research case study. As defined by Simons (2009), case study is a research-based, in-depth exploration from multiple perspectives of the complexity and uniqueness of a particular phenomenon in “real” life, inclusive of different methods. In this thesis, the phenomenon under study is the exploration of the three scientific practices and CT skills when early childhood education students engage in inquiry based-tasks and the case study is defined by a classroom (N=25) of 5-6 years old and their teacher.

The data, consisting of an inquiry-based learning unit comprised by 10 sessions of 30-45 minutes each in which students were engaged in various tasks for the purpose of examining the forces (see table 1), was collected through observation, audio recording, field notes and photographs during 2016 – 2017 in the context of a public school in
Santiago de Compostela (Spain). The unit was designed by Torque, a work group in which the teacher of the study is involved along with other early childhood school teachers who implement science activities in their own classrooms.

**Table 1. Description of the inquiry-based task unit**

<table>
<thead>
<tr>
<th>Inquiry-based task</th>
<th>What is it about?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>An approximation of gravity</td>
</tr>
<tr>
<td>2</td>
<td>An introduction to forces</td>
</tr>
<tr>
<td>3</td>
<td>Vectors as a way to represent the forces</td>
</tr>
<tr>
<td>4</td>
<td>Floatation</td>
</tr>
<tr>
<td>5</td>
<td>Archimedes’ principle</td>
</tr>
<tr>
<td>6</td>
<td>Review on Archimedes’ principle with an emphasis on form</td>
</tr>
<tr>
<td>7</td>
<td>Review on floatation with an emphasis on weight</td>
</tr>
<tr>
<td>8</td>
<td>How salinity affects floatation</td>
</tr>
<tr>
<td>9</td>
<td>Cartesian diver task (Archimedes’ and Pascal’s principle)</td>
</tr>
<tr>
<td>10</td>
<td>Submarines</td>
</tr>
</tbody>
</table>

The *first research question* has been partially addressed. We adopted qualitative methods to analyse the data, adopting McNeill and Krajcik’s (2012) definition of scientific reasoning with the objective to characterize the kinds of reasoning that emerged in every stage of the inquiry cycle when the children engage in an inquiry-based task about gravity. Currently, an analysis based on categories that emerged from the interaction between the data and the literature review is being developed under the form of a coding scheme. This coding scheme is being discussed with Prof. Avraamidou and her group with other doctoral students during a stay at the Institute for Science Education and Communication (ISEC) in order to triangulate the results and establish trustworthiness in the study.

For the *second research question*, a content analysis based on Facione and Facione’s (1992) CT skills and dispositions of one of the experiments was undertaken to identify which CT skills and/or dispositions are present in the children’s discourse when engaging in an inquiry task. Previously to this analysis, an interview to a purposefully-selected group of early childhood school teachers (Torque) was carried out in order to explore which conceptions they hold about CT in early childhood and if they try to promote it among their students.

**Preliminary findings**

This research is grounded within the Spanish early childhood education curriculum (LOE 2/2006, of May 3rd, Xunta de Galicia, 2009) that asserts children should acquire progressively scientific attitudes and abilities. In this sense, scientific practices are addressed in the curriculum, being inquiry skills the most present. However, school teachers have few opportunities to access to science subjects and training courses that
allow them to get teaching strategies to foster scientific practices in their classrooms (Bargiela, Puig, & Blanco-Anaya, 2018).

Results related to the first research question: We examined the kinds of scientific reasoning that emerges in early childhood students’ discourse at each moment of the inquiry-based cycle in the context of a curriculum unit about. The results showed that the theoretical reasoning (N=24) appears more often than the empirical-theoretical reasoning (N=12). Both kinds of reasoning are mostly present while students formulated their own hypothesis and, was in this process when they introduced diverse variables such as mass, form and air friction (table 2). Overall, the study revealed that engaging students in inquiry-based helps them to mobilized theoretical and practical knowledge and used them to reason about data. This study sheds light to the underexplored research area of children’s scientific reasoning when engaging in inquiry-based learning, providing evidence that it is necessary to abandon the misconceptions about children’s abilities in order to provide them with learning experiences. These results will be presented at the ESERA conference (submitted).

Table 2. Examples of the kind of reasoning and students’ scientific reasoning

<table>
<thead>
<tr>
<th>Kind of reasoning</th>
<th>Scientific concepts in children’s reasoning</th>
<th>Quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR</td>
<td>Mass</td>
<td>Student 1: “Because it is heavy.”</td>
</tr>
<tr>
<td>TR</td>
<td>Form</td>
<td>Student 4: “[because] if it is like this (spherical form) it cannot fly”</td>
</tr>
<tr>
<td>TR</td>
<td>Property of the matter (hardness)</td>
<td>Several students “Because [the cover and back cover of a book] are harder [than the sheet of paper]”</td>
</tr>
<tr>
<td>ETR</td>
<td>Air friction</td>
<td>Student 5 “No, it is because the air hits it.”</td>
</tr>
</tbody>
</table>

Results related to the second research question: The analysis of the early childhood students’ discourse during one experiment about an approach to the idea of gravity showed the presence of three CT skills (inference, explanation, interpretation) with different frequencies, as well as the absence of dispositions. The different presence was related to the didactic sequence and the teaching strategy used for the teacher, the questioning, specifically, with the type of question she formulates to the children. For example, if the teacher asks, “what would happen if…?”, the skill of inference has a higher presence, whereas if she poses the question “why would you think that…?”, students develop too the skill of explanation.
References (selection)


How Do Pre-Service Teachers Use Theoretical Frameworks When Diagnosing Student Thinking?

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Theoretical Framework

Diagnostic competence is a central element of adaptive teaching for heterogeneous learner groups (e.g., Vogt & Rogalla, 2009). Within the process of diagnosis, teachers identify student understanding and learning difficulties in order to respond to their needs (e.g., Kang & Anderson, 2015). Diagnosis not only includes that teachers assess student competence and their learning, it can also be directed towards identifying learning requirements of tasks. The (German) notion of diagnosis shows strong similarities to concepts of formative assessment (e.g., Gotwals & Birmingham, 2016; Ruiz-Primo & Furtak, 2007) and noticing (e.g., van Es & Sherin, 2002). In contrast to formative assessment, diagnosis may emphasize a little more the relevance of a focus on requirements of tasks and that the response component may include more than feedback. In comparison to noticing, diagnosis may have a stronger emphasis on student thinking in contrast to focusing on all classroom events (van Es & Sherin, 2002, p. 574.) which include more general aspects of teacher behavior.

The ability (and the willingness) to enact diagnosis represents an important component of teachers’ professional competence, which can already be addressed in pre-service teacher training (Leuders, Dörfler, Leuders & Philipp, 2018; v. Aufschnaiter & Alonzo, 2018). Addressing diagnosis in teacher education may include instruction on how to perform diagnosis (e.g., what are typical components) as well as instruction on theoretical frameworks that can help to unpack student thinking and design an appropriate response (e.g., Learning Progressions, Alonzo & v. Aufschnaiter, 2018).

In our work, we model five characteristic components of a diagnostic process (see Fig. 1):

At the beginning of the process, *data* (1), that can also be collected by oneself, is sifted through to describe *observations* (2) which are indicative of student thinking and may need further support. These observations can be *interpreted* (3). Here, it is essential to unpack what a student might be understanding already and which learning difficulties s/he encounters instead of classifying student thinking dichotomously into *right* or *wrong*. Since interpretations do not explain why students think or act the way they do, possible *reasons* (4) should be inferred. Like student behavior and possible interpretations, reasons can be diverse. Maybe the current situation itself leads to a specific behavior of the students or the complexity of the topic to work on has an influence. Reasons may also lie in a student’s own biography. In their conclusion of *consequences* (5) teachers need to think about what the student should learn next and how to create responsive instruction that reacts to the student’s learning needs. This can include the revision of tasks, for instance, if these are too difficult, too easy, or misleading. Diagnosis is an
iterative process where, for instance, interpretations could be uttered after observations. Moreover, alternative interpretations, reasons, or consequences are possible.

**Figure 1. Components of a diagnostic process and the gain from theoretical frameworks (similar components described for formative assessment: (1) & (2) elicit, (3) & (4) interpret, (5) respond, e.g., Kang & Anderson, 2015)**

For targeted and differentiated diagnosis, theoretical frameworks can be helpful. Such frameworks are, for instance, developmental models like learning progressions (LPs), a “description of the successively more sophisticated ways of thinking about a topic that follow one another” (National Research Council, 2007, p. 219). These theoretical frameworks do not only include theories, but also empirical findings such as typical student ideas at a certain level or typical learning pathways (Alonzo & v. Aufschnaiter, 2018). Together with the components, theoretical frameworks can guide (pre-service) teachers’ diagnosis by, for instance, helping them to find diagnostic questions and offer criteria that serve as a lens to analyze student thinking (see Fig. 1).

**Focus of the Study and Research Questions**

Central aim of this study is to investigate how pre-service physics teachers (PSPTs) use theoretical frameworks and information on components in their diagnostic processes. Over a physics education course (15 weeks) video-data of PSPTs working with different kinds of student vignettes (videos of students learning in physics, transcripts, and student products) is collected to analyze their diagnosis. For their diagnosis, the PSPTS are, for instance, prompted to unpack what particular students seem to understand about the topic, which questions they might want to ask to further clarify student understanding, and what exactly the particular student needs to learn next. In addition to working on diagnostic tasks, PSPTs are filmed during instruction about theoretical frameworks (LPs in particular). Also there, the PSPTs mainly work on tasks that, for instance, prompt them to analyze what has changed from one level to the next. Central research questions (RQ) are:

(RQ1) Which components (1-5) do the PSPTs address in their diagnostic process?
(RQ2) How do PSPTs construct the components and how do they relate these to each other?

(RQ3) How do the PSPTs incorporate LPs (and other theoretical frameworks) in their diagnostic process?

Design and Methods
The main study has been conducted in a physics education course on diagnosis in the winter semester 18/19 (further data can be collected in the winter semester 19/20). The course addresses central aspects of diagnosis and theoretical frameworks (mainly LPs). PSPTs working with preexisting vignettes of students (video, transcript, and student products) in small groups of 2-4 is central to the course. Vignettes offer the advantage to break down the complexity of real classroom situations. They can be viewed several times and with different foci. As such, they cannot replace real classroom experiences but are tools to promote PSPTs’ learning attending to students thinking and considering possible responses (e.g., Blomberg, Renkl, Sherin, Borko & Seidel, 2013). We use vignettes for both: Instances to promote PSPTs’ learning of the theoretical frameworks and as examples for practicing diagnosis. In addition to the course in the winter semester, a single session takes place in the following summer semester, which takes up LPs as a framework for constructing diagnostic tasks. PSPTs participating in the study are in their third or fifth semester and have already taken part in an introduction module in physics education (two courses).

A total of $N = 16$ PSPTs have given consent to be filmed in pairs. $N = 23$ PSPTs have allowed to investigate their written course material and pre-tests on their conceptual understanding of mechanics. These PSPTs include the participants who are filmed. Video-data is collected in 8 sessions in the winter semester and in the single session in the summer semester. Sessions last 90 minutes each at a weekly basis. When selecting the sessions, particular attention was paid to recording the introduction to the components of diagnosis and the introduction of a LP on force and motion (Alonzo & v. Aufschnaiter, 2018; Alonzo, 2012), altogether 3 sessions. In the other 5 sessions in the winter semester, the LP can be used by the PSPTs for other mechanical topics (circular motion).

For the analysis of the described data, a coding scheme has been developed (adapted from parallel projects on diagnosis, e.g., v. Aufschnaiter & Alonzo, 2018) to identify the components (RQ1) and frameworks used (RQ3). Coding can also offer some information on the content of discourse, time needed for specific activities, problems mentioned by PSPTs, and other aspects. For RQ2 an additional qualitative approach – which may lead into categories – will be applied to diagnose the PSPTs’ sense making of diagnosis at a more individual level.

The approach described was already tested in a pilot study with $N = 11$ PSPTs in the academic year 17/18 and has been expanded and modified since then. These pilot data will also be used to investigate whether the approach chosen has the potential to result in valid conclusions.
State of the Study
So far, video recordings of the main study have been started and the 8 sessions of the winter semester will be completely recorded in February 2019. At the ESERA summer school, the coding scheme, results from the pilot and/or main study, and open questions according validity and other methodological approaches (in particular on how to investigate RQ2) will be presented and discussed.

References


An empirical study on learning processes and actions of pupils while interacting with exhibits at a Science Centre

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Focus of the study
Educational programs in non-formal settings can work complementary to the school. Non-formal learning settings, such as science centres, can offer educational programs that are not feasible in schools due to lack of assets and infrastructure. Factors that influence out-of-school learning are the variety of activities, topics, and objects that enable students to act by themselves and be responsible for their own learning. In these out-of-school learning environments it is important to consider the complexity of the learning situation during a school visit (Griffin, 2012, Falk & Dierking, 2000). The current study therefore not only examines how students' individual learning processes are influenced by the characteristics of the exhibits they interact with, but also the expectations of the teachers on the interaction of the pupils with the exhibits, their preparation for the visit as well as the expectations and learning goals of the supervisors of the centres. This research is being carried out at the University of Oldenburg in Germany within the framework of the graduate program GINT (Geography, Informatics, Natural Sciences and Technology in non-formal learning areas) funded by the Land of Lower Saxony.

Review of the literature
Studies about informal learning environments show that pupils' interests in scientific topics can be aroused at these environments. However current research provides few indications on how pupils can develop scientific knowledge and competencies through self-directed interactions with exhibits. For example, previous studies have shown that common learning processes that are possible to occur during the interaction with exhibits are: a) remembering previous knowledge built on personal experience, b) establishing and recognising correlations between exhibits, c) asking questions and explaining (for example the function of the exhibit) (Hein, 1998; Falk & Dierking, 2000; Kelly, 2007). There have been suggestions in order to operationalise the link between exhibit characteristics and visitor activities. The four stages of Achiams praxeology (2013) that show the level of a users interaction with an exhibit are the following: (1) Task: The user is able to perceive the task or suggestion provided by the exhibit. (2) Technique: The user may execute or use a procedure to solve the task or execute a process in a particular situation (3) Technology: The user can justify his action. He can also explain what and why is happening while interacting with the exhibit. (4) Theory: The user is able to justify himself with abstract concepts. However, to what extent the learning goals are achieved, in what way they differ from those at school, and how they
can be described as inquiry based learning remains to be further investigated. There is also a lack of research about what influence teachers and the science centres' supervisors have on learning processes of pupils (Griffin, 2012).

**Research questions**

The study addresses the following questions:

1. What kind of learning processes and actions occur while pupils interact with the exhibits of a science centre during a school visit?
2. Which characteristics of the exhibits influence the actions and the cognitive processes of the pupils?
3. To what extent and how do the intentions and expectations of the science centres' supervisors and of the teachers influence the interaction and cognitive processes?

**Research design and methodology**

The study is based on the Model of Educational Reconstruction (MER) (Duit, Gropengießer, Kattmann, Komorek & Parchmann, 2012). The aim of the model is to take equally into consideration science subject matter issues and learning needs and capabilities to improve the quality of teaching and learning by exhibits in science centres. We apply the model to the situation in a science centre: The exhibits have a scientific and an educational structure that need to be analysed. The results of these analyses have to be systematically related to the empirical results on the learning processes and the influences of the teachers and supervisors (comp. Laherto, 2013). The empirical study is taking place in the Phänomenta Bremerhaven in Germany where 80 hands-on exhibits are provided to the public. The exhibits were analysed to determine which actions and which learning processes are possible while interacting with them, based on the "Praxeology" of Achiam. In addition, it is analysed which scientific content of the exhibits could be conveyed to the pupils by interacting with them and what interaction the exhibits offer. We have selected 5 of them in the field of physics (camera obscura, visible light, Bernoulli Effect, pulley system, brachistochrone) which offer different amounts of interaction.

**Research Phases:**

1. Certain exhibits underwent a potential analysis to determine what actions and what learning processes are possible while interacting with them (based on the "Praxeology" of Achiam (2013), which scientific content the exhibits offer.
2. The research questions were concretised and suitable research instruments such as interviews and questionnaires were either developed or adapted.
3. Pilot study: The centres' supervisors were interviewed. A random sample of 10 fourth grade pupils was participatory monitored and interviewed in groups of two during their interactions with the exhibits. Questionnaires were used before and after the visit to all of the 34 visiting pupils and the 6 accompanying teachers.
4. The empirically obtained data were evaluated using qualitative content analysis and adaption of research tools.

5. Main study: Participatory monitoring and interviewing of pupils during their interaction with exhibits and pre-post questionnaires for them in order to investigate their processes of decoding the exhibits and to interpret the extent to which the exhibits affect scientific learning. Pre-post questionnaires for teachers and video-based interviews with them will be carried. Until the summer school data collection of the main study will be completed.

Research tools and subjects of the study
The views of the centres' pedagogical leaders were recorded during a structured guideline interviews in order to find out their views on what the five exhibits are aiming for and what kind of pupils' learning processes they expected. Examples: “What is the main goal of this particular exhibit?”, “To what extend do you think that pupils will reach that goal?” Following, visits at the science were attended and a random sample of pupils was participatory observed and interviewed in groups of two during their interactions with the hands-on exhibits in order to investigate their interactions with the exhibits. The aim was to interpret the extent to which the exhibits affect scientific learning. Questionnaires with open ended and multiple choice questions were administered before and after the visit to pupils in order to find out which pupils' ideas emerged on the phenomenon of the selected exhibits and which the pupils' expectations were. There were also questionnaires for the teachers with open and multiple-choice questions before and after the visit, based on categories by Cox-Peterson, Marsh, Kisiel & Melber (2003) and Griffin & Symington (1997). They were about the teachers' views on the learning outcomes they expect from the pupils' visits, and how the visit could be integrated into the school curriculum. Also a video-based interview with the teacher will be conducted in order to find out their views on what kind of pupils' learning processes they expect.

Data analysis
In order to determine the actions and learning paths that occur while interacting with the exhibits we evaluated the empirically obtained data using qualitative content analysis (Mayring, 2015). Therefore, we related the data from the pupils, teachers and supervisor to each other systematically. In order to answer the research questions we will determine from the transcribed interviews and the observation grids, which stage of Achiams praxeology is reached by the pupils during their interactions with the exhibits. By qualitative content analysis, categories of learning processes like (a) remembering previous knowledge built on personal experience, (b) establishing and recognising correlations between exhibits, (c) asking questions and explaining etc. will be researched in the obtained data. The teachers and supervisors interviews about their expected pupils' interactions will be analysed in a similar way.
Preliminary results
In order to determine the actions and learning paths we evaluated and related the empirically obtained data as outlined in the following case study of the fourth grade pupil Stefan. This pupil was interviewed and observed during his interaction with the “Visible Light” exhibit. At this exhibit there is the possibility to fold three colour filters (red, green, blue) and a prism one by one or simultaneously in front of a light source. The written task at the exhibit was: "Look at the spectrum of visible light with the prism, and the filters will only pass through a certain area." Stefan recognises all objects (lamp, button, colour filter, etc.) at the exhibit. He retrieves his prior knowledge of the exhibit and can justify and explain his actions. However, although he placed the red and blue filters in front of the light source at the same time and could see that the light was largely absorbed by the filters, he remained in his initial opinion of his first questionnaire "the light should turn purple". His explanation for the phenomenon observed on the exhibit was that the filters are "too thick for any light to pass through". So Stefan stays with his initial opinion, that the phenomenon shown at this exhibit is colour addition instead of the actual phenomenon shown, that is colour subtraction. This example shows that the intentions of the science centres' leaders do not fit one by one to the learning processes of the pupils. Data also show that 5 of 6 teachers expect that their pupils had learned something new from the visit, although 4 of 6 notice the pupils' difficulty to understand the phenomena by interacting with the exhibits, because of the lack of further guidance and explanations.

References


What counts as scientific argument?: language ideologies and the engagement of multilingual students in discourse

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Problem Statement
Argument from evidence and reasoned dialogue have been posited to be central to the generation of scientific knowledge (Latour & Woolgar, 2013; Longino, 2002; Osborne, 2010) and feature prominently in the Next Generation Science Standards (NGSS Lead States, 2013). However, the language of science is often positioned as a barrier to engagement for students (Wellington & Osborne, 2011), due to its impersonal and authoritative nature (Lemke, 1990) and complex lexicogrammatical features (Fang, 2005). The language of science reflects the linguistic practices of the white, middle-class speakers who still largely dominate the community of professional scientists. Although researchers have argued that students need more opportunities to “talk science” (Lemke, 1990), students from non-dominant1 linguistic backgrounds (e.g. multilingual4 students and speakers of colloquial5 varieties) may experience identity conflict when appropriating scientific language (Brown, 2006). Given the rapidly increasing cultural and linguistic diversity in the United States, more needs to be known about how to support non-dominant students in engaging in disciplinary forms of talk, such as argumentation.

Literature Review
Scientific argument is often considered as a social practice (e.g. Osborne, 2010) and is sometimes considered as a cultural practice (e.g. Berland, 2010), but is rarely considered as a linguistic practice. The central argument of this dissertation is that scientific argumentation can be productively theorized as a linguistic practice that can be understood through contemporary theories of language acquisition. In this study, argumentation is interpreted through a transdisciplinary framework for language acquisition (Atkinson et al., 2016) that considers language to be constituted by three dimensions: the micro level of social activity, or interactions that draw on multiple situated semiotic resources, the meso level of sociocultural institutions, with attendant structures of power and agency, and the macro level of ideological structures, or belief

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1 Non-dominant is used to indicate students that come from marginalized socioeconomic, cultural, or linguistic backgrounds. The term minority is avoided given that these groups are often the majority in many schooling contexts.

4 The term multilingual is used to emphasize students’ strengths in using multiple languages, as opposed to the term English language learner (ELL), which reflects perceived student deficits. In reality, all ELLs in mainstream classrooms are users of English and all speakers of English, including native speakers, are learners of English, including the language of science.

5 Colloquial include non-dominant spoken registers, such as African American Vernacular English.
systems and cultural values. Building from this framework, I argue that the language of science is not empirically determined set of facts about language use, but rather a site of contestation in which particular priorities and values are negotiated.

Several ideologies of language that are relevant to the study of science can be identified in the applied linguistics literature. For example, the ideology of standardization attempts to impose uniformity upon language use (Milroy, 2001). Central to the ideology of standardization is the notion of correctness, or the prescriptive use of linguistic structures. This view is at odds with modern language pedagogy, which frames goals in terms of what students are able to do with language and their fluency rather than the accuracy of their linguistic production (Lee, Quinn & Valdés, 2013). The figures below summarize particular ideologies of language and implications for how these ideologies can organize the activity of the classroom.

<table>
<thead>
<tr>
<th>Monoglot Ideology</th>
<th>Polyglot Ideology</th>
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<tbody>
<tr>
<td>Description: (science) language is an objective, unified, bounded set of practices</td>
<td>(science) language is culturally and contextually negotiated</td>
</tr>
<tr>
<td>Implication: Students should move towards the “appropriate” use of academic language, the features of which are derived from written scientific texts</td>
<td>Students should use language differently across settings, contexts and modalities depending on the audience and drawing from diverse linguistic resources</td>
</tr>
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<table>
<thead>
<tr>
<th>Structuralist Ideology</th>
<th>Communicative Ideology</th>
</tr>
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<tbody>
<tr>
<td>Description: (science) language is constituted of a set of structural forms: morphology, vocabulary, syntax</td>
<td>(science) language is a means of accomplishing a social action through a range of semiotic resources</td>
</tr>
<tr>
<td>Implication: students should use particular linguistic forms correctly, which can be supported by tools such as vocabulary word walls and sentence stems</td>
<td>students should use language flexibly and fluently, which can be supported by giving students a need to communicate and structuring interactions</td>
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Language ideologies structure what kinds of contributions are valued in the discourse of the classroom (Wortham, 2001). Flores and Rosa (2015) critique discourses of appropriateness, arguing that they primarily serve to position the linguistic practices of non-dominant students as deficient, regardless of how closely these students’ practices resemble the supposed rules of appropriateness.
Research Questions
This study seeks to explore the role that ideologies of the language of science play in the classroom experience of students from non-dominant backgrounds. Specifically, this study will address the following questions: 1) How are language ideologies negotiated by the members of the classroom community? 2) How are language ideologies translated into particular forms of support to engage students in argumentation? 3) How do language ideologies afford and restrict opportunities for linguistically non-dominant students to participate in classroom discourse?

Research Design and Methods
These questions will be addressed through a multiple case study method (Yin, 2017) to explore how ideologies of language are similar and different across particular classroom contexts. The study will be conducted in a diverse, suburban school district in Northern California. Three focal classrooms with large numbers of students from non-dominant linguistic backgrounds will be selected from teachers participating in a professional development program on supporting argumentation and discussion in elementary science. Thirty observations will be conducted in each classroom over a period of six months. In each classroom, four focal students will be selected that represent a range of linguistic and cultural backgrounds.

Data sources will include ethnographic field notes, classroom artifacts, student work samples, whole and small group video recordings, and interviews with teachers and students. Field notes, artifacts, and interview data will be coded through an emergent, constant comparative method (Saldaña, 2015). Video data will be studied through microethnographic interaction analysis (Bloome et al., 2004).

Preliminary Findings
I will conduct classroom observations from January to June 2019, so I will come to the ESERA summer school with data and preliminary findings. Insights from the summer school will serve to support my approach to the detailed analysis I will undertake the 2019-2020 academic year.

References


Development and evaluation of an online learning environment providing bug-related feedback for general chemistry courses

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Theoretical framework
Since 2006, there has been a dropout rate of 42% in study programs of chemistry at German universities. Heublein, Ebert, Hutzsch, Isleib, König, Richter and Woisch (2017) worked out that 30% of those who quitted a study program of mathematics or a natural science started with low prior knowledge (PrK) at university and were not able to catch up. Averbeck, Fleischer, Sumfleth, Leutner and Brand (2017) were able to replicate these findings for chemical science study programs at the University of Duisburg-Essen (UDE) and Ruhr University of Bochum (RUB).

Focus of the study
Due to the need of next generation chemical scientists in Germany and all over the world it is necessary to support enrolled students in chemical science study programs in gaining a qualifying degree for further work in research. Since feedback is an important factor to influence learning processes (Hattie & Timperley, 2007) we searched for a way to give students the opportunity to gain bug-related feedback related to their mistakes independent from time and place. That led us to creating an online learning environment providing automatized computer generated informative tutoring feedback (ITF). Up to now, studies do not clarify the role of different levels of PrK for the efficacy of ITF sufficiently. Some studies report a connection between low PrK and students’ need for elaborated feedback components (Krause, Stark, & Mandl, 2009) while Smits, Boon, Sluijsmansand van Gog (2008) as well as Narciss & Huth (2006) could not find any benefit caused by elaborated feedback components for students with low PrK. Nevertheless, in subjects related to chemistry a connection between feedback content and PrK was found (Albacete & VanLehn, 2000; Narciss et al., 2006). To illuminate this partial controversial field of research, two feedback algorithms, which vary in content of feedback, are compared in this study. The first one, developed by Narciss et al. (2006), provides a bug-related tutoring feedback (BRT), containing detailed information about mistakes and specific advice for solving the task, seems more appropriate for students with low prior knowledge. This BRT-feedback algorithm will be compared to a corrective feedback algorithm, containing just information weather the solution is or is not correct, which is estimated more appropriate for students with high PrK (Smits et al., 2008).

Background ideas
Now the question is, why there is such a specific need for tutoring feedback in study entry phase. One reason may lay in the different way school and university teaching are
organized. While students at secondary schools get feedback from their teachers very often, they need to call actively for feedback at university. Hence, in study entry phase students need to get used to be the active part in gaining feedback leading to a change in behavior to fit in this new system of different teacher-student-interaction (Rost, 2012). Surprisingly, students with low and high prior knowledge achieve the same knowledge gain (Averbeck et al. 2017). Thus, the big challenge is to foster learning progress for low PrK without demanding too little from students with high PrK. Two different approaches appear to be promising: adaptive task difficulty or adaptive feedback. We decided to support the students with bug-related feedback to increase their learning success because this approach allows to address misconceptions at the same time. Feedback in general is the informational response that is given to a system after completing a process or a part of it to influence behavior in comparable situations for the good (Narciss et al., 2006). Students need feedback to evaluate their steps in learning chemistry. Certainly, they could also learn from special working books and with the given sample solutions. Although, this presupposes an adequate amount of PrK to find the mistakes (Jacobs, 1998). That would leave the students with low PrK behind, again, because there is neither direct response nor help in case of failure. Hence, good feedback mentions the constitution of the learner (e.g. PrK) itself (Hattie & Timperley, 2007) as well as the constitution of the learning environment (e.g. difficulties or typical mistakes) and tries to show mistakes (cognitive function) and misconceptions (metacognitive function). This given feedback will of course be processed in an individual way (Narciss et al., 2006).

For the development of such an online learning environment providing the mentioned types of feedback, several aspects play a major role. First, there are of course the requirements of the curriculum. Second, there are the design principles of multimedia learning (Mayer, 2009) regulating the visualization of tasks. Third, there are the technical requirements towards the online tool. On the one hand tasks should be visualized and conditioned comparable to genuine paper-pencil tasks, on the other hand the task itself should be well constituted to pave the way for specific bug analysis and for bug-related tutoring feedback. “Chemistry [as] a visual science” (Wu & Shah, 2004, p. 465) with its many diagrams, (structural) formula and reaction equations, requires a complex to program set of task-types that allows automatized recognition of specific learners’ mistakes.

**Research question**

The controlled comparison of the two feedback algorithms mentioned above seems promising to gain knowledge about the impact of PrK on the efficacy of various ITF feedback components, which leads us to the research question of this study:

RQ: How do the two feedback algorithms (BRT-feedback vs. corrective feedback) differ in efficacy in fostering learning progress under consideration of prior knowledge in the general chemistry course in the first semester?
Considering the findings of researchers who postulate an impact of PrK on the efficacy of various ITF components the content of the theoretical framework legitimates to deduce the following hypotheses:

H1: The BRT-feedback algorithm especially fosters learning progress of students with low PrK compared to those with high PrK.

H2: The corrective feedback algorithm especially fosters the learning progress of students with high PrK compared to those with low PrK.

Study design
In order to deal with these research questions a quasi-experimental cross-two research design ($N = 100$) is used. We randomly matched first year chemistry students with low and high PrK to two intervention groups in equal proportion to compare the mentioned feedback types adequately. Due to short time between first survey and the start of the intervention PrK was indicated by students’ choice of chemistry courses at upper secondary school, since the choice of chemistry courses is known as a good predictor for both, PrK and study success (Averbeck et al., 2017). Moreover, we surveyed control variables of the sample at the beginning of the semester. We tested several scales of cognitive skills (Heller & Perleth, 2000), (pre) content knowledge in general chemistry (adapted to Freyer, 2013), mathematical skills and further control variables (motivation to learn/ to study and learning strategies during study program). As part of the intervention, which includes the whole first semester, a short survey is given to the students after each set of tasks to evaluate the treatment. Here we focus on the perceived mental effort, perceived usefulness of feedback and item difficulty and the rating of the learning environment in general. Furthermore, log files will provide detailed information about time-on-task and the feedback study time. After the semester we are going to conduct a post-test about expertise in general chemistry and collect the exam results. The pilot study has just begun this winter semester (2018/2019). Hereby, we want to evaluate the validity of first sets of tasks and the online learning environment itself. We managed to provide 60 feedback supported tasks to 10 themes in chemistry, e. g. redox reaction. So every set of tasks containing six tasks is dealing with one of these topics whereby every student has to solve at least two task of each set correctly in a row. Furthermore, the feedback of this tasks will be rated by experts to assure its quality on qualitative base. Next year at the same time, the main study will be conducted with a full set of online tasks accompanying to the lecture of general chemistry.

Expectations
Due to ongoing data collection, the first results are expected for March 2019. In addition, the main study provides a full set of computer based learning tasks. So this learning environment could be established as a non-stationary and time-unbound learning offer for further generations of students. (This could ease the change in the students’ behavior from being the passive part to being the active part in gaining feedback during the study entry phase by detaching the offer of feedback from a reference person.)
References


Pythagoras

Mentors: Mariona Espinet, Pasi Nieminen
Becoming Science Teachers Together: Course Creation and Exploration Through Participatory Action Research

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Outline
In this participatory action research study, I, along with pre-service elementary teachers enrolled in a science methods course will explore science teacher identity without the constraints of a traditional predetermined course curriculum. Building off current identity of work in education (specifically Gee, 2000; Carlone & Johnson, 2007; & Avraamidou, 2016), this co-creation of a course will allow preservice teachers to conceptualize the kinds of science teachers they want to be, as opposed to the kinds of science teachers they are told to be. Through journaling, discussions, reflections, and experiences, we will co-create the curriculum together based on their needs as future science educators, constantly thinking about our subjectivities to disrupt and shift power relations to create the course together/with (Foucault, 1988). For this study, I will be focusing on science teacher identity of those teaching elementary age students within a science methods undergraduate course. Topics include identity, science teacher identity, elementary education, and teacher preparation.

Problem or issue being addressed
Avraamidou (2014) stated that “the majority of research regarding teacher identity focuses on teachers at the middle and high school levels leaving a gap of knowledge about elementary teachers’ identity” (p. 4). What is interesting to note about this is that middle and high school level teachers would be choosing a specific content area to teach, unlike the general preparation of elementary teachers. This means elementary teachers teach all subjects, including science, but research has not focused on how elementary teachers come to see themselves as science teachers. According to Mensah “very few studies actually deal with elementary teachers in their construction of a science teacher identity” (2016, p. 51). She goes on to state that since elementary teachers are prepared to teach all core subjects, their views of themselves as science teachers is limited and sometimes fearful (Mensah, 2016). This, alongside the lack of science instructional time in elementary schools in the United States, drives my study (Trygstad, Smith, Banilower, & Nelson, 2013).

Clarification of meaning of any key terms
In this study, both terms identity and subjectivity are used. Science education literature commonly uses the term identity in work that I will draw off of, but I propose thinking about how preservice teachers come to view themselves as science teachers through and
as subjectivity. Subjectivity can be defined as the beliefs, thoughts, and views - conscious and subconscious - of an individual and how they see themselves relating to the world, all of which are produced by positions as subjects (St. Pierre, 2001; Jackson & Mazzei, 2012; Bazzul, 2016). It is an “ongoing process of ‘becoming’ – rather than merely ‘being’ – in the world” (Jackson & Mazzei, 2012, p. 53). Subjectivities are never completely constituted, but are always changing and evolving based on relationships and context. Contexts and those involved play a role in how the subject understands and perceives her/himself (Mansfield, 2000). As used in this study, identity will be one expression of our subjectivities (St. Pierre, 2000). It is important to note here, as Jackson (2001) mentions, identity in a humanist definition assumes a common thread or experience; however, identity as a sense of self, or an expression of subjectivity, is about different experiences and understandings, meaning this is different for each person.

**Educational context of the study: Situating the study**

With a focus on pre-service elementary teachers, I will explore various aspects of science teacher identity. Many science teacher identity studies use methodologies such as narrative inquiry, interviews, and case studies. While drawing on the results from these studies of the idea that students’ identities as science teachers have the ability to change in the length of a methods course, I pose a different theoretical framework and methodological approach.

**Review of literature**

Avraamidou (2016) defined teacher identity as having three aspects: “a) teacher identity is socially constructed and constituted; b) teacher identity is dynamic and fluid, constantly forming and reforming; c) teacher identity is complex and multifaceted, consisting of various sub-identities that are interrelated” (p. 154). Teacher identity is not something gained in the first-year teaching, but rather is a subjectivity of those within teacher education programs and, therefore, is a site of constant conflict and change (Jackson & Mazzei, 2012). As Beauchamp and Thomas (2009) stated, “A teacher education program seems to be the ideal starting point for instilling not only an awareness of the need to develop an identity, but also a strong sense of the ongoing shifts that will occur in that identity” (p. 186). It is within teacher education programs that a recognition of becoming a certain kind of teacher is taking place.

In a later narrative inquiry study, Avraamidou (2016) takes a more focused look at the experiences, or critical points, of a student’s life history in her view of herself as an elementary science teacher. Avraamidou (2016) points out multiple negative experiences in science classrooms during K-12 schooling, and how a shift in experiences in science classrooms were impacting how this student was viewing herself as a science teacher. Through a combination of reflection on her story and new experiences in science education, the student could begin to see herself as a teacher of science. Reflecting on experiences to examine beliefs about science and science teaching are practices involved in both Avraamidou (2016) and Mensah’s (2016) work. The practices
are important when taken with previous work by Avraamidou (2014) that stated, “beginning elementary teachers do not have many memories of science learning experiences except from a few ones that involved experimentation and their memories of science teachers involve stereotypical images of strict and eccentric middle-age men.” (p. 827) It is in the discussion of and reflection on these experiences that teachers can begin to question their impact on identities as science teachers.

Statement of research questions
In PAR, traditionally questions of research are created with participants. In this situation, it is more than the questions that will be created together, as the entirety of our course will be designed based on the questions and needs of the students. Currently, for purposes of the study design, the research questions are 1) How do pre-service teachers conceptualize science education, 2) How do pre-service elementary teachers (re)conceptualize who they are as science teachers and 3) What experiences do they need in their becoming a science teacher? These questions will guide, but not limit, our course design and implementation. As in a PAR project, students will have the opportunity to create new questions that represent their concerns in becoming science teachers. Their responses will lead to further questions, and these questions may replace the initial research questions.

Outline of research design and methods
Methodology: Participatory Action Research
My study works through collaboration by means of Participatory Action Research (PAR) between myself, as an instructor, and pre-service elementary teachers, as undergraduate students. PAR gives us a space to negotiate the traditional power relations between teacher-students and researcher-participants by allowing for an authentic collaboration where the students’ realities and views of who they are and want to be as science teachers lead the class. Through self-reflective inquiry, the students and I work together to create the experiences the students identify as necessary for them to become science teachers. The framework of PAR embraces the unknown, accepting that things will not be predetermined, but determined together. Greenwood, Whyte, and Harkway (1993) suggested that a mandated PAR project is impossible, and that the goal of PAR is to emerge into a truly collaborative process between participants and researcher. PAR is neither linear nor clean; it is a messy, unpredictable process. As Miller (2107) stated, those involved in PAR “need to consider implications of the unknown, the unpredictable and the unmeasurable as aspects of always entangled but never fully conscious or static subjectivities” (p. 495).

Methods
It is with this understanding of PAR as previously discussed – an unknown, unpredictable, and messy collaborative process—that I (re)think on the methods I imagine using, embracing that this may or may not be what the class decides on together,
and that this can change throughout the duration of the course. The methods used to begin this emerging PAR project will consist of multiple reflective practices in accordance with the definition of PAR (Baum et al., 2006). The course in which the study takes place is a fifteen-week course focused on elementary science methods. Students in the course are enrolled in the teacher preparation program and are in their last semester of course work before completing their full-time residency in an elementary or middle school. While the course will be relatively open in respect to design, as the syllabus will be co-created, I have prepared activities for the first class meeting. These activities are strategic to construct and begin reflections of ourselves, individual and as a group, as elementary science teachers.

The semester started with pre-reading and reflection activities in order to allow students to begin understanding how our non-traditional course will function. Students did not receive a syllabus prior to class, rather, we co-created the syllabus during the first class. As previously mentioned, self-inquiry and reflection are key pieces in PAR projects (Baum et al., 2006). Data consists of various documents including the syllabus, assignments, readings, activities, and journals, as well as teacher observations and notes. Individual journal reflections will be required at the end of every class and class conversations will dive in deeper to concepts on science education and science teacher identity.

By working and creating together, we are deciding for ourselves what it means to become teachers. Upon the conclusion of our first class, I thanked the students for their excitement and contributions. “I’d much rather a teacher ask what we want to do in the course than just make it for us!” was the response given to my gratitude, and with that we concluded our first session and moved on with our becomings together.

References


Analyzing the Use of Educative Curriculum Materials in Physics Teaching

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Introduction
In the long run, research in science teaching strives to improve student learning. To achieve this goal, it is necessary to support teachers’ professional development so that they are able to offer high instructional quality. Usually pre-service teacher education programs, in-service teacher trainings or teacher self-study of educative curriculum materials provide this support. The present study focuses on the last strategy by characterizing teachers’ use of educative curriculum materials for planning and performing physics lessons. Even if some educative curriculum materials for teaching physics have already been evaluated positively in Germany, they are rarely implemented. Nevertheless, research has shown that teachers’ study of educative curriculum materials has the potential for a high impact on teachers’ classroom practices. Thus, the purpose of my study is a better understanding of teachers’ interaction with educative curriculum materials when they apply to these materials for teaching. By analyzing this process in more detail, it should be possible to improve the further development of educative curriculum materials.

Literature Review
Developing educative curriculum materials is a useful way to transfer innovative teaching approaches to teachers because the use of curriculum materials is well established in school practice (Loewenberg Ball & Cohen, 1996). Moreover, there are findings, which suggest that educative curriculum materials can support teachers’ practices. For example, Arias, Smith, Davis, Marino and Palinscar (2017) found substantial differences in student achievement for students who were taught by teachers using curriculum materials with or without educative features. Charalambous and Hill (2012) also determined that a Standards-based curriculum enabled teachers to offer higher instructional quality.

But there is also evidence that teacher interaction with (educative) curriculum materials is a very individual process and depends on many factors like teachers’ knowledge, beliefs about teaching and learning, experience and school environment (Remillard, 2005). For instance, Roehrig, Kruse and Kern (2007) observed 27 teachers using a reform-based chemistry curriculum and found that traditional teachers modified the material significantly whereas inquiry-oriented teachers followed the curriculum closely. Another problem seems to be that pre-service teachers “tended to not read educative text feature [sic!] in potentially educative ways” (Land, Tyminski & Drake, 2015, 16). If these findings hold also for in-service teachers, one might question whether the desired
professional development by teachers’ self-studies can take place under these circumstances.

To sum up, the use of educative curriculum materials is a possibility to support teachers’ professional development. However, there is also evidence that teachers’ interaction with curriculum materials is a complex process. Up to now, there is a lack of systematic analyses, especially for physics instruction in Germany. Hence, my study investigates the relationship between educative curriculum materials and teaching practice in physics.

Objectives
This study explores the implementation of educative curriculum materials in physics classes.

1) How do teachers perceive different elements of educative curriculum materials like worksheets, texts or educative features?
2) Which characteristics of the elements of the educative curriculum materials determine teachers’ use of them?
3) Which context factors have an impact on teachers’ curriculum practices?

Thus, the study focuses on the relationship between teachers’ beliefs about teaching and learning, teachers’ use of educative curriculum materials and the implementation into their classroom instruction.

Method
The chosen educative curriculum materials focus on a teaching unit in quantum physics for the German Gymnasium whose last two years are comparable to the first two years of American college. Because of the high level of mathematics, the lack of visualizations and the discrepancy between the contents of quantum physics at school and at university, the educative curriculum materials were developed with the intention to design a coherent concept of quantum physics with the focus on qualitative understanding in order to avoid typical misconceptions. The educative curriculum materials and the teaching unit based on them were evaluated successfully to foster students’ achievement in comparison to the traditional way of teaching quantum physics (Müller & Wiesner, 2002).

In my study the participants receive the educative curriculum materials as a suggestion for teaching quantum physics but the use of them is facultative. In this context, it should be noticed that German teachers are more independent in their curriculum planning to fulfill national standards than teachers in other countries and as a consequence they usually take into consideration more different curriculum materials for self-study (Westbury, Hopman & Riquarts, 2000).
For data collection, the participants are interviewed at the beginning of the unit to obtain information about teachers’ practices, beliefs about teaching and learning and their self-efficacy about teaching quantum physics. Furthermore, I videotape two predefined lessons to explore the implemented curriculum and teachers’ classroom practices. In a stimulated recall after each classroom observation the teachers are asked about their instructional decisions and the modifications of the materials they made. In a concluding interview at the end of the unit, I deliberate with the teachers their experiences when implementing the given curriculum materials. The different instruments for data collection were also implemented to further validate teachers’ statements following a mixed methods approach.

Pilot Study
In a pilot study I conducted the first interview with five Gymnasium teachers for physics and collected further data about three of the teachers as mentioned before. The objective of the pilot study was to improve the guidelines of the different interviews, to develop a coding scheme for data analysis by qualitative text analysis (Kuckartz, 2014), and to explore preliminary assumptions which will be examined in the main study. The different categories of the coding scheme were developed, based on the literature and afterwards adapted and complemented by reconciling them with the text data. The final coding scheme consists of five main categories: (1) beliefs about teaching and learning, (2) lesson planning, (3) the use of curriculum materials, (4) the understanding of quantum physics, and (5) reflection on the unit.

The findings of the pilot study suggest that teachers often seem to have low self-efficacy about teaching quantum physics. In addition to that all participants taught quantum physics in a similar order starting with photons, moving on to wave characteristics of electrons and ending with a qualitative statistical interpretation following closely the national curriculum. According to this, it is remarkable that the teachers followed different goals by teaching quantum physics (cf. Remillard, 2005). All of them reported that they would like to point out the gap between quantum physics and classical physics but some of them also mentioned showing similarities between physics and chemistry, discussing models or outlining the interpretation of the theory of quantum physics.

The analysis of the stimulated recalls indicates that the use of the educative curriculum materials varies for different teachers. For example, a participant who had never taught quantum physics before adapted more of the materials than the others. Maybe, teachers with little experience in teaching adapt more of given curriculum materials (Remillard, 2005). Most of the used elements were intended for the implementation in the classroom and not for teachers’ self-study – comparable to the results of Land et al. (2015).

Overall, even though most of the teachers assess quantum physics as a difficult topic to teach at school, they did not adapt much of the educative curriculum materials. Factors like experience and goals seem to have a great impact on curriculum use. Moreover, although the participants pointed out factors of subject content for the selection of
curriculum materials design, spelling or structure seem to be crucial whereas an empirical evidence for effectiveness is irrelevant for them.

**Discussion**
While this study focuses on a specific topic in physics and has a small sample size it offers a first in-depth look into teachers’ interaction with educative curriculum materials. Furthermore, the preliminary findings are in line with the results of prior studies and provide evidence about assumptions concerning the use of educative curriculum materials formulated in previous research.

For the main study I am going to collect data of about 10 teachers to validate the observed teachers’ interactions with the educative curriculum materials. I expect to find certain patterns of using curriculum materials and their implementation depending on teachers’ characteristics.

**References**


Creativity in primary and lower secondary science education

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The focus of the study

Our society is characterized by rapid change, new information and innovative technology. Accordingly, the coming renewal of the curriculum for year 1-13 in Norway emphasizes that students need to learn how to make use of their knowledge in new and unknown situations and that innovative and creative skills should form part of the school curriculum and assessment of students’ work (Ministry of Education and Research, 2016). This is in line with how the report Science education for more responsible citizenship (European Commision, 2015) emphasizes that smart, sustainable and inclusive growth requires strengthening of our capacity of knowledge, innovation and creativity. Creativity is an important factor in science, at a professional level. Science is characterized by rapid development, collaboration and innovations, and this should also be reflected in school science. By introducing and enhancing scientific creativity in education, we are able to reflect a very important aspect of professional science in a way that it shows how ‘real’ scientists work. Still, concerns remains about the extent to which students’ creativity is being developed in schools. Many students perceive and experience that scientific investigation is a straight forward method with little room for students’ own ideas, creativity and innovation skills (see e.g. Askew, 2013).

This project will investigate in what ways students’ creativity can be strengthened in science education and in what way student assessment can incorporate and support creativity in science education. The project will draw out principles for facilitating and enhancing creativity from literature and research on creativity, and use these principles in the development and implementation of science activities and strategies in collaboration with four teachers in primary and lower secondary school. The project will also investigate science teachers understanding and thoughts about creativity in science education.

The project will try to answer in what way the developed teaching design fulfills the criterias set by the principles for creativity, and whether or not we can see a strenghtening and enhancing of students’ creativity (RQ1). Second, the project will try to answer the research questions; RQ2: What is the science teacher’s understanding of the phenomena of creativity in the context of science education?, and RQ3: What do literature and research on creativity say about what we can do to strengthen and facilitate students’ creativity in science education?

Short review of relevant literature

Literature often divides between teaching for creativity and creative teaching, where the former makes creativity a learning outcome, and the latter is only a characteristic of
teaching to make the learning more interesting and exciting (see e.g. Kind & Kind, 2007). This project focuses on teaching for creativity rather than creative ways of teaching.

Research on teaching for creativity is a wide field which contains a variety of understandings, and it is no consensus about to what creativity means in different situations. However, this definition can be directly linked to education and teaching and will form the basis for my project; Creativity is the creation of an idea or an object that is both novel and useful (see e.g. Sternberg & Lubart, 1999). It is also important to acknowledge that creativity is not just for a small group of experts, but something all learners can engage in (see e.g. Craft, 2000).

A way to incorporate creativity in science education, according to literature, is through inquiry-based learning. The idea behind inquiry-based learning approaches is, among other things, to mimic ‘real’ science and ‘real’ scientists’ creativity (see e.g. Abd-El-Khalick et.al, 2004). Inquiry can enhance students’ creativity when we make room for the students own ideas in a supporting environment where there’s room for imagination, wonder, knowledge need and collaboration (Hadzigeorgiou et al., 2012). Another way is to enhance the interaction between science and technology, e.g. by combining Science with engineering practices (NGSS, 2017). By integrating engineering practices in the school’s science education together with inquiry-based learning, the education will be perceived as more authentic and help train the students’ creative competence in science.

For scientific creativity to be valued as an important part of the school’s science education, there’s a need to find ways to assess scientific creativity. Treffinger et.al. (2002) suggest four ways to how teachers can assess creativity: behavior or performance data, self-report data, rating scales and tests. Tests can have an element of assessing creativity built into them, but Askew (2013) asks whether tests are the best way of assessing scientific creativity because creative outcomes are more likely to arise from deep, flexible knowledge in specific content areas and extended periods of work and reflection rather than as a quick ‘eureka’ moment of extraordinary insight. Nevertheless, teachers need to be able to make judgement of creativity to be able to help learners improve.

**Research design and methods**

The project takes form as a qualitative study, based on the methodology Educational Design Research (EDR). EDR seeks to increase the impact, transfer and translation of educational research into improved practice by combining research with systematic development in several cycles (Anderson & Shattuck, 2012). The project contains of three cycles of designing, implementation and analysis, and involves the use of mixed methods and collaborations between researcher and practitioners. In collaboration with four teachers from two different schools, one primary and lower secondary school, the project will design teaching activities and strategies with the aim of strengthen and facilitate students’ creativity. The teaching design will build on the principles for
creativity drawn from the literature review. The designs will be implemented in the teachers’ science classes. The implementation generates data that later will be analyzed and used to improve the design (see table 1). The data are generated from (1) observation of whole class and small groups using video- and audio recordings, (2) interviews with teachers and students using video- and audio recordings, (3) field notes, and (4) collection of students written work and products.

Table 1 Descriptions of the cycles of EDR

<table>
<thead>
<tr>
<th>Cycles</th>
<th>Phases</th>
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<tbody>
<tr>
<td>Cycle 1</td>
<td>Theory building and formulation of principles, and designing of teaching strategies and activities (Design phase); Implementation of design in science classes and collection of data (Implementation phase); Analysis of data from the implementation phase (Analysis phase).</td>
</tr>
<tr>
<td>Cycle 2</td>
<td>Improvement of the teaching design (Design phase); Implementation of design in science classes and collection of data (Implementation phase); Analysis of data from the implementation phase (Analysis phase).</td>
</tr>
<tr>
<td>Cycle 3</td>
<td>Improvement of the teaching design (Design phase); Implementation of design in science classes and collection of data (Implementation phase); Final analysis of data from the implementation phase (Analysis phase).</td>
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</table>

In order to know what and how the teachers think about creativity in science education, I conducted a semi-structured interview. As I intended to clarify the meaning of creativity for the teachers, I performed a phenomenological analysis of the transcribed interview (RQ2). I will also conduct an observation of the classes in front of the implementation phase to see how the students interact with each other and the teacher.

Analysis
Using EDR and mixed methods creates a large amount of data, and data reduction is necessary. Because of the huge amount of data available in a EDR-project, I choose to reduce the data down to three levels of interest; the cognitive level (observations of thinking through students’ representations and explanations), the interpersonal level and the classroom level (observations of interactions through ethnographic techniques) (Collins, Joseph & Bielaczyc, 2004). The data from the implementation phase of the EDR will be analyzed up against the principles of how we can strengthen and facilitate creativity in science education. And the aim is to find out whether or not the designed activities and strategies fulfills the criterias set by the principles for creativity, and whether or not we can see a strengthening and enhancing of students’ creativity. For the interview- and observational data. I will use a combination of theory driven analysis and inductive approaches to identify major topics and categories related to the principles of creativity. This is followed by an analytical coding, which requires more interpretation.
The collected products and written work will be analyzed against the same principles and emerging topics as the interviews and observational data.

**Preliminary findings**
Based on a comprehensive literature review of relevant literature on creativity in general and scientific creativity in specific, several principles for enhancing creativity have emerged. The principles are: (1) student must have knowledge about the subject, creative working strategies, and creative thinking strategies, (2) education must be based on students’ interest and motivation, and freedom of choice, (3) a pedagogical learning environment needs to facilitate and encourage creativity, (4) the classroom climate must be open, safe and democratic, and (5) students must have access to resources and materials, flexible use of time and variation of contexts. Teaching methods that support these principles are student-centered, inquiry-, problem- and play-based. Focuses on collaboration, discussions and debates, and includes creative expressions from other domains like art and IT.

The interviews with two of four teachers yielded detailed information about their thoughts on creativity in science education. Preliminary analysis indicates that teachers presents a positive view on creativity, they enhance the importance of freedom and inquiry, and reveals an uncertainty about the difference between teaching creatively and teaching for creativity. Further and more detailed analysis will be conducted in December 2018. The data analysis following the first and second implementations in schools are expected to be finished before the summer 2019 and will be presented at ESERA summer school.

**References**


Developing the Pedagogy of Argumentation and Teacher Agency: A Multiple Case Study

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Introduction
Argumentation has been a common goal in the science curriculum in schools over the past decade (Science Teacher Education Advanced Methods [S-TEAM], 2010). Some researchers have emphasised that only if it is specifically addressed in the curriculum and explicitly taught through task structuring and modelling will students gain the understandings and skills of argumentation needed to explore its use in science (Erduran & Jiménez-Aleixandre, 2008). The studies on argumentation (Kuhn, Zillmer, Crowell, & Zavala, 2013, Osborne, Erduran, & Simon, 2004) have shown that engaging students in productive argumentation is difficult because students often struggle with tasks that require them to craft arguments, support their arguments by using evidence and data, and evaluate them. Ryu & Sandoval (2012) suggest that promoting students’ practices, skills and understanding of argumentation needs time to develop, and that this development appears only after sustained engagement. Previous research with teachers has had a focus on developing the instructional strategies of argumentation (Osborne et al., 2004), or teaching materials including technology-enhanced learning tools (Clark & Sampson, 2007), or on designing professional development workshops for the practice (Simon, Erduran, & Osborne, 2006; Simon, Richardson, Howell-Richardson, Christodolou, & Osborne, 2009). Recent research has shown that teachers still consider argumentation as a challenging practice. They struggle to distinguish the structural components and the dialogic nature of argumentation during classroom discussions, and to pose the appropriate questions required to help the students engage in argumentation (McNeill & Knight, 2013). Teachers might start with a lack of agency with regard to pedagogical knowledge and strategies, resources for teaching science as argumentation, and also professional histories and confidence to incorporate it into their practice. Therefore, teachers need to have a range of appropriate strategies (Evagorou & Dillon, 2011), and materials as well as pedagogical knowledge on argumentation. The concept of teacher agency has emerged in research to explain teachers’ active efforts to make intentional choices and actions in a way that makes a significant difference in their practices (Toom, Pyhältö, & Rust, 2015) and also to evaluate new practices is that teachers pro-actively develop their pedagogy and shape their practices in classroom contexts (Biesta, Priestley, & Robinson, 2015). It is suggested that it might be essential to facilitate collective sensemaking among teachers in schools through thoughtful reflections on their agentic orientations (Rajala & Kumpulainen, 2017). However, little is known about the significance of teacher agency in developing pedagogy, understanding the elements of agentic teachers’ practices in the light of contemporary
schooling (Eteläpelto, Vähasantanen, Hökkä, & Paloniemi, 2013), and and teacher agentic orientations as reflected in their practices (Rajala & Kumpulainen, 2017) and the enactment overtime. The concept of teacher agency has informed the analysis of argumentation pedagogy in this study.

The Aim of the Study and Research Questions
The aim of this study is to examine how science teachers develop the pedagogy of argumentation and how those teachers become more agentic with regard to teaching science as argumentation by working collectively with their colleagues. Furthermore, it is an investigation into whether teachers become more agentic (or not), and how that has an influence on students’ engagement of argumentation and the construction of oral and written arguments. The research questions are:

1. How do science teachers develop pedagogy for argumentation in the processes of planning, implementing activities and scaffolding argumentation in their classrooms?
2. How does working collectively support teachers to become more agentic in their teaching practice of argumentation?
3. If science teachers become more agentic, how do students’ engagement in argumentation and construction of oral and written arguments develop?

Research Methods
Through a multiple case study (Yin, 2009) including elements of design-based research (McKenney & Reeves, 2012), this study is based on investigating the changes in science teachers’ pedagogy of argumentation, in their oral contributions that show facilitation of argumentation and scaffolding argumentation processes, and their agentic behaviour in their practice, and students’ construction of oral and written arguments. Three science teachers volunteered to take part in this study, each providing a case. It also allows for an in-depth examination of the lesson design process, examination of lesson implementation process, and their reflection on their practices for each participant as a unique case (Yin, 2009). This study follows the processes of planning and implementing activities in classrooms, and reflective discussion on the experiences of teaching practice with argumentation. Their practices with argumentation are determined through audio and video recording their practices in argumentation, and conducting interviews about their lesson plans, and their reflections on their practices following each lesson. In addition, data from two groups of students’ discussions and the students’ worksheets provide data on oral and written argumentation. The initial process of data analysis involves the transcription of the audio and video-recorded lessons from the science teachers, the transcription of audio-recorded of lesson planning process and reflection on their practice. The transcription, coding and analysis of the data generated are undertaken using NVivo 12. The codes and categories were derived from the literature and mainly from the study of Simon et al., (2006). The codes were developed using this framework.
The Results of the Study
This study builds on argumentation in science education research by focusing on how science teachers develop pedagogy for argumentation by working collectively with their colleagues and how they become more agentic in their teaching in this regard. The analysis of teachers’ use of a more dialogic approach in their practices has enabled to identify the kinds of teachers’ instructional strategies that may enable student argumentation to proceed, and scaffold the argumentation process. The initial findings from the analysis of the classroom practices and interviews show that although all of the teachers have clearly been teaching the same lessons, they made different decisions in terms of both the instructional strategies and the activity structures to support students’ oral and written argumentation. The teachers have exhibited some understandings of how to incorporate argumentation into science classrooms, and some development in their understanding of pedagogy for argumentation. Initially, they found it difficult to fully implement in their teaching practices and experienced some difficulties in explaining to their students what they need to do through each activity, in organising students as a group in terms of their level of achievement, or abilities, and in managing time constraints both in terms of structuring and developing lessons.

The analysis of teachers’ oral contributions to facilitate argumentation show that their initial approach to implementing argumentation was altered and extended over the two years. I have found that developing the pedagogy to understand and implement argumentation required the important process of reflection on previous experience. This process helps teachers to construct a new pedagogical understanding – in this case, of argumentation and its value for learning science. It can be noted how self-reflection, working collectively with their colleagues and getting feedback from each other scaffold their pedagogy of argumentation. Working collaboratively with teachers has also resulted in the design, and plan and implementation of argumentation activities which they feel empowered to use and own (Simon et al., 2006). Furthermore, the results provided a sense of developing agency and agentic behaviours in their practices. Finally, I conjecture that sustained practice might be a key mediator for engaging both teachers and their students in argumentation and continuously developing their argumentative skills over time. It is possible that they have a more extensive knowledge and understanding of the nature of the pedagogy, which makes them more receptive to the teaching of science as argumentation and ownership of its aims and intentions.

References


Concept learning in science and technology. A help in the construction of a complex knowledge system in student memory

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Introduction
This PhD focuses on the design and implementation of an instructional approach aiming to help French students to construct a complex knowledge system in their memory. Student conceptual understandings are a major issue for decades. The literature shows that learning of special concepts is not self-evident. For example, students have recurrent and obvious learning difficulties about the force concept in Newtonian mechanics. Moreover, it is proved that classical instructions have little impact on these. The research tests an educational device aiming to help French teachers to teach difficult concepts better.

Educational context
In 2016, France’s results on the PISA survey were mixed. Only 8% of high-performing students can use abstract scientific concepts to explain complex and unfamiliar phenomena (OECD, 2016). Regarding these observations, debates on student learning issues are, more than ever, reaffirmed. Several educational reforms have been initiated, but with no satisfactory results. Therefore, for instance, curricula should focus more on how to elaborate well-designed teaching and learning methods. In this line, a focus on knowledge acquisition that make sense socially and culturally is then needed (Ginestié, 2017). Such reconsiderations require new perspectives for learning, and other thinking modes to be revisited to resituate knowledge. Consequently, educational systems that consider the construction of deeper knowledge in student memory are a major challenge for more effective teaching and learning processes.

The issue addressed
This research addresses the issue that learning some difficult concepts, such as force, implies to build a complex knowledge network (or system) in the learner’s cognitive system. This construction requires systemic learning approaches that consider, inevitably, the student’s cognitive architecture. In the next paragraph, I propose briefly some relevant elements permitting to capture such an approach.

Review of literature
Knowledge approaches in conceptual change
The literature has referenced many epistemologies focusing on student conceptual understanding. I focus first on two models in conceptual change: Knowledge-as-Theory
(KaT) and Knowledge-in-Pieces (KiP) approaches. The contrasts between these lie in the way they consider the evolution of naïve ideas. KaT considers naïve ideas as coherent, implicit (Vosniadou, 2013), while KiP postulates that ideas as intuitive and consisting of many fragmented and inarticulate primitives, that are context-dependant (diSessa, 2017). KiP epistemology, which seems more relevant to me, assumes learning as a transformation of one complex knowledge system into another (diSessa, 2018). But, student should articulate knowledge elements in memory (Bastien, 1997; Schneider & Stern, 2010). Yet, cognitive loads are expected to be generated because of a high element interactivity when learning a difficult concept. These loads may be managed by a model I describe below.

**The four-components instructional design (4C/ID) model**

Despite the debates between epistemologies in conceptual change, some instructional design principles present different but converging ideas. For example, cognitive load theory (Sweller, van Merriënboer, & Paas, 2019) explains how the information processing induced by the learning tasks can affect student ability to process new information and to construct knowledge in long-term memory. So, based on Sweller’s cognitive load theory (Sweller, Ayres, & Kalyuga, 2011) and Mayer’s theory of multimedia learning (Mayer, 2014), a model called 4C/ID (van Merriënboer & Kirschner, 2018) has been elaborated. This model aims to deal with complex learning which is characterised by high element interactivity in a learning process. 4C/ID-model introduces four interrelating blueprint components in complex learning: **learning tasks, supportive information (the theory), procedural information (the how to’s) and part-task practice.** This model will inspire me on the design of an educational instruction.

**Students’ misconceptions about force**

I focus on the force concept for which its development in the history has followed many debates between scientists since Antiquity (Coelho, 2010; Lehoucq & Lévy, 2003) and recently, technologists (Jouin, 2002). From Aristotelian, Galilean, to Newtonian senses, naïve ideas have received many characterisations. In the literature, I retained primarily, four characterisations on students’ misconceptions about force (Ioannides & Vosniadou, 2002): (1) **Force is an internal property of physical objects**, (2) **Force is an acquired property of physical objects that explains their movement**, (3) **Force is the interaction between an agent (animate) and an object (inanimate)**, and (4) **Force is the interaction at a distance between a physical object and the earth**. These meanings support the exploratory study to probe teacher views on student misconceptions. However, given that these meanings are less coherent to KiP (diSessa, Gillespie, & Esterly, 2004), the research considers a more global definition of Newtonian force concept. It is based on six conceptual dimensions (Hestenes, Wells, & Swackhamer, 1992): **kinematics, the three Newton’s laws of motion, the superposition principle and the types of forces.**
Research question
So, regarding these theoretical elements, the research aims to answer to the following question: ‘How instructional strategies can be designed to help students to build in their cognitive system, the complex knowledge system associated with learning of a concept such as force?’ I hypothesize that it is necessary to help the learners to elaborate the knowledge elements of the complex system, and to build links between these. To test this hypothesis, an educational device will be implemented. This device will attend to define how the teacher will offer support to students to elaborate the knowledge system and to foster their understanding process (Musial, Pradere, & Tricot, 2012).

Design and methods
Regarding the six dimensions of force concept, and based on the KiP epistemology implemented in the organisational framework of the 4C/ID-model, the research aims to design an instructional approach helping teachers to teach difficult concepts better. An exploratory survey based on a research questionnaire has been addressed to French teachers in science and technology (South-east of France) to investigate, firstly, their views about student misconceptions and difficulties, as well as their own teaching methods. This survey is being followed by an individual protocol analysis with both pre-test and post-test using the Force Concept Inventory and a remediation. Then, some interviews will be conducted with teachers. Expected results will allow to estimate the effectiveness of the strategy about complex knowledge acquisition. Then, implications for science and technology teaching will be discussed.

Preliminary findings
The exploratory study shows, for example, that teachers’ responses on student misconceptions are rooted in the naïve idea ‘force as a cause of movement’ [Table 1].

Table 1. Teacher views on student misconceptions: rank ordering

<table>
<thead>
<tr>
<th>Force meanings (Ioannides &amp; Vosniadou, 2002)</th>
<th>Medians</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Force as an internal property of object</td>
<td>4</td>
</tr>
<tr>
<td>2. Force as a cause of movement</td>
<td>1</td>
</tr>
<tr>
<td>3. Force as an interaction between an agent and an object</td>
<td>3</td>
</tr>
<tr>
<td>4. Force as an interaction between an object and the earth</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 1 indicates that teachers consider student naïve ideas mainly rooted in theory of motion which posits force as the causal agent of motion. This result was highlighted by Viennot (1979) in French teaching forty years earlier (Ndiaye & al, to be published).

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Structural characteristics of learning opportunities in teacher training programs and their effects on pre-service physics teachers’ professional knowledge

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Focus of the study
The idea of an exclusive teacher knowledge was first proposed by Shulman (1987). Over the last decades, two of Shulman’s original seven knowledge bases are considered to compromise the core topic-specific knowledge bases: content knowledge (CK) and pedagogical content knowledge (PCK) (Grossman, 1990).

Teacher professional knowledge (in particular CK and PCK) is widely considered an important factor for both quality instruction and student learning. Multiple studies have found positive effects of teachers’ professional knowledge on instructional strategies, cognitive activation as well as students’ outcomes (e.g. Keller, Neumann, & Fischer, 2017). However, little is known about how pre-service teachers actually acquire/build/develop their knowledge. Studies show that pre-service teachers need formal learning opportunities to develop CK and PCK (Kleickmann et al., 2013). In addition, practical training at schools are a powerful source for PCK development as well (van Driel, de Jong, & Verloop, 2002). But individual factors are also considered to play a role in how students utilize these learning opportunities (Poropat, 2009). In summary, there is a lack of evidence which characteristics of teacher education programmes and individual factors of pre-service teachers in detail facilitate learning.

This study aims to obtain insights into the characteristics of effective teacher training programs. To achieve this evidence, I intend to examine curricular structures of teacher training programs and their impact on the development of CK and PCK. In addition, I will investigate how individual factors affect the usage learning opportunities. Finally, I will focus on the benefit of a specific classroom experience in which pre-service teachers are intended to teach for three months.

Review of relevant literature
Following Shulman’s (1987) idea, PCK can be understood as an amalgam of pedagogic and content which enables teachers to adapt content for teaching purposes. Furthermore, PCK is an exclusive area of expertise only held by teachers: it is “their own special form of professional understanding” (Shulman, 1987, p. 8). Whereas CK comprises knowledge of a subject area on the one hand and substantive and syntactic structures of the domain (e.g. common methods of proof) on the other hand (Grossman, 1990).

To develop an appropriate CK and PCK, formal learning opportunities such as lectures or seminars have the most notable effect (Kleickmann et al., 2013). But several (German) studies show differences between different teacher education programs and thereby
between learning opportunities (Tatto & Senk, 2011). More precisely, CK and PCK of academic-track pre-service teachers is higher compared to nonacademic-track pre-service teachers (e.g. Brunner et al., 2006). Additionally, the yearly growth of academic-track pre-service teachers’ CK is higher than for nonacademic-track pre-service teachers’ CK (Kleickmann et al., 2013). Hence, these results confirm differences in learning opportunities for future academic-track and nonacademic-track teachers. But except for the number of learning opportunities, no other factors for varying development were examined. For instance, nothing is known about effective chronology of CK and PCK courses or the appropriate degree of students’ involvement in courses.

It should be noted that the high-quality learning opportunities will not determine learning success in training programs alone. Individual factors like motivation are also suggested to determine effective teacher training (Poropat, 2009). Indeed, studies describe a certain stability in motivation of pre-service teachers over years of teacher training program (Roness & Smith, 2010). However, the actual usage of learning opportunities in teacher education programs as well as the interplay between existing learning opportunities and individual factors of pre-service teachers were hardly examined. Existing studies in this field show positive correlation between academic performance and cognitive ability, as well as motivation, agreeableness, conscientiousness and openness (Poropat, 2009). But the already small number of evidence in this field subsume individual factors of different professionals and do not highlight teacher profession separately. For instance, it is vague to what extent motivation affect pre-service teachers’ learning in teacher training programs.

In addition to (formal) learning opportunities, Grossman (1990) describes teaching experience as another source for CK and PCK development. For example, studies show that in the early months of working at a school teachers see science from a different perspective (Kind, 2009). Thus, through classroom experience pre-service teachers are able to adjust science for teaching thereby accomplish PCK development. This role of classroom experience and its associated mechanisms need more attention and evidence to align teacher training programs with pre-service teachers’ needs (Kind, 2009).

**Research questions**

Currently, little is known about the interplay between CK and PCK developments (in particular with regard to Shulmans (1987) amalgam hypothesis) under specific structural and individual circumstances and the impact of teaching experiences. To address this lack of evidence the research questions are:

1. To what extent does the development of CK and PCK depend on curricular structures of TTP?
2. What kind of pre-service teachers’ individual characteristics affect the usage learning opportunities? And how does the usage influence CK and PCK?
3. In what manner do protracted teaching experiences influence PCK?
Research design and methods

To address the research questions, a large-scale sample will be used. The study started during winter 2014 and spanned a period of three years. The participants were invited to complete three surveys at their universities. These surveys focused on participants’ CK and PCK as well as on generic pedagogical knowledge and individual characteristics. In addition, pre-service teachers participated in three online surveys in-between the years, which focused on individual experiences of their teacher training programs. The project could recruit a total of $N = 123$ pre-service physics teachers from 22 universities.

The longitudinal data of pre-service teachers’ CK and PCK provides the opportunity to discover the development of CK and PCK under different contextual (e.g. structure of training program) as well as individual factors. To answer the first research question, the different contextual characteristics will be clustered by analysing the curricula of teacher training programs at the 22 universities. Following, “prototypes” of teacher education programs will be identified. Along with the longitudinal data, criteria of effective teacher training programs could derived.

To answer the second research question, the individual data has to be associated with individual increases in CK and PCK. For this purpose, data from the three online surveys will be explored to align individual experiences (like motivation and openness) with individual development in CK and PCK. These individual factors together with curricular characteristics establish a basis for further structural equation modelling which explain the usage and efficiency of learning opportunities in teacher education programs.

To detect the influence of classroom practice on PCK (in terms of Gess-Newsome (2015) on PCK and PCK&Skill) it is necessary to capture students’ reflection-in-action. Gess-Newsome (2015) proposes think-aloud-interviews in which pre-service teachers “review teaching videos and attempt to remember what they were thinking that influenced what they did and why” (Gess-Newsome, 2015, p. 37). In accompanying pre-service teachers in the TTP in Schleswig-Holstein, Germany during their first teaching experiences the interaction between PCK and PCK&Skill can be pointed out. Doing so, it will be possible not only to evaluate the classroom experience but also their structural demands.

Preliminary findings

For first analysis pre-service teachers’ individual experiences (relevance, difficulty and students’ involvement in courses) in learning opportunities for PCK are examined (see Figure 3). ANOVA and following Tukey tests show significant differences in quality of learning opportunities over years: (i) A significant increase of the difficulty from year 3 to 5 ($Cohen’s d = 1.04$). (ii) A significant decrease of relevance from year 1 to 5 as well as year 2 to 5 ($Cohen’s d = -2.10/-1.25$). (iii) A significant decrease of students’ involvement in courses from year 1 to 4 ($Cohen’s d = -1.87$). Next, these results will be linked to pre-service teachers’ CK and PCK development.
Figure 3. Quality in learning opportunities for PCK perceived by pre-service teachers

References


Nature of Science through Problem Based Learning: Effects on science epistemological conceptions and students’ performance

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Focus of the study
The promotion of scientific literacy faces several obstacles today, namely, students’ (Lederman et al., 2019) and teachers’ (Kartal et al., 2018) lack of informed conceptions about the Nature of Science or NOS (Lederman, 2007). We consider that methods that enhance questioning, communication, argumentation and collaboration are adequate, and we have chosen Problem-Based Learning (PBL), within the scope of this project, since we hypothesize that students’ analysis of the designed resources, including the problem situation, can induce the cognitive conflict (Loyens et al., 2015) between their prior conceptions and the more informed conceptions of NOS. We also took into consideration that PBL is described as developing skills such as communication and collaboration, decision making, problem solving, critical thinking and autonomous learning (Wilder, 2015). In addition, this method has been the subject of previous studies (Sousa, 2016a, 2016b).

The evaluation of students’ epistemological knowledge, as well as the identification and description of their epistemological conceptions has been object of study in the framework of a wide range of lines of investigation in several countries worldwide, however in Portugal there is a lack of studies.

Short review of relevant literature

2.1. Nature of Science
The concept of NOS has a long history of controversy (Matthews, 1998). It has recently been discussed whether there is only one NOS or more than one, whether one should speak of one Science or several, whether or not there are methods common to all scientists of various disciplines (Kampourakis, 2016a). NOS refers to the characteristics of scientific knowledge (NOSK), associated with the way knowledge is developed; while the investigative process includes the procedures that scientists use in their work and how the resulting scientific knowledge is generated and accepted (Lederman & Lederman, 2014). Despite the controversy in the definition of NOS, the most consensual NOS aspects for K-12 education and fundamental to all citizens, are related to scientific knowledge (Lederman et al., 2002). However, there is some controversy surrounding the NOS aspects generally referred to as consensual but that several authors state whether it is necessary to substitute or enrich with other aspects (Allchin, 2017; Hodson & Wong, 2017, Matthews, 2015).

We consider NOS including NOSK and the investigative process according to Kampourakis (2016b) and selected the following aspects: laws and theories (their meaning and differences), observations, objectivity and exploration based on theory, social and cultural
influence on science, imagination and creativity in scientific investigations, mutable and provisional characteristics of scientific knowledge, methodology of scientific research (which includes characteristics of the investigative process) and Science as a form of knowledge.

2.2. NOS teaching using PBL

PBL is a student-centered approach that requires students to apply their knowledge and skills by proposing a valid solution to the problem presented (Savery, 2006). In PBL, students are confronted with problems whose content has not been previously taught to them (Ertmer & Simons, 2006) through which they acquire knowledge (substantive, procedural and epistemological) and develop reasoning, communication and attitudinal skills. In PBL, an ill-structured problem situation is presented by the teacher to the students, and is intended to be motivating, encouraging students to identify gaps and inaccuracies in their own knowledge, formulate questions and to search for additional, relevant and necessary information for resolution (Wirkala & Kuhn, 2011). Working in small groups, students follow a sequence of procedures with the purpose to answer problem questions included in the problem situation, either by searching for bibliographic sources, or by planning and carrying out practical activities. Currently many PBL modalities coexist (Barell, 2007; Savery, 2006), and we will follow an adaptation of DiCarlo (2006).

Research questions

As a result of the research problem (What are the effects of a Nature of Science enriched PBL process in both science epistemological conceptions and performance of 8th grade students and preservice teachers?), the following research questions were formulated:

- Q1: What are the Portuguese 8th grade students’ science epistemological conceptions?
- Q2: What differences are observed in the science epistemological conceptions of 8th grade students, upon a NOS enriched PBL unit?
- Q3: What differences are observed between PBL and non-PBL 8th grade students’ science epistemological conceptions?
- Q4: What are the effects of a PBL unit in 8th grade students’ performance?
- Q5: What differences are observed in the epistemological conceptions of preservice teachers, before and after an integrated didactic intervention of NOS using PBL?

Research design and methods

Our project includes collection and analysis of qualitative and quantitative data. Our aim is to characterize NOS conceptions and to test teaching-learning approaches that promote changes in these perceptions in order to design a course for teachers. This research project is subdivided into the following main steps: defining problem (questions, hypotheses and research objectives), questionnaire survey before and after didactic intervention (pre-and post-test respectively), performance questionnaire before and after each didactic intervention and questionnaire survey in several Portuguese State-funded schools.
The researcher will perform the didactic interventions. The voluntary participants are Portuguese 8th grade students, preservice teachers and observing teachers. Anonymity will be ensured, informed consent will be obtained and regarding minor students the respective guardians of education will be asked for the informed consent.

The techniques of data collection that will be used are: questionnaire survey, interview (to the observing teachers), observation and content analysis.

The data obtained in the pre- and post-test, before and after the didactic interventions, respectively, will be analyzed by descriptive and analytical statistics in order to verify any pre- and post-test differences. Statistical analysis will be carried out using appropriate software, namely Statistical Package for the Social Sciences).

**Preliminary findings**

Pre-service teachers were presented with Life Science’s problems about timely themes included in the national curriculum of middle and high school level, such as the consequences of introduction of invasive plants in ecosystems (Sousa & Chagas, 2018). Upon reading, brainstorm and discussion in small-group, each group presented a different solution to the class and all the solutions were discussed. Students were also asked to identify the NOS items present in the problem and their ideas were discussed. We observed that all of them were able to identify the NOS items included, such as the methods used by scientists, interaction between scientists, and the importance of publishing. The learning process was also assessed, using an anonymous questionnaire. All the students considered that they performed an important role in their own learning process (88% of students classifying as 4 or 5 in a scale 1 to 5). We are studying the applicability, and potentialities of this method in pre-service science teacher education. A questionnaire that identifies the scientific epistemological conceptions held by middle school students, is under development and validation, and its pilot version has been used to assess the change of middle school students upon a short PBL intervention about the origin of life by the researcher (Sousa & Chagas, 2019).

**References**


Archimedes

Mentors: Deb McGregor, Fatih Tasar
Empirical study of the effectiveness of two professional development formats for teachers on "discovery experimentation", a scientific inquiry approach

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Outline
Professional Development programs should perpetuate professional learning processes and development beyond achieving a university degree in teaching. For this reason, effective formats for Professional Development (PD) for teachers must be designed. With regard to recent findings on teacher performance, there is a need in Germany for PD in science teaching regarding experimentation (in the sense of scientific inquiry).

To get an insight into possible positive effects of elements of PD trainings and, hence, to support the goal of developing effective PD programs for science teachers, in this study, two largely identical PD formats on experimentation are investigated contrastingly.

The central distinction between both the formats is the depth of cooperation among the participating teachers: One PD format is designed to meet the concept of co-construction whereas the other PD format is designed with focus on individual support by the trainers (individual-constructive).

These co-constructive elements are realized: the joint work on development tasks between PD-group-sessions, visiting colleagues’ classes and reflecting these mutually (Emden & Baur, 2015).

The comparison between both the PD formats investigates the development of teachers’ Pedagogical Content Knowledge (PCK) and their Beliefs regarding scientific inquiry using questionnaires and paper-pencil-tests. Additionally, potential changes in teaching practice are evaluated by using qualitative content analysis on videotaped scientific inquiry lessons.

Motivation and State of Research
Modern science education should essentially address four basic challenges: learning science, learning about science, doing science and learning about socio-scientific issues (Hodson, 2014). TIMSS and PISA have shown deficits for German students with regard to the aspects "learning about science" (NoS-aspects) and in particular concerning "doing science" (Baumert, Bos, & Lehmann, 2000), which is understood to connect domain-specific problem-solving with the learning of scientific processes, including experimentation. Research in science education has identified some teaching deficits and, thus, potentially viable aspects to address in PD: experiments are seldom used effectively, many student experiments are trivial, not goal-orientated and experiments
often do not correspond with students’ abilities and interests (Harlen, 1999). In addition, guided experimentation can only convey a limited understanding of the processes of scientific inquiry and Nature of Science (Schulz, 2010). In order not to destroy the "surprise effect", teachers may choose not to formulate a hypothesis, which otherwise is indispensable for the scientific process (Tesch & Duit, 2004). Planning of experiments or evaluating of data is rarely required from students and they are often not given the opportunity to contribute their own ideas (Tesch & Duit, 2004).

In order to overcome the gap between the goals of science-oriented teaching, that require students to self-directedly do science, and the currently frequently practiced consuming science, efficient PD-formats are expected to be an adequate tool (Hazelkorn, 2015).

In Germany, most current PD programs are attended individually by subject-teachers (i.e. biology, chemistry or physics) from several schools. The duration of PD programs rarely exceeds one day and the content does often not consider the actual teaching practice (or demands) of participating teachers (Gräsel, 2008). In addition, there is usually no serious evaluation of the PD program and its (long-term) effects (Gräsel, 2008). Thus, actual design of PD is in many ways contradictory (at least not well aligned) to what has been identified as effective in (recent) research on PD for science teaching (Garet, Porter, Andrew, C., Desimone, & Birman, Beatrice F. Suk Yoon, Kwang, 2001; Gräsel, 2008).

Participation of all teachers of one department forming a professional learning community, content focus, coherence with individual and institutional frameworks, self-active learning and longevity have been identified as particularly effective features of PD programs in science education (Capps, Crawford, & Constas, 2012; Emden & Baur, 2017; Gräsel, 2008). Few inconsistent research findings are available on the effects of co-constructive PD (Gräsel, 2008; Krajcik, Blumenfeld, Marx, & Soloway, 1994).

Capps et al. (2012) claim that connections between PD on inquiry-based learning and its desired effects, on PCK, Beliefs and attitudes towards inquiry-based teaching, teaching practice and, ultimately, student performance, need to be investigated conjointly.

**Research question**

How does the individualist-constructive PD format, the co-constructive format respectively, affect teaching practice in lessons on scientific inquiry?

**Design and methods**

During the project period, eight Schools of five teachers (n = 40) each participate in the scientifically monitored PD-program. Teachers of one school form a PD-group which is assigned randomly to either of the PD-formats (co-constructive vs. individualized-constructive). There are two waves of PD with 4 schools each covering 1.5 academic years.
All schools are located in the metropolitan region of Stuttgart and exhibit comparable socio-cultural structure. In both training waves and both formats, data on PCK and on Beliefs are surveyed concurrently (pre, while, post) with validated tests and questionnaires (PCK: Backes, Tepner, & Sumfleth, 2012, Beliefs: Engeln, Euler, & Maass, 2013).

Teaching practices are surveyed using two different methods: through pre/post videography and through two teaching visits by PD-instructors over the course of one academic year (used observation protocols: Krajcik et al., 1994; Wee, Shepardson, Fast, & Harbor, 2007).

Figure 4: Project plan for one of two identical training waves

The qualitative content analysis of the video transcripts regarding the teaching practice during scientific inquiry lessons is the PhD thesis’s principal goal. The qualitative content analysis expands to capture the principles of the scientific inquiry-oriented paradigm “discovery experimentation” (Emden & Baur, 2017: enabling students’ responsibility and autonomy, structuring the inquiry process scientifically, reflecting the inquiry process, allowing students’ novel insights into nature).

In the summer of 2019 first qualitative results of the content analysis and a first quantitative evaluation of the questionnaires will be available. The appropriate triangulation of the data is a possible point of consultation.

References


Focusing Pre-Service Teachers: Measuring Diagnostic Knowledge about Evolution

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Background

Problems in the Teaching and Learning of Evolution
Evolution through the process of natural selection is the central comprehensive explanatory principle for the life sciences. Evolutionary processes and mechanisms are the basis of all topics in biology (Tibell & Harms, 2017). Accordingly, the overarching goal of biology teaching is to support students to acquire conceptual biological knowledge in evolution. Natural selection is the key mechanism of evolutionary change that leads to adaptive features to new environmental conditions. In connection with the process of natural selection numerous misconceptions are described, which inhibit students’ understanding (Gregory 2009). Common categories of misconceptions have been identified as for example teleological and anthropomorphic ones (Opfer, Nehm, & Ha, 2012). These lack reference to e.g. sexual recombination of genes or mutations. Misconceptions are firmly anchored in students’ minds and are highly resistant to instruction (Anderson, Fisher, & Norman, 2002).

Diagnostic competence of (prospective) teachers
Gregory (2009) summarizes that teaching and learning the processes of evolution requires from the teacher an effort to identify, confront, and replace misconceptions. This study attempts to address this demand by developing a digital tool for measuring diagnostic knowledge of pre-service teachers about evolution. Weinert (2001) created a concept of key competences of teachers. Among these, diagnostic competences plays a central role. It is defined as the ability, to assess persons appropriately. In teaching, however, diagnostic competence is not only relevant for summative assessment but it’s also central for supporting students in their learning processes (formative assessment). According to Helmke et al. (2004), pedagogical knowledge (PK), content knowledge (CK) and pedagogical-content knowledge (PCK) are key elements of diagnostic knowledge. In summary, diagnostic competence is of particular importance, because it is the prerequisite for formal assessment, such as the writing of reports, and is crucial for adaptive teaching.

The Student Inventory
The Student Inventory is a computer-simulated instrument that can be used to measure the diagnostic knowledge of participants in an experimental setting. It enables the compilation of judgement-relevant and judgement-irrelevant information about virtual students (Kaiser et al., 2015). The judgement-relevant information can be for example
test quality or performance in knowledge test of the virtual students. The judgement-
irrelevant information is, for example, preliminary performance, gender or grade. The
task of the participants is to diagnose and evaluate judgement-relevant information of
the virtual students. Afterwards the participant’s judgments were compared with the
virtual student’s ability profile, which was previously set in the Student Inventory. Thus
it can be examined whether an adequate judgement was made or a bias of the judgement
by judgement irrelevant information.

Research questions
1. Is there a halo effect (judgement error) of the judgement-irrelevant information on
the judgment-relevant information?
2. Are pre-service teachers able to distinguish between virtual students’ scientifically
correct explanations and misconceptions in their written performances?
3. Is there a connection between the performance of pre-service teachers in the
CK/PCK-Test about evolution and their diagnostic ability?

Method
We used the already existing Student Inventory and adapted it for our purposes (Kaiser
et al., 2015). The biological example for our study is the industrial melanism of the
peppered moth. With the Student Inventory, we have attempted to provide pre-service
teachers (following called: participants) with a realistic virtual classroom environment in
which action-related diagnostic knowledge can be tested and measured.

Participants
The Student Inventory was completed by a total of \( N = 27 \) pre-service teachers. All of
them were in the pre-service for the grammar school teaching profession in Schleswig-
Holstein (Germany) and studied biology as one of their teaching subjects. On average,
the pre-service teachers were 29.3 (SD = 4.8) years old and 77.8% female.

Procedure
The examination took approximately 60 minutes and the participants were given 6
exams by virtual students. Each exam includes (1) a multiple-choice knowledge test
about evolution (judgement-irrelevant information), which had already been answered
by the virtual students, and (2) a written explanation of the natural selection of the
peppered moth (judgement relevant information), which expresses either a
misconception or a scientifically correct explanation of natural selection. The quality of
performance reached by the individual virtual student in the multiple-choice knowledge
test differ in a good (19 out of 20 points) or bad (12 out of 20 points) and should only be
received by the participants. The main task of the participants is to evaluate the written
performance of the virtual students independently from the performance in the multiple-
choice test. The evaluation of the virtual student written performance included the
scoring and grading as well as the identification of the present misconception
(anthropomorphic or teleological) or scientifically correct way of thinking. The text
qualities (anthropomorphic, teleological, scientifically correct) were evaluated by an inter-rating of three independent experts and resulted in a reliability of Rel. = .94. After the 6 exams, questions are asked about the content knowledge (CK) and the pedagogical content knowledge (PCK) in evolution.

Analyses
Within the exams, the judgment-relevant information (text quality; written answer of the virtual students) was randomly combined with the judgment-irrelevant information (preliminary performance in the multiple-choice test), so that each text quality was available with each quality level of the multiple-choice performance. The design was a fully crossed 2x3 design. This results in two independent variables: (1) The text quality of the written performance of the virtual students and (2) performance in the multiple-choice test. The dependent variables are: (1) The diagnostic ability of the pre-service teachers and (2) the assessment of the written answers of the virtual students. Through the following knowledge tests (CK, PCK) about evolution, it is possible to investigate the impact of declarative knowledge on the participants’ diagnostic ability.

Results
The analyses of variance revealed a significant main effect of the performance in the multiple-choice test ($F(1,26) = 5.94, p < .022, \eta^2 = .186$) and the text quality ($F(2,25) = 78.65, p < .000, \eta^2 = .863$). No interaction effect between performance in the multiple-choice test and text quality was found ($F(2,25) = .243, ns$). Thus scientifically correct texts are rated higher, than texts with misconception. So the participants were able to distinguish between scientifically correct and incorrect statements of the virtual students. Texts were also rated higher if the performance in previous multiple-choice test in the same exam where good in contrast to being bad indicating a judgment error (halo-effect).

Pre-service teachers were able to distinguish between scientific explanations (90.75% identification rate) and non-scientific explanations (91.7% identification rate) in the written performances of the virtual students. Problems were found by diagnosing the specific category of misconceptions with a low identification rate of 36.1%. Thus, we have significant differences in the diagnosis of the scientific explanations compared to the diagnosis of the specific misconception category ($x^2(1) = 43.29, p < .001, \phi = .517$).

The psychometric characteristics of the evolutionary biological knowledge test (CK, PCK) were satisfactory (Cronbach’s $\alpha = .633$). The correlation between performance in the evolutionary biological knowledge test and diagnostic ability (diagnosis of scientific and non-scientific explanations) of the participants showed a strong effect ($r = .631, p < .001$). In addition, there is a moderate correlation between the performance in the evolutionary biological knowledge test and the diagnostic ability of the specific category of misconception ($r = .499, p < .008$). This result gives an indication that the declaratively available CK and PCK could probably have an influence on the diagnostic ability shown by assessing the virtual student exams. Further investigations should strengthen this hypothesis.
References


Learning cutting-edge research topics via school visits to research centers

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Outline of the study
There is a need to integrate new scientific and technological developments in science teaching, especially if one takes into account the ever-changing and renewed scientific and technological knowledge. Out-of-school learning environments, such as research centers, museums, etc. can significantly contribute to this direction. Especially, research centers constitute a unique environment where students have the potential to come in contact with cutting-edge research topics, as they offer authentic conditions of scientific knowledge development.

However, the problem that arises nowadays is the fact that although there are many places of non-formal learning, they do not constitute a network that is somehow combined with formal learning (Lewenstein, 2001). Also, students often are not aware of any specific goals when they visit out-of-school places and thus they may subsequently be unprepared for learning (Storksdieck, 2001). The result is that eventually the entertainment prevails over the educational potential of the visit (Rennie & McClafferty, 1996).

From the above, it emerges a particular interest for science education of how school and out-of-school education can be appropriately combined, especially on learning cutting-edge research topics. This study aims to investigate how science teachers design and carry out a school visit to a research center focused on learning cutting-edge research topics.

Literature review
Learning is a cumulative process that includes connections among all the learning experiences that students come in contact during their lifetime either inside or outside the formal education system (Dierking et al., 2003). Especially nowadays, great emphasis has been put on the learning that can take place in organized science venues outside schools. That is mainly due to the fact that many studies have recognized the ability of such places to provide many benefits to their visitors, both in cognitive and emotional level (Dewitt & Storksdieck, 2008). Such places can contribute to the change of daily school routine, can stimulate the interest and curiosity of the students and provide an incentive for further engagement with science, much more than classroom teaching (Pedretti, 2002; Salmi, 2003).

However, in order to maximize the students’ benefits not only at an emotional but at a cognitive level as well, teachers have to recognize the importance of their role and take into account a number of recommendations about best practices that can maximize the
effectiveness of visits to non-formal environments as learning experience. For instance, it is suggested that teachers have to become familiar with the setting before the visit, inform their students about the expected learning outcomes, plan pre- and post-visit activities and take advantage of the uniqueness of the setting (Dewitt & Storksdieck, 2008). Despite the fact that school visits to other settings of non-formal science education have been extensively studied, there is lack of studies regarding visits to research centers, especially with the teachers’ involvement (Neresini et al., 2009). So, this research intends to make a further step in this direction, by investigating how teachers plan and carry out a visit to a research center, in order to facilitate students’ understanding on cutting-edge research topics.

Research questions
The detailed research questions of the current study are:

a) What are the aims of a school visit in a research center as defined by the provider?
b) How can school visits to a research center be improved, in terms of understanding cutting-edge research topics, through collaboration between teachers and researchers?

Research design and method
The research framework of this study is the Model of Educational Reconstruction (MER; Duit et al., 2012), a model which consists of three intimately connected parts: a) clarification and analysis of scientific subject matter, b) investigation into student and teacher perspectives regarding the chosen subject and c) design and evaluation of the learning environments. This model is flexible enough to be applied to non-formal learning environments, which are characterized by the absence of specific curriculum and the specific educational aims are set by the institution where the visit will take place (Laherto, 2013). So, the development phase, as presented in the middle of Figure 1, can be divided into four steps: first of all the research center aims are set, then the specific educational aims of the visit are defined, after that the ideas and the means for communicating them are clarified and finally the actual visit takes place.

Figure 1: The suggested procedure for developing visits to non-formal learning environments based on MER
The design of the present study includes two main phases. The aim of the first phase was to study the school visits that took place at the research center “Foundation of Research and Technology in Hellas” (FORTH) during the school year 2016-2017. During that period 11 high-schools visited the research center. In order to record the activities that took place during the school visits, an observation sheet based on the work of Sajons and Komorek (2018) was developed. The observation sheet focused on nine dimensions: institution aims, students’ prior knowledge, orientation of the activities, extent of students guidance, self-assessment of effectiveness, relation with the curriculum, external control/guidance of the students, orientation in the understanding of a framework and the role of the staff and the teachers as well. So as to enrich the data, interviews were also carried out both with the school teachers and the person in charge for the school visits at FORTH. The findings of the first phase were used to design the second phase of the study.

The second phase of the study, which is in progress since last October, aims to investigate how science teachers plan and realize a visit in FORTH, in order to facilitate students’ understanding about cutting-edge research topics. For that purpose, ten science teachers from various types of high-schools were invited to participate in the study. A plenary kick-off meeting took place where teachers were at first informed about the setting of the study and then were divided into two groups. Each group of five science teachers, along with science researchers from FORTH and science education researchers compose a Community of Learners (CoL), which aims to design the school visit at FORTH by optimizing its educational value. Both groups deal with cutting-edge science research that is carried out in FORTH, in the field of innovative material properties (polymeric and photocatalytic materials) as far as the first CoL is concerned, and the effect of light on matter (multi-spectral imaging and optical tomography) for the latter CoL. Each group visited FORTH and was informed by scientists about their research work. Then, 3 meetings with each CoL took place, focused on: clarification of the scientific subject matter, science education research related both to the topics under inspection and to visits in out-of-school contexts. Finally, teachers will have to design and carry out the visit in FORTH. Data is going to be collected through audio/video recordings of the meetings, semi-structured interviews with teachers and FORTH researchers and will be analyzed based on the factors that impact the effectiveness of a school field trip (Dewitt & Storksdieck, 2008).

Preliminary findings
The results so far, mainly come from the first phase of the study, as the second one is still in progress. Based on the nine dimensions previously identified, the observation of the school visits at FORTH led to the following findings: the aim of the school visits is solely determined by FORTH’s staff and their purpose is to understand a more general context with no connection to the school curriculum. The staff of the research center is very encouraging and supporting to students' questions, the guidance is strict and in many activities prior content knowledge of the students is required.

At the same time, teachers' interviews led to some interesting findings, which can be summarized as follows: a) only few teachers reported as the purpose of the visit the learning
of the scientific content, b) none of the teachers had planned any pre-visit activities and c) the majority of them would not conduct any post-visit activities in the classroom. These findings are in alignment with the current literature (see Storkdieck, 2001). Also, most of the teachers reported that the content of the visit was not relevant to what their students had recently taught. At the same time, teachers made some useful suggestions that were taken into account during the second phase of the research and could lead to the improvement of the school visits, such as: more hands-on and closer to their students’ interest activities, the necessity of pre-visit activities, smaller groups of students and a longer duration of the visit.

References


Learning and teaching motivation in biology classes – An empirical investigation of students’ and teachers’ motivational qualities and their interdependencies from an SDT point of view

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Rationale

Our current age of rapid scientific and technical progress as well as increased ambiguity places high cognitive demands on society and requires adequate ethical requirements to cope with them. Thus, it is imperative that individuals growing up under these circumstances acquire a sufficient degree of scientific literacy, a critical skill that enables social and democratic participation (OECD, 2016; Yacoubian, 2018). One way to create an educational environment that allows for the acquisition thereof is to enable a social and institutional context of self-determined learning. Self-determination theory (SDT; Ryan & Deci, 2017) offers a psychological framework which focusses the preconditions of non-alienated in-depth learning and understanding. According to SDT, one’s prosperity and well-being depend on the extent to which his/her environment allows him/her to satisfy three basic psychological needs (i.e., the need for autonomy, competence, and relatedness; see Ryan & Deci, 2017). SDT considers motivation as a dynamic product of subject-environment interactions (Deci, Ryan, & Williams, 1996). One’s perceived degree of self-determination has a significant influence on the quality of his/her individual experiences and motivation (Ryan & Deci, 2017). These general implications of psychological functioning are particularly relevant for educational learning processes (Reeve, 2002). Reeve (2002) emphasizes that the quality of one’s motivation and experience is strongly linked to various desired educational aims such as curiosity, pleasure, creativity, and academic performance. Although empirical evidence has shown that self-determined motivation has positive effects on learning (see, e.g., Reeve, 2002), controlling teaching behavior and pressure-based methods are the most common modi operandi in school settings (Reeve & Assor, 2011). These methods are problematic from an SDT perspective because perceived pressure undermines one’s perception of autonomy, thus resulting in less self-determined behavior and poor qualities of motivation (Ryan & Deci, 2017). Even though motivation is a precondition for effective, non-alienated, and long-lasting learning (Deci et al., 1996; Reeve, 2002; Ryan & Deci, 2017), Gillet, Vallerand, and Lafrenière (2012) have found a decrease of students’ self-determined motivation. Against the background of these considerations, in the current study we examined how the satisfaction of the three basic needs as well as need-frustrating environmental factors contribute to students’ quality of motivation in biology classes.
Hypotheses

H1: Perceived pressure is a negative predictor of students’ motivational quality in biology classes.

H2: The satisfaction of the basic needs for autonomy, competence, and relatedness are predictors of students’ motivational quality in biology classes.

Methods

We conducted a cross-sectional study investigating students’ basic need satisfaction, perceived pressure, and their quality of motivation in biology lessons. Four hundred fifty-three students from four different German secondary schools participated in our study (Mage = 14.29, ± 1.01 years; 51% female). We used three different test instruments. The first was a translated and adapted version of Van den Broeck and Colleagues’ (2010) “Work-related Basic Need Satisfaction Scale,” which contains three subscales measuring the perceived satisfaction of the needs for autonomy (Cronbach’s α = .73), competence (α = .80), and relatedness (α = .79). To measure the students’ perceived pressure in their biology classes, we adopted Martinek’s (2012) pressure scale for teachers (α = .84). The quality of motivation was measured using the “Scales assessing Motivational Regulation for Learning” (Thomas & Müller, 2016). This questionnaire contains four subscales, external (α = .64), introjected (α = .74), identified (α = .77), and intrinsic motivational regulation (α = .85). We calculated a multiple regression model using the three basic needs and perceived pressure to analyze whether and to what extent these factors predicted the students’ motivation quality.

First results

In Figure 1, the results of the heteroscedasticity-robust multiple regression are illustrated. This model explains 43% of the variability in the students’ motivational quality in biology classes. The perception of autonomy, competence, and relatedness were significant predictors of students’ motivational quality. In contrast, the students’ perceived pressure was found to be a significant negative predictor. Thus, all hypotheses were confirmed in the context of biology teaching.
Figure 1 Results of the multiple regressions (N = 453). The general model parameters, the $R^2$ and the results of the F-test are reported. In addition, all predictors with their specific standardized beta-coefficient ($\beta$) and their corrected t-tests are illustrated.

The beta-coefficients indicate that the satisfaction of the basic psychological needs showed a positive impact on motivational quality. That is, those students whose needs for autonomy, competence, and relatedness were satisfied showed more self-determined motivation. By contrast, the perception of pressure had a negative impact on motivational quality. High-pressure experiences might undermine the perception of self-determination, thus leading to heteronomous motivational types and a poor quality of motivation.

**Further research**

These results represent the first step of a cross-sectional main study that builds the foundation for further research. To gain a more sophisticated understanding of the motivational interdependencies from a learning perspective, we seek to revise and extend the aforementioned model; a differentiated perspective of students’ perception of pressure is needed. What dimensions of students’ perceived pressure can be defined and to what extent do they influence the motivational quality of students? In addition to the aforementioned learning perspective, we shall investigate the motivational dispositions of biology teachers. This is assumed to be an essential factor of the instructional quality and students’ learning (Kunter et al., 2013). In this context, Müller, Hanfstingl, and Andreitz (2009), for example, identified a lack of systematic research regarding the motivational processes of (in-service) teachers. Although studies have since then been conducted in the areas of general psychology and educational science (see Han & Yin, 2016), they still lack in science, particularly with regard to biology education. We shall address this research desideratum of by focusing on teaching perspectives as well. Several studies have shown that the teaching style and
the design of a need-supportive environment can have a positive effect on various desired educational outcomes such as motivation and performance (see, e.g., Reeve, 2002). However, what moves teachers to behave in a controlling or need-supportive manner? We would like to approximate this question from a motivational perspective. Therefore, a central aim of our research is to address the question: To what extent do the perception of pressure and degree of basic needs satisfaction of biology teachers predict their teaching style? In the third stage of our research, we shall combine these two views. By focusing on an integrative teaching and learning perspective, we will investigate the extent to which teacher motivation is linked to the motivation of their students in biology classes.

Although Roth, Assor, Kanat-Maymon, and Kaplan (2007) were able to confirm a meaningful connection between teacher motivation and student motivation, further research attempts have been contradictory (e.g., Kunter et al., 2013; Müller et al., 2009). Thus, we questioned students as well as their teachers using the same motivational constructs (motivational quality, basic needs satisfaction, and pressure perception). In addition, we assessed the how content biology teachers feel in their profession and their affinity to either autonomy-supportive or controlling teaching styles. Our long-term goal is to extend the sample and to integrate both the teaching and the learning perspective in one comprehensive model. The last point highlights particular challenges we face: How can these complex interactions be transformed into a statistical model? Moreover, which theoretical and empirical perspectives should also be taken into account? For this, we hope for inspiration and enriching discussions at the ESERA Summer School 2019.

References


The relationship between teachers’ pedagogical content knowledge and student learning in electrostatics

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Introduction
The South African education system has been described as ‘struggling’ by the Centre for Development and Enterprise (CDE, 2015) given its limited production of scientifically literate students. Several diagnostic reports from the Department of Basic Education (DoBE) and the Trends in Mathematics and Science Study (TIMSS) have repeatedly shown that South African students perform poorly in local and international assessments. Given the challenges faced by students in science subjects worldwide, particularly physics (Thomas, 2013), scholars have investigated factors that affect student learning. Many factors have been identified, ranging from the socio economic status of schools to the abilities of the students themselves. Although the factors are many, teachers’ classroom instructions are regarded as the central figure that can make or break effective learning (Akiba, LeTendre & Scribner, 2007, CDE, 2015). These instructions are widely regarded as being shaped by teachers’ pedagogical content knowledge (PCK) (Cochran, DeRuiter & King, 1991). PCK is a knowledge base that describes the transformation of raw content into teachable forms (Shulman, 1986) and is regarded as “what teaching is about” (Cochran et al., 1991, p. 5).

Purpose of the study
Although PCK is widely recognised as a prerequisite for teacher effectiveness, there is a paucity of information regarding its relation to student learning (Shulman, 2015). A review study by Wayne and Youngs (2003) revealed that general teachers’ characteristics have weak relationships with student achievements. However, those characteristics did not include PCK. Some of the studies that explored the influence of PCK on student learning were detached from the classroom and relied on teachers’ written accounts of their practices (Kanter & Konstantopoulos, 2010). Alonzo et al. (2013) on the other hand inferred PCK from classroom observations using secondary data. The results of these and other studies reported varying relationships between teachers’ PCK and student learning. In this study, I intend to explore this relationship in the topic of electrostatics by focusing on specific concepts of the topic. My assumption is that the concepts will not be taught and be understood equally. The topic of electrostatics chosen for this study because it has hardly been researched in terms of PCK. Furthermore, it is among the challenging topics for South African students in physical sciences. This study will be guided by the following question:

- What is the relationship between teachers’ PCK and student learning in electrostatics?
Theoretical background

The PCK construct has been through many developments since it was introduced in education as researchers adopted and adapted it to suit their research. Veal and MaKinster (1999) developed a taxonomy that classified PCK into three levels of generalisation; general PCK, domain specific PCK and topic specific PCK. These levels, in the same order, describe PCK for teaching a specific subject, a domain, and a topic; for example a science subject, a physics domain and the topic of electrostatics respectively. Mavhunga (2012) developed a Topic Specific PCK (TSPCK) model that describes teachers’ PCK about specific topics according to five components namely; student’ prior knowledge, curricular saliency, what is difficult to teach, representation including analogies and conceptual teaching strategies. Curricular saliency describes teachers’ knowledge of key concepts, the sequence in which concepts should be taught and the interrelatedness of the concepts within a topic.

In recent times, PCK researchers have finally reached a consensus about the nature of the construct and its place in education through sharing ideas in PCK summits. The summits resulted in the development of the ‘2012 consensus model of PCK’ (Gess-Newsome, 2015) which was later modified to what came to be known as the refined consensus model (RCM) (Carlson & Daehler, in press). The RCM identifies three realms of PCK namely, collective PCK (cPCK), personal PCK (pPCK) and enacted PCK (ePCK). These realms describe the knowledge shared by a broader community of teachers, the knowledge held by an individual and the subset of knowledge used for classroom instruction. Furthermore, the RCM acknowledges the existence of teachers’ specialised knowledge in different grain sizes, namely discipline-specific, topic-specific and concept-specific knowledge. As indicated earlier, this study will explore PCK at concept specific level with the aim of relating it to student understanding of the specific concepts. Guided by the RCM, this study will be conceptualised within the enacted PCK realm which describes the subset of knowledge that is linked to student outcomes. This realm also regards planning, teaching, reflection as the aspects of classroom instructions as well as the pedagogical reasons that shape these aspects. In addition, the model acknowledges the fact that classroom instruction is not the only factor that shapes learning.
However, the RCM does not describe components of PCK at any grain size of specialised knowledge. As a result, I will frame teachers’ concept-specific PCK using the components of the TSPCK model given their applicability at this level.

**Data collection**

Given the aim of the study, it is important to invite teachers that possess varying levels of PCK while teaching in similar schools. It has been reported in various studies that PCK develops through experience and that pre-service teachers predominantly lack it (Kind, 2009). As such, two pre-service and two experienced teachers will be invited to participate in the study. Furthermore, their grade 11 students will also be invited because the topic of electrostatics is taught extensively in the grade according to the South African physical science curriculum.

Given the elusive and the tacit nature of PCK, Baxter and Lederman (1999) suggested that it should be explored using multiple strategies. In this study I will use a Content Representation (CoRe) tool (Loughran, Mulhall & Berry, 2004) to capture teachers’ ‘reported PCK’ while their ‘enacted PCK’ will be captured through lesson observations. For this study, reported PCK refers to the knowledge that teachers portray in writing. Although this knowledge is important as it informs lesson preparation, it does not necessarily reflect the PCK that ultimately manifests during actual teaching (Author, 2018). As a result, only the enacted PCK will be correlated to student learning. Given its importance in this study, the enacted PCK will be supplemented by video stimulated recall interviews (VSRs) to enable teachers to describe their thoughts that lead to
observable classroom instructions. Evidence of student learning will be gathered through a test set relative to the standards of the DoBE. The test will consist of different types of questions and the items will explore student learning in the same concepts that will frame the PCK of the teachers.

**Data analysis**

This study will follow a mixed method research design (Maree, 2010). Although the data reflecting teachers’ PCK will be analysed qualitatively, it will be quantified on a four point scale using a concept specific PCK rubric (Mavhunga, 2012; Park, Jang, Chen & Jung, 2011). Evidence of student learning will also be averaged according to the same concepts as average percentages. A Pearson’s correlation coefficient will be determined to establish the strength of the relationship between teachers’ PCK and student learning. Evidence of student learning will also be interpreted qualitatively using content analysis. The analysis will focus on the students’ responses to the test items to explore whether teachers’ explanations influenced their understanding.

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Teachers’ experiences of Collective agency through self-organising communities. A Freirean approach to science education research

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Outline of the Study
School science teachers in Valparaiso, Chile, are self-organising into professional communities that seek to promote scientific literacy and to make science more socially relevant to students’ lives through the transformation of their praxis. This study proposes to explore teachers’ exercise of agency within and through these communities. Through agency, we are capable of changing both the world and ourselves, guided by a future purpose that seeks the common good. In this study, the focus of agency is oriented towards teachers’ experiences seeking to improve scientific literacy as a community practice to make informed decisions concerning science and to be able to identify how science is embedded in our lives. Through a comparative case study, three self-organising communities of science teachers in Valparaiso will be critically explored and analysed through a Freirean lens. A Freirean lens implies a transformational view of education and research and that we recognise ourselves as autonomous, unfinished, and conscious beings, understanding that it is in dialogue with others that we give meaning to the world, and seek its transformation for a socially just future. The findings of this study aim to document these experiences of collective agency and contribute to existing research and debate around the goals of science education.

Literature Review and theoretical framework
Studies using the notion of agency in science education have focused on analysing the close relationship between agency and professional identity (Moore, 2008), learning and professional development (Rivera-Maulucci et al., 2015), social justice (King & Nomikou, 2017), in the context of educational reforms (Ryder et al., 2018) and how to develop critical agency in students (Calabrese-Barton & Tan 2010)

Two main ideas are present in the conceptualization of teachers' agency. First, most of the recent studies reviewed are based on the dialectical idea of structure-agency, where agency is always understood as collective and the power lies in the ability of humans to reflect and evaluate social contexts, creatively imagining alternatives and collaborating with others to achieve their transformation (Archer, 2000). Under this conceptualization, agency cannot be separated from broader structural factors, such as the social and material environment of which we are part (Calabrese-Barton & Tan, 2010). The second idea is temporality, where agency is understood as informed by experiences, oriented towards a possible future, and enacted in the present (Freire, 1992).
The theoretical framework of this study is rooted in a Freirean view of teachers’ agency and science education. Human agency is the power that within people to be able to make changes (Archer, 2000) oriented toward a desired future (Emirbayer & Mische, 1998). This implies an ontological hope, where that desired reality is possible starting with our actions in the present projecting into that desired future (Freire, 1970). In the teaching context, the concept of agency will be understood collectively, since it is in the horizontal interaction with others in which teachers re-signify their beliefs and knowledge about the purposes of education (Gimeno, 1991). Understanding agency as collective implies understanding the human being as present in the world, capable of transforming it, and as autonomous, where it is through Freire’s concept of “conscientization” that we can realise our need for the other in order to achieve the desired transformations.

Regarding science education, the goal for the future is to have scientifically literate youth, since scientific knowledge is understood as powerful knowledge that must be accessible to all (Young, 2011), and oriented to be more relevant to the lives of students (Reiss, 2014). This contextualising of the curriculum to be more relevant to students’ lives will only be possible through the transformation of pedagogical praxis (Basu et al., 2009). Thus, the concepts of autonomy, hope, presence in the world, and conscientization, together with collective agency and the purpose of science education underpin this research. This changes science from knowledge and skills that must be learned to a social activity that has the understanding and transformation of the world and the community that surrounds us as one of its purposes (Calabrese-Barton, 2001). This could be achieved, for example, by analysing the environmental crises that affect the lives of people (Dillon & Scott, 2002).

Research Questions
1) How and why science teachers exercise collective agency through self-organising communities in Valparaiso?
2) In what ways does teachers’ collective agency enabled or supported through the case study communities afford opportunities to reproduce or transform their praxis within science curriculum and pedagogy?

Research Design and Methods
This study is rooted critical constructivism (Kincheloe, 2005) with a Freirean lens, meaning that knowledge is constructed in dialogue with others within the world, and being conscious of our capability of transforming it. A comparative case study methodology (CCS) (Bartlett & Vavrus, 2017) will be used considering the global, national and local aspects of the subject to be studied. The analysis in CCS is conducted considering three axes. A horizontal axis that will be the comparison of three self-organising communities of science teachers to gain theoretical insights about agency seeking to transform science education. A vertical axis, to situate the horizontal axis, in
relation to both the local and global context in subjects related to agency, science education trends, and related policies. Finally, a transversal axis that historically situates the background, in particular policies around teachers’ collaboration and the science curriculum. In an adaptation of Bartlett and Vavrus’ model, however, this temporal axis will also consider the projective dimension of agency within future orientations of participants in the communities. The analysis will be carried out using a Critical Narrative Analysis (Souto-Manning, 2014). This recognises the relevance of the local, national, and global contexts and their mutual impacts through the process of analysing data. This study is also influenced by critical ethnography (Carspecken, 1996) and narrative inquiry (Riessman, 2008), considering stories as an experience of creating meaning. This occurs both for participants, as they tell their stories, and for the researchers, when they interpret and recount stories to advance theoretical and analytical points (Rivera, 2012). This is consistent with Freirean ideas because it recognises every method used as a process of interaction in dialogue. During the fieldwork, focus groups, semi-structured interviews, and a personal diary of reflections will be carried out. The analysis will be conducted using the data gathered from the focus group, interviews, and journal diary to create codes and themes based on the Freirean lens, as well as issues that might appear in the field-work. The analysis strategy will make use of dialogic analysis (Riessman, 2008), in which attention to verbal forms, context in which the dialogue occurs, etc., will be the focus while listening, transcribing and reading the data.

**Preliminary findings**

Some teachers who are part of these self-organised communities also take the principles of these communities into their workspaces. For example, a teacher shared his experience trying to promote a new way of understanding science week in the science department where he works. He was successful in developing, for the first time, an awareness campaign around issues related with environmental education in the city. This is in line with "relational" type agency in which teachers seek to break the barriers of, for example, the science department, and thus achieving a different understanding of the curriculum. One of the goals of teachers participating in these communities is to be an example and to show other teachers that by making science more relevant to students’ lives is possible, and by working in collective is a way of achieving this by helping to illuminate praxis. Moreover, they wish to share their experiences and have some sort of influence at the local and national level promoting collaborative work not necessarily at the school but also outside of it. In their words “this makes me happy and I want others to know about it!”

**References**


STEM education in Denmark: Challenges and prospects for implementation

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Focus of study
Following a nationwide science program called Science Marathon (SciMa) I investigate how Danish science teachers from middle school implement STEM education in their teaching practice, and what challenges and prospects they encounter in this process.

SciMa is aimed at middle school students ages 11 – 12. Students work with real world challenges by applying STEM concepts and knowledge in a problem-solving process. SciMa is based on an engineering design process to facilitate integrated STEM teaching and learning.

Literature review
STEM is an acronym for Science, Technology, Engineering and Mathematics. The STEM agenda originates from vocational and economical concerns about providing a future STEM workforce. Hence, it is often seen as “pre-vocational learning” (Pitt, 2009, p. 37). Accordingly, policymakers, educators end employers emphasize the importance of giving students a strong STEM education (Pearson, 2017). Integrated STEM highlights the interconnectedness among the STEM disciplines through application of knowledge and skills from each discipline to real-world problems (Moore & Smith, 2014). Research suggests there are many learning gains of integrated STEM, e.g. the development of complex skills such as communication, collaboration, and problem solving (Stohlmann, Moore, & Roehrig, 2012). In addition, integrative approaches to STEM education can improve students’ interest, deep learning and achievement in each subject (Moore & Smith, 2014). Thus, the framing of STEM only as an economical agenda is challenged by many. However, challenges arise, when STEM is implemented in the school curriculum. It is not clear how STEM should be taught and what the educational goals are beyond meeting the needs of the workforce (Pitt, 2009, p. 41). The STEM disciplines are not normally linked in the school’s curriculum, and on top of that, only a few guidelines exist for teachers to follow regarding how they should teach integrated STEM (Wang, Moore, Roehrig, & Park, 2011, p. 33).

Similar challenges in comprehensive school in Denmark are evident. Although Denmark has been affected by the international STEM agenda, the acronym is not mentioned in the national curriculum. In fact, the scope of STEM in comprehensive school is often limited to a focus of mathematics and science. However, many stakeholders from a range of different fields advocate for a greater emphasis on STEM education (Teknologipagten, 2018). And, several governmental and non-governmental initiatives have in recent years
been funded to promote integrated STEM in comprehensive school (e.g. Engineer the Future, 2018). In 2014, a major school reform introduced new learning goals in the science curriculum. Additionally to acquiring content-based knowledge from each subject of science, interdisciplinary learning goals across the subjects of science as well as learning complex skills like innovation and problem-solving were emphasised in the science curriculum. Despite curricular ambitions to achieve interplay between these different forms of learning goals, they have been charged with tension. Many teachers don’t know how to teach integrated, and on top of that, the curriculum is structured in silos, making integration difficult (Sillasen & Linderoth, 2017).

Research question
STEM has become part of the educational agenda Denmark, and thus, it has become relevant to ask; How do Danish science teachers resolve STEM education in practice?

Sub-questions: 1) How do science teachers implement STEM education in their teaching practice? 2) How are double bind situations potentially embedded in Danish science teachers’ practices regarding implementation of STEM education? 3) How are the science teachers able to transform their practices in response to double bind situations?

Outline of research design
I apply cultural-historical activity theory (CHAT), presented by Engeström (2015) and Roth and Lee (2007) as analytical framework. CHAT is a dialectical theoretical approach to individual and collective human development and learning. Opposite categories are seen as non-identical expressions of the same thing, thereby encompassing built in contradictions (Roth & Lee, 2007, p. 195). Thus, an action conducted by a subject is part of the structure of a collective activity defined by a collective motif. An individual action presupposes all other parts in the collective activity and vice versa. The outcome of actions can be production of new knowledge that is consumed by others and thus transforms the system to function in new ways. This means, that the dialectical relationship between individual subjects and the community is one of exchange (Roth & Lee, 2007, p. 199). The activity system is depicted as a triangular model (Engeström, 2015). The top of the triangle symbolises a mediated act between a subject, (a group or an individual with agency), an object (being acted upon) and an artefact (tools or signs) that mediates the relation between subject and object. The bottom of the triangle symbolises the collective level of activity consisting of a community with a division of labour and rules. Inner conflicts between one or more of the components in the activity system can bring about new forms of practice that potentially develop over time and result in an expansion of the activity system in its totally (Engeström, 2015). In accordance with CHAT, I conduct an ethnographic field study to investigate the activity of implementing STEM education in Denmark. Through participant observations (Spradley, 1980) I follow four middle school science teachers from four different school districts, when they conduct SciMa in their teaching practices (90 hours of observations). I view the teachers’ actions related to SciMa as part of the activity system of the school.
This perspective enables me to investigate how their actions are shaped by the school culture, consisting of a community of teachers, a division of labour and the rules and norms they follow. Thus, I am able find out what inner contradictions are at stake in the activity system. In addition, I have conducted qualitative interviews (11 with teachers, 3 with school leaders) to capture how central actors reflect on STEM in practice.

I have structured my qualitative data using thematic analysis (Braun & Clarke, 2006). I have gone through a process of inductively coding my data corpus, consisting of written field notes, interview transcriptions and photos to find emerging themes. For each theme, I have gathered all relevant data identified across the data corpus. Then I have created a mindmap to establish relations among different themes and subthemes.

Preliminary findings

I present a preliminary finding from school 1 where I followed a male science teacher called Henry, age 37, with 13 years of teaching experience at school 1. His colleagues referred to him as the one in charge of SciMa. Henry’s ambition was, that the students learned to master the engineering design process. His teacher-colleagues from middle school did not necessarily know the engineering design process, and thus, he taught all members of his team about it. He distributed tasks among the teachers during SciMa. Eight teachers from the same middle school team worked together during SciMa. Three of them were science teachers and five of them were arts teachers. Each teacher was in charge of one student-challenge. For example, a language teacher was in charge of a challenge where students had to build a tower applying knowledge about constructions.

During my observations, I noticed some tensions in the activity system. The arts teachers told they felt insecure about the activity because it was based on STEM knowledge. They described it like: ”being on thin ice”. However, because they were a part of a team that valued differences, they overcame their concerns and instead focused on the strength of the team: “We know each-others’ strengths and weaknesses. I know exactly who to call in every situation”. Another issue concerned the number of hours spent on the activity and how much priority to give to science. Each teacher spent 30 hours on SciMa during a school week. One arts teacher said: “I think we spend too many hours on science activities this year […] But, I don’t know what else to do than to involve us [arts teachers] in the activity, because in middle school students only have science two hours a week. How else would an activity like this ever be possible?” The arts teachers agreed to be a part of the STEM activity, because they felt, it would not be possible to carry out without the support of the whole team and extra resources they could provide.

Looking at school 1 as an activity system, the middle school teachers are organised in a local community defined by the object of their actions; conducting SciMa in order for their students to master an engineering design process. In this community, Henry takes a role of leadership. However, he is only able to carry out SciMa as he has envisioned, because he is supported by his arts and science teacher colleagues. A strong sense of
team spirit valuing different skills and competences reflected this community of teachers and presupposed their joint activity.

I regard the ESERA summer school as a great opportunity to get qualified feedback of my preliminary findings, and to network with scholars in the field of STEM education.

References


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