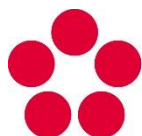




# **ESERA SUMMER SCHOOL 2017**

## **BOOK OF SYNOPSES**



Jihočeská univerzita  
v Českých Budějovicích  
University of South Bohemia  
in České Budějovice



Edited by Lukáš ROKOS, Jan PETR, Iva STUHLÍKOVÁ

University of South Bohemia in České Budějovice,

Czech Republic

2017

# ESERA SUMMER SCHOOL 2017

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## ESERA

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

There are also special interest groups (SIGs) in the ESERA: SIG 1 (Early Years Science), SIG 2 (Video-Based Research of Teaching and Learning Processes), SIG 3 (Science Education in Out-of-School Contexts), SIG 4 (Science, Environment, Health) and SIG 5 (Science Identities).





# ESERA SUMMER SCHOOLS

The summer schools for science education PhD students are held every two years. The students have possibility to present their research work at these summer schools and discuss its strenghts and weaknesses. Students work in the small groups of approximately 7 students and two experienced „coaches“.

The participants of the summer school also attend plenary lectures and workshops provided by experienced tutors as well as social events prepared by organizing committee. The maximum number of participants is 49 so students work in 7 groups. The number of staff members differ each summer school but normally it is about 18 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 „coaches“, and some of them also provide pleanary lectures or workshops.

The first ESERA summer school was held in the Netherlands in 1993. The second summer school took place in 1994 in Greece. Since then, summer schools have been held at two years intervals. The ESERA Executive Board decided to organize a trial summer school in June 2017 so the summer schools will take place every year again.

## LIST OF ESERA SUMMER SCHOOLS

- **2017: České Budějovice, Czech Republic**
- 2016: České Budějovice, 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

# ESERA SUMMER SCHOOL 2017

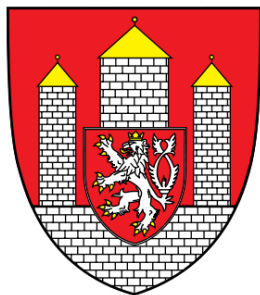
## THE VENUE – ČESKÉ BUDĚJOVICE

České Budějovice (*Budweis* in English or *Böhmisch Budweis* in German) is the largest city in the South Bohemian Region. It is political and commercial capital of this area and also the seat of the University of South Bohemia and Academy of Sciences. The city is located in the valley of the Vltava River at the confluence with the Malše River. The city has 93 285 inhabitants (2015).



### BRIEF HISTORY

České Budějovice was founded by the King Ottokar II of Bohemia in 1265 as royal city so the king could strengthen his position of power in South Bohemia. The first inhabitants and settlers came from the Bohemian Forest and Upper Austria. The strong fortifications made the city strategically important place during the Hussite Wars. The sixteenth century brought the city unprecedented prosperity and considerable profits flowing into the city coffers particularly from the local silver mining as well as from the beer brewing, fish farming and the salt trade. As a part of the Habsburg Monarchy from 1526, Budejovice remained a loyal supporter of Emperor Ferdinand II in the Thirty Years' War. Budějovice underwent a short occupation by Prussia during the Silesian Wars and the war between the Habsburgs and the French army in 1742.



The horse-drawn tramway, erected between 1825 and 1832 as the first on the European Continent, linked České Budějovice to the upper Austrian city of Linz, and together with the Vltava Waterway accelerated the transportation of goods. New enterprises were established such as a pencil factory (Koh-i-Noor Hardtmuth in 1847), breweries, utensil factory etc. After 1990 it became a statutory city with its own city mayor. Traditional commercial and cultural relations were restored with Austria, Germany and other European countries.

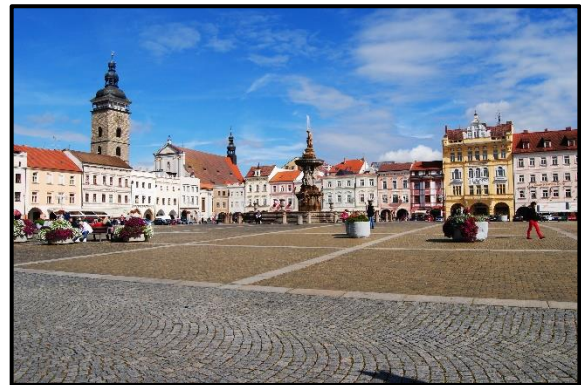
During the Second World War in March 1945, Budějovice was twice targeted by US Air Force raids that greatly damaged the city and caused great loss of life. At the end of the war, on 9 May 1945, Soviet troops liberated the city. On the following day, the Red Army and the American Army met on the main square in a joint celebration of the city's liberation.

### SIGHTS

The old town preserves interesting architecture from the Gothic, Renaissance, Baroque, and 19th century periods. This includes mainly buildings around the large Ottokar II Square. The most valuable historic building in České Budějovice is the Dominican convent with the Gothic Presentation of the Virgin Mary church from the 13th century, on Piaristic Square

*Selected sights:*

- Otakar II Square with Samson fountain
- Historical City Hall
- Black Tower and St. Nicholas Cathedral
- Piarist Square
- Panská street
- City fortifications





# UNIVERSITY OF SOUTH BOHEMIA IN ČESKÉ BUDĚJOVICE

The University of South Bohemia (USB) is a public university located in České Budějovice. The university has 11,000 students in more than 200 bachelor, masters and doctoral programmes at 8 faculties – Faculty of Economics, Faculty of Fisheries and Protection of Waters, Faculty of Philosophy, Faculty of Education, Faculty of Science, Faculty of Theology, Faculty of Health and Social Sciences, Faculty of Agriculture. The university also offers courses and education programmes for the general public.



## HISTORY OF USB

The University of South Bohemia was founded in 1991, following the tradition of educating teachers and university experts in various fields of agricultural production, theological studies and the tradition of fish farming and fisheries.

The University originally consisted of two faculties - Faculty of Education (since 1948 a branch of the Faculty of Education of Charles University, which later became an independent faculty) and the Faculty of Economics (since 1960 part of the Prague University of Agriculture).



The three newly created faculties also became the University's foundation stones: Faculty of Biology, Faculty of Theology and Faculty of Health and Social Studies. In 2006, the Faculty of Philosophy, then one year later, the Faculty of Economics were also established. The original Faculty of Biology was replaced in 2007 by the Faculty of Science. In 2009, the Faculty of Fisheries & Protection of Waters was established.



The University of South Bohemia collaborates with more than 300 universities around the world. It supports foreign study and research trips by students and academic staff.

## USB CAMPUS

The campus is located in a quiet part of the town and it is used for relaxation, cultural and social events. An English style park has been created. You will find there much greenery, sport grounds and benches, including the unique Václav Havel benches designed by the architect Bořek Šípek. The nice roads and modern lighting create a positive atmosphere.

The campus regularly hosts concerts and events for students and the general public: The first year student welcome, Building a May poll, Light Show, Waste Show and many others.





You can also walk along the nature trail in the tree lined avenue, walk around the experimental plots and animal pens. The information boards contain interesting information on agriculture and the food industry.

The campus is under constant development. In 2014, the new contemporary science and technology building and a joint building for the Faculty of Agriculture and the Faculty of Fisheries & Protection of Waters are being finalized. Investment continued with the development of a new university kindergarten and a student club.

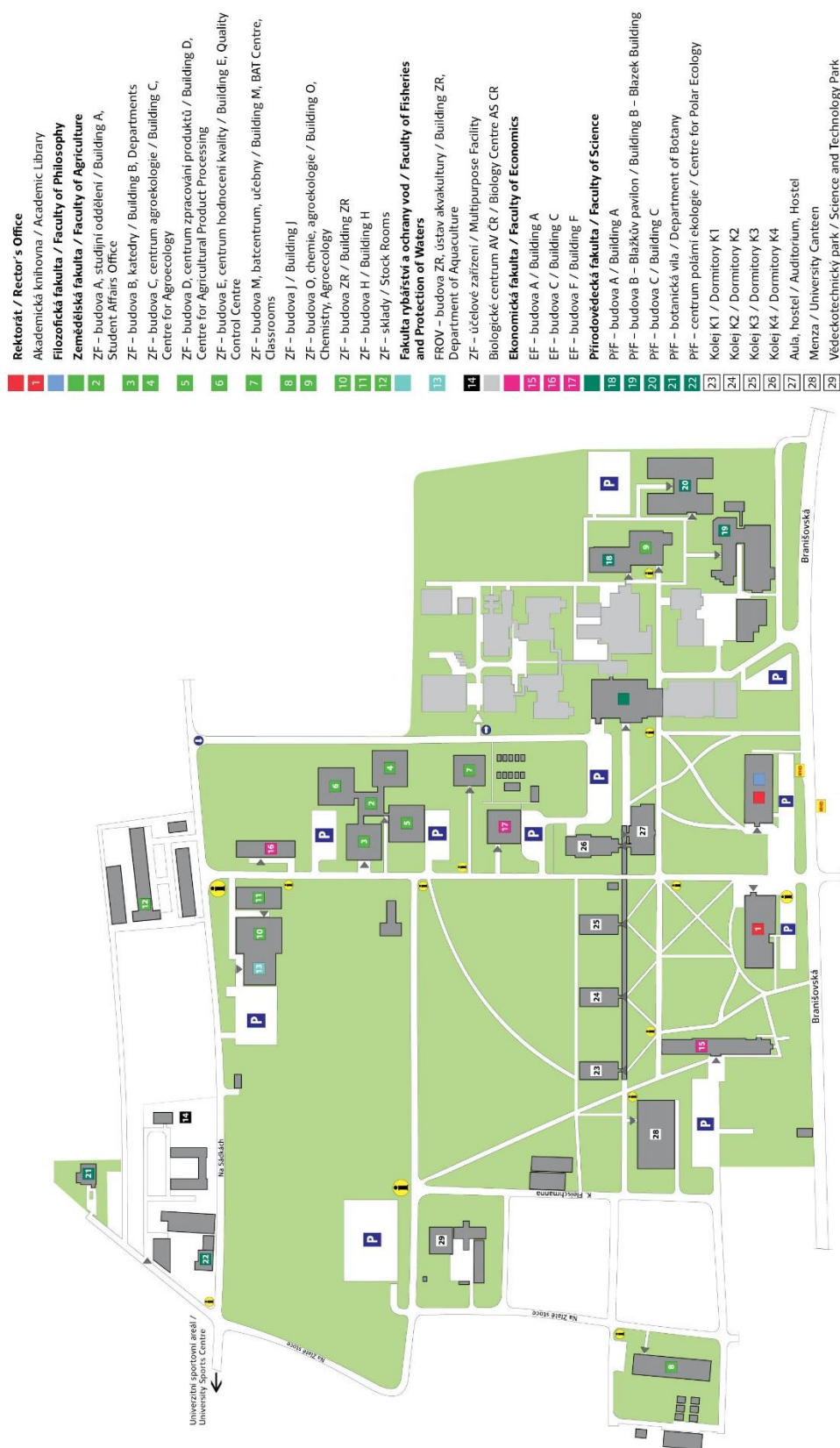


# VENUE – MAP OF CAMPUS



Jihočeská univerzita  
v Českých Budějovicích  
University of South Bohemia  
in České Budějovice

## Mapa kampusu / Map of the Campus





## TRAVEL INFORMATION

The city of České Budějovice has convenient location close to the borders of three countries. It is approximately 100 km to Linz, 130 km to Passau, 150 km to Prague, 200 km to Vienna and 300 km to Munich. The easiest way is to fly to Prague International Airport (Vaclav Havel Airport Prague) and then travel by bus to Ceske Budejovice. Because the Prague airport is on the periphery, passengers have to use city transportation system.

We recommend to take bus Airport Express from Prague International Airport (Vaclav Havel Airport) to the Central Railway Station in Prague. This bus leaves from Terminal 1 as well as from Terminal 2 – every half an hour and price is 60 CZK (approx. 2,5 EUR). Tickets are available at driver and baggage are carried free of charge. The first bus goes at 5:30 and the last one leaves at 21:00 (from the airport to the railway station). In the opposite direction the first bus goes at 6:30 and the last one at 22:00.

When you arrive to the Central Railway Station in Prague, continue by train to České Budějovice. First train usually goes at 5:32 and then every hour (or half an hour – depends on the daytime). The price is 165 CZK (approx. 6,5 EUR) and you can find more information at Czech Railways website (<https://old.cd.cz/en/default.htm>).

The last part of your journey will be by public transport in České Budějovice from Mercury Center / Railway Station to the campus of University of South Bohemia. Take bus No. 3 and your final stop is called “Jihoceska univerzita” (University of South Bohemia). Ticket will be provided by student-staff at Railway Station in Ceske Budejovice or you will get further information about public transport before your travel.



## ORGANIZING COMMITTEE OF ESERA SUMMER SCHOOL 2017

### IVA STUHLÍKOVÁ, leader of organizing team

I am a former teacher of mathematics and physics, but immediately after finishing my teacher training I went on in studying psychology. I got professorship in educational psychology in 2008, before that I worked also within general psychology research on emotions and motivation. My research interests are therefore divided between these two fields. An example of my recent research on motivation is participation in MARS 500, which was a broad international project of simulated flight to Mars. Within educational psychology domain my most favourite work recently was participation in two European 7FP projects on inquiry in science education (S-TEAM) and formative assessment (ASSIST-ME).



I joined the ESERA community just through this collaboration and I found the research and community life of ESERA very interesting and inspiring. Thus taking over to organize the Summer School 2016 and 2017 is not only a challenge but a pleasure as well.

### JAN PETR, member of organizing team

I am an assistant professor at the Department of Biology, Faculty of Education, University of South Bohemia. My scientific and research focus contains two fields. The first field is presented by entomology, ecology and fauna of water insects, especially with focus on dragonflies (Odonata). The second field is theory of science education at pre-primary and primary level. I am also interested in didactical application of methods of direct study of nature in the biology and integrated science lessons, e.g. school experiments or observations with the use of principles of inquiry based education.



### LUKÁŠ ROKOS, member of organizing team

I am assistant professor and researcher at the Department of Biology, Faculty of Education, University of South Bohemia. I have master degree in Biology and Chemistry Teaching for Secondary Schools and I have completed PhD study in the field of Biology Didactics. Topic of my dissertation was *Assessment of inquiry-based scientific teaching in biology learning*.

I was member of research team in the international project ASSIST-ME (*Assess Inquiry in Science, Technology and Mathematics Education*) and took care of one local researching group in the Czech Republic. This time I am involved into two national projects focused on collaboration between researchers and teachers in the Czech Republic.





## STUDENT ASSISTANTS AT ESERA SUMMER SCHOOL 2017

- Petra KECLÍKOVÁ

- I am a student of Biology and English at Faculty of Education, University of South Bohemia. I have a bachelor degree in Biology and English Teaching for Elementary Schools and I currently continue with a master degree. I am writing my thesis on the Department of English and the theme is: *Phraseologisms in English and Czech Online news*. Because of my positive approach to life I am really looking forward to meeting new people through ESERA summer school and spending whole week learning new things.



- Jana VOMÁČKOVÁ

- I am a student of Biology and English at Faculty of Education, University of South Bohemia. I have a bachelor degree in Biology and English Teaching for Elementary Schools and I currently continue with a master degree. I am writing my thesis on the Department of Biology and the theme is: *The dialogue among students as a method of a peer assessment within inquiry tasks regarding human biology in biology lessons*. I am very sociable person and I like meeting new people and learning new things.



# SCHEDULE OF ESERA SUMMER SCHOOL 2017

	Thursday June, 29	Friday June, 30	Saturday July, 1	Sunday July, 2	Monday July, 3	Tuesday July, 4	Wednesday July, 5		
9:00	Arrivals	Opening	Group Work	Group Work	Group Work	Group Work			
9:30		Lecture #1							
10:00									
10:30		Coffee	Coffee / Poster	Coffee / Poster	Coffee / Poster	Coffee / Poster	Staff / EB Meeting		
11:00		Initial Group Meeting	Lecture #2	Lecture #3	Lecture #4	Lecture #5		Check-out	
11:30									
12:00		Lunch	Lunch	Lunch	Lunch	Lunch			
12:30									
13:00		Informal Time	Informal Time / Meet the Staff	Neuro- education / Discussions	Informal Time / Meet the Staff	Informal Time			
13:30						Group Work		Group Work	Poster Session
14:00									
14:30									
15:00	Check-in	Coffee / Poster	Coffee / Poster	Trip to Český Krumlov and dinner	Coffee / Poster	Coffee / Poster			
15:30					Registration	Workshop (W1, W2, W3)		Workshop (W4, W5, W6)	Workshop (W1, W3, W5)
16:00	Group Work Presentation								
16:30									
17:00	Informal Time	Informal Time				Informal Time		Closing	
17:30									
18:00	Dinner and Welcome Party	Dinner	Dinner			Farewell Dinner			
18:30		Social Programme			Free Time				
19:00									
19:30									
20:00									
20:30									












## LIST OF REVIEWERS

- BILICAN Kader, Kirikkale University, Turkey
- BJÖRKLUND Lars, Linköping University, Sweden
- BLAŽEK Josef, University of South Bohemia in České Budějovice, Czech Republic
- BOEVE-DE PAUW Jelle, University of Antwerp, Belgium
- CASTELLS LLAVANERA Marina, Universitat de Barcelona, Spain
- DE HOSSON Cécile, University Paris Diderot, France
- DILLON Justin, University of Bristol, Great Britain
- EVANS Robert, University of Copenhagen, Denmark
- FORBES Cory, University of Nebraska-Lincoln, United States of America
- FURTAK Erin, University of Colorado Boulder, United States of America
- GRAULICH Nicole, Justus-Liebig Universität Gießen, Germany
- HARMOINEN Sari, University of Oulu, Finland
- HOLMEGAARD Henriette Tolstrup, University of Copenhagen, Denmark
- CHAKRAVERTY Devasmita, Washington State University, United States of America
- IDIN ŞAHİN, Hacettepe University, Ankara, Turkey
- KARADEMİR Ersin, Eskişehir Osmangazi University, Turkey
- KAUERTZ Alexander, Leibniz University Hannover, Germany
- KORTLAND Koos, Utrecht University, Netherlands
- LEVINSON Ralph, UCL - Institute of Education, United Kingdom
- MAZORODZE Ronald, UCL - Institute of Education, Great Britain
- PAPÁČEK Miroslav, University of South Bohemia in České Budějovice, Czech Republic
- PETR Jan, University of South Bohemia in České Budějovice, Czech Republic
- RANKHUMISE MMUSHETJI Petrus, Central University of Technology, Free State
- ROPOHL Mathias, IPN - Leibniz-Institute for Science and Mathematics Education, Germany
- RUSEK Martin, Charles University in Prague, Czech Republic
- RYBSKA Eliza, Adam Mickiewicz University, Poland
- SCHWARTZ Renee, Georgia State University, United States of America
- STUČLÍKOVÁ Iva, University of South Bohemia in České Budějovice, Czech Republic
- ŠORGO Andrej, University of Maribor, Slovenia
- TASAR Fatih, Gazi University, Turkey
- TELLİ Sibel, Canakkale Onsekiz Mart University, Turkey
- TEPLÝ Pavel, Charles University in Prague, Czech Republic
- TESTA Italo, "Federico II" University of Naples, Italy
- VON AUFSCHNAITER Claudia, Justus Liebig University Giessen, Germany
- VORHOLZER Andreas, Justus-Liebig Universität Gießen, Germany

## LIST OF PARTICIPANTS

Total number of 47 PhD students participate at the ESERA Summer School 2017. These participants were selected from 69 applicants. The participants of 19 different nations will meet in Ceske Budejovice this summer.

<div>AXELITHIOTI Panagiota</div> <div></div> <div></div>	<div>BHULANA Lubabalo Albert</div> <div></div> <div></div>
<div>BITTORF Robert Marten</div> <div></div> <div></div>	<div>BUBER Ayse</div> <div></div> <div></div>
<div>CELIK Kübra Nur</div> <div></div> <div></div>	<div>COPPARD Elizabeth</div> <div></div> <div></div>
<div>ČEŠKOVÁ Tereza</div> <div></div> <div></div>	<div>DÖNMEZ Ismail</div> <div></div> <div></div>

<p>GANDOLFI Haira</p>  	<p>GARCIA-LLADÓ Angela</p>  
<p>GIERL Katharina</p>  	<p>GIGL Florian</p>  
<p>GLOMM Theresa</p>  	<p>GORGES Anne</p>  
<p>GUILFOYLE Liam</p>  	<p>HÄGELE Jörn J.</p>  
<p>HEEG Julian</p>  	<p>HÜFNER Sybille</p>  

<p>IVANAUSKAS Audrius</p>  	<p>JACKOWSKI Andreas</p>  
<p>LÄMSÄ Joni</p>  	<p>MASSOLT Joost</p>  
<p>MCGOWAN- SMYTH Jennifer</p>  	<p>MIZZI Doreen</p>  
<p>MÖLLITS Aet</p>  	<p>NOOR Mohd Syafiq Aiman Mat</p>  
<p>NORRIS Stuart</p>  	<p>NOWAK Anna</p>  



OETTL  
Michaela



OLSSON  
Daniel



POLS  
Freek



SAADI  
Zakaria



SAHIN  
Emine



SCHAD  
Vanessa



SINAKOU  
Eleni



SMERDEL  
Snježana





STÄCKER  
Jenny



STERN  
Florian



<p>SURENDRAN Shone</p>  	<p>TAKEI Sandra</p>  
<p>TAMM Marja</p>  	<p>TASKIN Nazli Ruya</p>  
<p>TIMONEN Laura</p>  	<p>VITÁSKOVÁ Anna</p>  
<p>WARREN Clare</p>  	<p>YANIŞ Hilal</p>  
<p>ZAPPIA Alessandro</p>  	



## LIST OF STAFF

18 persons from 12 different countries will serve as staff at the ESERA Summer School 2017. 14 of them will be group coaches and they will work in small groups with PhD students. There will be 5 persons responsible for plenary lectures and 6 persons involved in workshops.

<div>BJÖRKLUND Lars</div> <div></div> <div></div>	<div>BOEVE-DE PAUW Jelle</div> <div></div> <div></div>
<div>DILLON Justin</div> <div></div> <div></div>	<div>EVANS Robert</div> <div></div> <div></div>
<div>FURTAK Erin Maria</div> <div></div> <div></div>	<div>GRAULICH Nicole</div> <div></div> <div></div>
<div>HARMOINEN Sari</div> <div></div> <div></div>	<div>KORTLAND Koos</div> <div></div> <div></div>

<p>LEVINSON Ralph</p>  	<p>MARTIN Sonya</p>  
<p>NIEMINEN Pasi</p>  	<p>RUSEK Martin</p>  
<p>SCHWARTZ Renee</p>  	<p>TASAR Fatih</p>  
<p>TESTA Italo</p>  	<p>VORHOLZER Andreas</p>  

#### PLENARY SPEAKERS

- Jelle Boeve-de Pauw (*University of Antwerp, Belgium*)
- Justin Dillon (*University of Bristol, United Kingdom*)
- Erin Maria Furtak (*University of Colorado Boulder, USA*)
- Ralph Levinson (*University College London, United Kingdom*)
- Renée Schwartz (*Georgia State University Atlanta, USA*)

## WORKSHOPS LEADERS

- Lars Björklund (*Linköping University, Sweden*)
- Justin Dillon (*University of Bristol, Great Britain*)
- Robert Evans (*University of Copenhagen, Denmark*)
- Erin Marie Furtak (*University of Colorado Boulder, USA*)
- Sari Harmoinen (*University of Oulu, Finland*)
- Sonya Martin (*Seoul National University, South Korea*)

## POSTER FEEDBACK AND ROVING COACHES

- Koos Kortland (*Utrecht University, Netherlands*)
- Jouni Virii (*University of Jyväskylä, Finland*)
- Deb McGregor (*Oxford Brookes University, United Kingdom*)

## OTHER GUESTS

- Michaela Plassová (*University of South Bohemia, Czech Republic*)

## PLENARY LECTURES OVERVIEW

### LECTURE 1: SUPPORTING CHANGES IN TEACHER PRACTICE WITH A LEARNING PROGRESSION: RESULTS OF THE ELEVATE STUDY

Erin Marie Furtak, University of Colorado Boulder, USA

Friday 30/06, 9:30 – 10:30

We know that in order for teachers to achieve meaningful changes in their classroom practices, they need opportunities to participate in long-term professional development. However, how does teacher learning relate to changes in their classroom practices and, in turn, how does that influence student learning? This interactive plenary session will present the Elevate study, a four-year study of high school biology teachers' engagement in a professional learning experience centred on a learning progression for natural selection. Together, we will look inside teachers' participation in the professional development sessions, their classroom practices, and results of student achievement.

### LECTURE 2: RESEARCHING SOCIO-SCIENTIFIC ISSUES – AN ONTOLOGICAL PROBLEM

Ralph Levinson, University College London, Institute of Education, United Kingdom

Saturday 01/07, 11:00 – 12:00

School science curricula draw on Vision I perspectives of scientific literacy (Roberts, 2007), that the way to understand the world is based on a set of canonical laws, theories and facts. Such a vision presupposes that explanations can be derived from Covering Laws based on regularities, for example the Gas Laws. This positivist, empiricist approach privileges descriptive over normative statements: there is no logical relationship between the world described through scientific research and the world, as it ought to be, the realm of ethics and justice.

I argue that these assumptions present insurmountable pedagogical problems for teaching and researching socio-scientific issues. Drawing on critical realist literature, I argue that aspects of the natural *and* social world are ontologically real but mediated through human thought and therefore epistemologically negotiated. For example, feelings of hunger are ontologically real; hence, knowledge of human nutrition leads us to exposing those causal mechanisms that prevent people from having a healthy and balanced diet. Such mechanisms lead researchers to identifying oppressive social structures; hence, the study of science has intrinsic social justice impacts. There are also implications for educational research because epistemological constructivism generates mixed methodologies to expose injustice.

## **LECTURE 3: NATURE OF SCIENCE AND SCIENTIFIC INQUIRY FOR SCIENTIFIC LITERACY**

**Renée Schwartz, Georgia State University Atlanta, USA**

Sunday 02/07, 11:00 – 12:00

Helping all students understand what science is and how scientists generate and justify new knowledge is a goal of science education around the world. These concepts, known as the nature of science and the nature of scientific inquiry, can promote scientific literacy by breaking down barriers and misconceptions about science. This lecture presents the current framework and research for inquiry-based science teaching and the nature of science that foster connections of science with and for society. Such connections promote global scientific literacy. Teachers need to not only learn the concepts of nature of science and scientific inquiry, but they also need to learn effective pedagogical strategies for embedding these concepts into their science instruction. Pedagogical content knowledge for nature of science and nature of scientific inquiry is a growing area of research, as teachers around the world face myriad challenges to meet their national standards for science education. This lecture will outline current and future directions of research on nature of science and scientific inquiry for advancing scientific literacy.

## **LECTURE 4: ECO-SCHOOLS EVALUATION AND INNOVATION PROJECTS – INTERACTIONS BETWEEN RESEARCH, RECOMMENDATIONS AND PRACTICES**

**Jelle Boeve-de Pauw, University of Antwerp Belgium**

Monday 03/07, 11:00 – 12:00

I will present the findings and implications of a large scale project that we did for the Flemish government in which we evaluated the eco-schools project in Flanders. We brought together indicators for environmental school policy, didactical approaches, nature at school and linked them to the educational outcomes of the eco-school project (students and teachers). This is done in a mixed-method approach. The results of the research project initiated a large-scale reform of the eco-school project in Flanders. We have also coached the eco-schools team in a follow-up project, to help them redefine their own role through competence-based experiments. The plenary could focus on the interactions between research, recommendations and practices. This project is a nice illustration of the nexus between research and practice, and it shows that results can contribute to educational and policy practices.

## **LECTURE 5: LEARNING SCIENCE OUTSIDE THE CLASSROOM**

**Justin Dillon, University of Bristol, United Kingdom**

Tuesday 04/07, 11:00 – 12:00

The majority of research in science education has been carried out in classrooms and laboratories. However, as we all know, huge opportunities exist to engage with science and scientists beyond the classroom – for example through field-work, in museums, science centres and botanical gardens and online. In this interactive talk, I will look at the strategies that researchers have used to study the impact of learning outside the classroom in a range of contexts. I will focus on research methods and on how collaborations between ‘researchers’ and ‘practitioners’ can be mutually beneficial. We will also look at pedagogical approaches used in out-of-school contexts and consider how transferable they are to school settings. Finally, we look at why there is no such thing as ‘informal learning’.

# **WORKSHOPS OVERVIEW**

## **WORKSHOP 1: USING VIDEO IN SCIENCE EDUCATION RESEARCH: METHODS FOR DATA COLLECTION AND ANALYSIS**

**Sonya N. Martin, Seoul National University, South Korea**

Friday 30/06, 16:00 – 18:00 and Monday 03/07, 16:00 – 18:00

In this workshop, graduate students will be introduced to brief history about video use in teacher education and educational research. I offer an overview of how video has been used and trace how developments in video technologies have influenced the education and preparation of science teachers. Following this introduction, students will learn about different features of various video analysis tools to help them decide which tools are appropriate for their research.

Students will consider strategies for data collection and storage and we will discuss consent, privacy and ethical issues related to video data collection and analysis. Next, I will provide an overview of various methods for analyzing video (including zooming, controlling time, and conducting microanalysis and off-print analysis). To do this, I will share examples from published articles in science education and teacher education journals to highlight some ways in which video can be used as evidence for investigating different issues in science teaching and learning. Finally, students will be supported to develop a brief plan for using video (set-up, capture, data logging, and points for analysis) for their own research. We conclude with a discussion about implications for future practice and research in the preparation and professional development of science teachers.

## **WORKSHOP 2: PUBLISHING AND REVIEWING IN SCIENCE EDUCATION**

**Justin Dillon, University of Bristol, United Kingdom**

Friday 30/06, 16:00 – 18:00 and Monday 03/07, 16:00 – 18:00

Why, as academics, do we write? Who are our audiences? How do we get better at writing? This workshop focuses on writing for publication in different venues such as academic and professional journals. We will look in some detail at the submission, review and publication process found in the major international journals. The criteria used to evaluate papers will be presented and examples of good and bad practice – of authors and reviewers – will be discussed. By the end of the workshop, you should feel confident that you know how the system works and be aware of its strengths and weaknesses.

## **WORKSHOP 3: MAKING TACIT KNOWLEDGE EXPLICIT: THREE METHODS TO ASSESS ATTITUDES AND BELIEVES**

**Lars Björklund, Linköping University, Sweden**

Friday 30/06, 16:00 – 18:00 and Monday 03/07, 16:00 – 18:00

This workshop will show how to use a mixed method approach to measure attitudes, believes and other subjective data from students and other informants. It will show how a combination of qualitative and quantitative techniques for analysis will render useful results even from a small group of informants. A recent study exploring what university examiners considered important when grading student theses will be used as an explicit example. The aim of that particular study was to elicit teacher's explicit but also tacit and subjective criteria, used when they were grading university-student theses. Other examples; What do primary students want to study in the field of astronomy, what content do students appreciate in the area of sex education, what do teachers think about the concept of 21<sup>st</sup> – century-skills.

The combined methods are:

- Holistic assessment and grading using Comparative Judgement (Pollitt, 2012; Thurstone, 1927). This is a method considered having a strong inter-rater-reliability.
- The eliciting of individual personal criteria or attitudes using the Repertory Grid Technique (Björklund, 2008; Kelly, 1955).
- The sorting and ranking of a large set of propositions using the Q-Methodology (Stephenson, 1953). A very interesting alternative to Likert scale surveys, easily administered online.

## **WORKSHOP 4: STUDYING FORMATIVE ASSESSMENT TASKS AND CLASSROOM PRACTICES WITH MIXED METHODS**

**Erin Marie Furtak, University of Colorado Boulder, USA**

Saturday 01/07, 16:00 – 18:00 and Tuesday 04/07, 16:00-18:00

In this workshop, participants will have an opportunity to engage with original data from the Elevate Study to learn about the project's different approaches to reducing, coding, and analyzing multiple sources of data including professional development videotapes, teacher-designed formative assessment tasks, classroom video, and measures of student learning. We will briefly discuss rationales from the literature that mixed-methods researchers must be methodologically 'omnivorous,' and then will learn about the construction and application of the different coding systems and frameworks associated with the Elevate study.



## **WORKSHOP 5: ETHICAL QUESTIONS BASED ON PHD RESEARCH**

**Sari Harmoinen**

Saturday 01/07, 16:00 – 18:00 and Tuesday 04/07, 16:00 – 18:00

The PhD researches can have connections to the many kinds of ethical questions. How to implement results so that there is no possible to personalize the participants? Are there someone who benefit and someone who suffer from the results? How is the co-writer? Which are the names in article? What are your questions? Bring them with you. This is an opportunity to share your ideas with others.

## **WORKSHOP 6: STRATEGIES FOR MAKING SENSE OF DATA: CONVENTIONS AND WAYS TO A VALID INTERPRETATION OF DATA**

**Robert Evans, University of Copenhagen, Department of Science Education**

Saturday 01/07, 16:00 – 18:00 and Tuesday 04/07, 16:00 – 18:00

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.

Then the workshop will 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.

## **ADDITIONAL WORKSHOP: NEURAL CORRELATES OF ARITHMETIC FUNCTIONS**

**Michaela Plassová, University of South Bohemia in České Budějovice, Czech Republic**

Wednesday, 07/02, 13:00 – 13:45

Mathematics plays a cardinal role in our lives, nevertheless Brun and Paster (2010) state that approximately 40% of children finishing primary school leave with insufficient knowledge of basic arithmetics. In our research we focus on understanding neural mechanisms and the whole complex of mental operations and structures which enable symbolic as well as nonsymbolic processing of numbers and quantity in children. We have developed a specific research task with the objective to stimulate brain centres of nonsymbolic mathematics. Research (e.g. Park & Brannon, 2014, Wang et al., 2016, Park et al., 2016) shows that solving these tasks contributes to improvement in general arithmetics both in children and adults. In our workshop you can try our research task on your own and learn about its use in mathematics education.

## **SYNOPSES**

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.

## **SESSION A: ASSESSMENT AND EVALUATION**

# ADOPTION OF ICT-BASED MATRICULATION EXAMINATION CHANGES SCIENCE TEACHERS' PERSPECTIVES TO TEACHING AND ASSESSING ICT RELATED SCIENCE SKILLS

**Marja K. Tamm**

University of Helsinki, Faculty of Educational Sciences, Finland

## BACKGROUND

The upper secondary school matriculation examinations reform in Finland is on full speed and all the exams are being changed into computer-based during 2016–2019. Papers, pencils and calculators are replaced with an USB-booted operating system in a LAN connected examination environment including an online test browser and a set of programs (incl. LibreOffice, Geogebra, CAS computer software programs, LoggerPro, MarvinSketch, ect.) First computer-based matriculation examinations were held in autumn 2016 (In Geography, Philosophy & German). Chemistry and Physics will be computer-based in autumn 2018 and Math in spring 2019. Since the examination system includes “all the software that the student uses during his/her studies” enable the test environment open questions that can be solved using multiple different programs depending on the students’ preference. The structure of the new computer based examination in science subjects is going to include 3 sections: Section I: 1 question, 20 points, (1 completed, max. 20 p.), automatically corrected test items. Measures mostly memorization and understanding, but may also test other thinking skills. Section II: 7 questions, 15 points (4 completed, max. 60 p.). Measures mostly understanding, applying and analyzing, but may also test other thinking skills. Section III: 3 questions, 20 points (2 completed, max. 40 p.). Measures mostly analyzing, assessing and creating, but may also test other thinking skills. Items include digital data and materials. (Matriculation Examination Board, 2016)

The use of different programs in the matriculation examination enables new types of questions in science examinations. There has been a lot of discussion over what are science skills and what are ICT skills and when do these come together so strongly that you cannot differentiate them. For example analytical measuring devices and curve fitting processes or taking advantage of the molecular modeling properties during a science exam are done differently with software. Computer-based assessment environment enables complex problem solving (CPS), though researchers have not yet been able to prove how large role students ICT skills (ICT literacy) play in these kinds of new question types (Greiff et al. 2014). In *The National Core Curriculum for General Upper Secondary Schools 2015* (National Board of Education (Finland), 2015) ICT skills were included into the goals of the common parts and into the subject specific parts and course specific chapters. In 2016 the curriculum reform in upper secondary schools was implemented and all the new upper secondary schools students were advised to buy their own personal computers. Curriculum and matriculation examination reforms are therefore simultaneous in science subjects.

## THEORETICAL FRAMEWORK

Apostolopoulou et al. (2014) researched upper secondary math, physics and chemistry teacher's use of ICT in teaching. According to the results the theoretical knowledge and practical information about the science software supported the pedagogical implementation of ICT in science education. Research of professional development training (PDT) has shown indications that ICT is best adopted if the pedagogy with ICT is similar to the pedagogy already being used by the teacher before the adoption process (Karasavvidis et al. 2014). Sharing teaching materials and information is easier for teachers if the goals of the individual and the society are similar (Hendriks, 1999).

## RESEARCH AIMS AND QUESTIONS

- 1) *How does the computer based Matriculation Examination change the perspectives to using ICT in Science education?*
- 2) *What pedagogical or practical changes does the ICT-based matriculation examination reform demand from the teachers?*
- 3) *How do upper secondary school teachers use ICT-based learning and assessment tools?*

## METHOD

The data to this research was collected during the winter 2016-2017 from an in-service teacher training program called "The Pedagogical use of the information and communication technologies (ICT) in mathematics, physics and chemistry". The teacher training program included two full days and tasks in between plus pre and after questionnaires. The course was held within 14 locations around Finland and approximately 375 teachers participated the training. The data selected to this poster includes the questionnaires (N=305 teachers) and the conclusions part is supported with qualitative discussions online with the courses teacher trainers (N=7) about the results and perspectives. The questionnaires included a background section, likert scale sections: attitude, teaching and assessing tools, planning and executing assessment, software skills and willingness to learn new software skills, resources, and open questions. This data includes a possible positive bias due to the fact that the teachers taking part in this voluntary teacher training (on Saturdays) are likely to be more motivated towards this change. The gathered data is studied by qualitative methods, statistic survey analysis and triangulation (Cohen, et al., 2011).

## RESULTS

The data (N=305 teachers) shows that the teachers feel the need to add the use of ICT into their education and assessment. To the open question "*How does the matriculation examination change your teaching and the way your students learn*" 227 teachers (74 %) replied that it requires learning new software and using more software during the lessons. 41 (13 %) teachers replied that this changes their time consumption and that using ICT requires a lot more time and effort and less time is actually used to learning math/science. 16 teachers (5 %) answered that this reform changes nothing in their teaching and in their students learning or that even though computers replace paper and pencil nothing actually

changes. Only 41 teachers (13 %) gave some concrete examples to the ways that the ICT changes their teaching or their students learning and the items in the exams. The examples included: “Math and science will change radically and symbolic calculating programs and Geogebra will be used during all the lessons”; “Teaching science concepts can be done differently with simulations, animations and other visual tools”; “Students need to get excited with the possibilities that the software enables to solve the problems”; “Using different programs, choosing the best ones for the problems and taking advantage of the programs abilities in problem solving will change a lot”; “modelling chemistry and analysing curves etc. is very different with computers” and “test items will change since the programs are too able to solve some of the old problems and the data analysing features enable new item types”.

The teachers varied very much in their subject specific ICT skills measured with Likert scales. Teachers are changing teaching and assessment tools gradually. (see chart 1.)

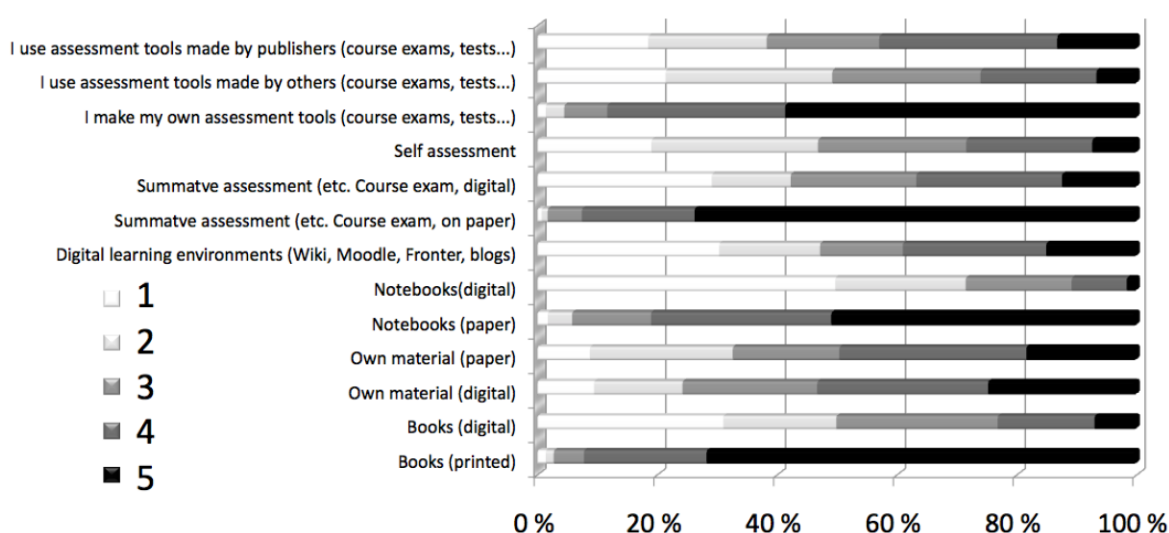


Chart 1. Teachers use of teaching and assessment tools. (1 = rarely or never, 5 = very often or always when possible)

## CONCLUSIONS

Since the new curriculum is much more ICT oriented it's only natural that the matriculation examinations will also measure the use of ICT in Science Exams. However the teachers' perspectives towards the use of ICT in science education are changing gradually. First step is the lower lever advantage of ICT (to simply use the programs during the lessons quite similarly than they would use paper and pencil = not taking advantage of the properties of the programs), the second step enables them to use ICT in more ways and actually benefit from using ICT in the selected task. The third step is combining different programs and digital data or simulations to accumulate items and answers that would not have been possible to do without ICT. This follows the new three part in the upcoming computer based science matriculation examination. Based on this data and these teacher training courses it looks like most of the teachers are still at the first or the second level. Next year teacher training needs to focus especially

targeting the third level task items, so teachers could speed up the process and students would be prepared to these new type of questions that have not been even possible with paper and pencil tests. Meeting and discussing with a lot of science teachers has shown that the ones that reach the third level assignments are usually the ones that have already found the exiting properties of the programs and have found the programs actually very useful. The teachers that complain time consumption are more likely to be the ones that are just in the first level (where time is often not saved, ICT just causes extra work). The next question is would it be more useful to start the adaptation process from the exiting tasks where ICT is actually making a huge difference or from transferring paper and pencil tasks to computer? Earlier research indicates the latter, but this might need more research since the first experiments might have a lasting effect on teachers' motivation and attitude towards taking advantage of ICT in teaching, learning and assessing science skills.

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## **SESSION B: BIOLOGY EDUCATION**

## WHY BIOLOGY TEACHERS SHOULD BE CRITICAL OF SCIENTIFIC TEXTS

**Theresa Glomm**

Leibniz Universität Hannover, Department of Science Education, Germany

### BRIEF OUTLINE OF THE STUDY

It is not possible to teach biology without scientific content. The crucial task of a biology teacher is to make complex scientific topics comprehensible for learners. This is a complicated and challenging task. Biology teachers should know about scientific content from a scientific perspective (e.g. Davis et al. 2006), they should consider their students' conceptions but also know about pedagogy (e.g. Shulman 1986; 1987). They need to have a profound knowledge base since "[s]cience education is an interdisciplinary domain" (Dahncke et al. 2001: 45). Thus, science educators should equally consider the conceptions of scientists and those of students for the reconstruction of accessible subject matter for instruction. Crucially important is to consider students' ideas not as misconceptions but as learning opportunities.

Shulman (1986; 1986) developed an approach concerning so-called pedagogical content knowledge (PCK) which "goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" (Shulman 1986: 9). Briefly, one aspect of PCK is the appropriate representation and formulation of concepts for instruction and knowledge about students' conceptions. What has not been pervasively considered is the necessity of a critical and systematic method to set theory into practice and reconstruct conceptions of a certain subject matter for instruction.

The Educational Reconstruction is a research frame which equally considers students' conceptions and scientific conceptions (Kattmann et al. 1996; Duit 2007; Duit et al. 2012). This research program contains three interrelated research tasks, including the scientific clarification. Clarifying scientific content aims at "clarification of the specific science conceptions and the content structure from an educational point of view" (Duit et al. 2005: 3). It means critically analyzing language used in scientific textbooks to work out core scientific conceptions and principles. Language is like a window providing insights into underlying conceptions and thoughts because it reveals the way we are thinking (cf. Gropengießer 2007; Lakoff & Johnson 1980). Thus, the words and terms being used to inform about science subject matter have the power to influence the reader's construction of conceptions in a rather appropriate or inappropriate way.

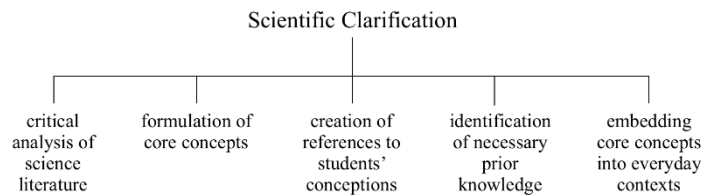
Most important for enhancing students' appropriate learning of scientific subject-matter is a careful and critical preparation of the specific content from an educational perspective (Kattmann et al. 1996; Duit 2007; Duit et al. 2012). Scientific content, i.e. presented in academic textbooks, cannot simply be used as such for instruction because it is written for experts (cf. Duit et al. 2005). The following example emphasizes this:

“The circulatory systems of amphibians, reptiles, and mammals have two circuits, an arrangement called double circulation [...] The two ventricles pump in unison; while some blood is traveling in the pulmonary circuit, the rest of the blood is flowing in the systemic circuit.”

(Reece et al. 2014: 918ff.)

Here, when reading the given example, the reader gets the idea that there exist two separate blood circuits in the human body – one pulmonary and one systemic circuit. The expression “double circulation” also suggests that there are two separate systems involved in blood circulation. However, there is only one blood circuit with circulation in two loops of the same circuit. Learners should understand this correctly because otherwise misunderstandings and misconceptions of blood circulation and related aspects of this topic, like functions of the heart or respiration, are likely to emerge (e.g. Lee & Kim 2014).

Descriptions of scientific content in textbooks are often very specific and complex; certain scientific knowledge is presumed and highly specific terminology is used. Often, these wordings are misleading or even wrong. Consequently, the process of a subject-matter clarification is necessary to reconstruct core conceptions of the relevant subject matter. These central conceptions should be used as starting points and goals for preparing meaningful science lesson instruction (Gropengießer & Kattmann 2013; Duit et al. 2012).



So far, the critical analysis of scientific content basically consists of two steps: a) the so-called elementarization and b) the (re-)construction of scientific conceptions for instruction (Duit 2007; Duit et al. 2012). However, the process and the methods of the scientific clarification have not been systematically developed in the context of science lesson preparation (Kattmann et al. 1996; Duit 2007; Duit et al. 2012). Thus, one aim of this research approach is the systematization of the subject-matter clarification, i.e. the investigation into which analytical steps are necessary to work out scientifically clarified core conceptions of certain biological topics from an educational perspective. We found at least five tasks and competencies which should be considered when dealing with scientific literature. The following chart presents these five steps (adopted from Gropengießer 2016):

Clarifying scientific subject-matter should be regarded as a subject-specific pedagogical task which preservice science teachers should develop while gaining pedagogical content knowledge (cf. Shulman 1986). Having to apply a critical perspective on the representation of science content may also trigger beneficial self-reflective thinking of preservice science teachers' own learning and thinking processes. In general, self-evaluation and reflection of one's own lesson planning is considered an essential ability of science teachers (cf. Gropengießer 2016: 240).

Unfortunately, many studies about critical thinking dispositions of science teachers and preservice science teachers attest low critical thinking dispositions (e.g. Akgun & Duruk 2016), although various studies on this issue show its importance in general (e.g. Bailin 1999, 2002; Ennis 1993; Vieira et al. 2011). Therefore, an investigation into how preservice science teachers manage to do such a necessary critical analysis of scientific content, i.e. a subject-matter clarification, to critically work out core conceptions usable for instruction from an educational perspective is necessary.

## RESEARCH QUESTION

- 1) *How do preservice biology teachers treat and clarify content knowledge for instruction?*

## RESEARCH DESIGN AND METHODS

The theory of embodied cognition (Gropengießer 2007) referring to embodied cognition and conceptual metaphor theory (CMT) (Lakoff & Johnson 1980; Lakoff 2014) constitutes the theoretical frame. One fundamental assumption is that language and thought are closely interconnected. Examining language enables access to underlying conceptions.

The first object of this research approach are representations of scientific content in scientific textbooks which will be analyzed with these two qualitative research methods: the qualitative content analysis (Mayring 2008) and the systematic metaphor analysis (Schmitt 2005). This is necessary to work out the issue with scientific literature from an educational perspective and to develop a systematic procedure of preparing adequate subject-matter structures for instruction, which includes refining the five tasks and competencies mentioned above.

The second object of the study is the investigation into preservice science teachers' ideas and competencies concerning the preparation of scientific subject-matter structures for instruction. The data will be generated with the help of qualitative interviews with biology preservice science teachers. Afterwards, qualitative research methods (Mayring 2008; Schmitt 2005) are adequate to systematically analyze the interview transcripts and to interpret underlying conceptions. These findings will be used to develop learning arrangements that potentially help students to learn a proper procedure of critically clarifying scientific content as part of their lesson planning competencies. The analysis of further qualitative interviews will help to comprehend the students' learning progressions and evaluate the learning arrangements.

All in all, biology teachers and preservice science teachers should be critical of the representation and wording of scientific texts. Therefore, working on their lesson planning competencies is necessary. (Preservice) science teachers need to learn this systematic procedure of reconstructing core conceptions to enhance fruitful learning.

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## HUMAN INTUITIONS AND GENETIC DETERMINISM

**Florian Stern**

University of Geneva, Switzerland

### OUTLINE OF THE FOCUS OF THE STUDY

Achieving scientific literacy is the goal of science education in schools across all industrialized nations. This is particularly important in research fields such as genetics and genomics, because they raise a growing number of socio-scientific issues. There is widespread agreement that in order to educate future citizens who will be literate about genetics, school instruction needs to accurately present the current genetics knowledge and its associated socio-scientific issues. Research in genetics education and the public understanding of genetics suggests that “genetic determinism”, the conception that single genes determine single or complex traits, is widespread. The problem with this conception is that, by current standards, it is scientifically inaccurate and socially unhelpful in dealing with socio-scientific issues, often leading people to wrong conclusions about the implications of genetics research for society. Conceptual development research suggests that such conceptions are often produced or influenced by deep human intuitions, such as design teleology and psychological essentialism. Design teleology is the idea that this contribution is the outcome of intention or design (Lennox and Kampourakis, 2013). Psychological essentialism is the intuition that organisms have essences, which are fixed (Gelman, 2003; Wilkins, 2013). The aim of this study is to investigate the extent of the association between these intuitions and secondary students’ conceptions of genetics.

### SHORT REVIEW OF RELEVANT LITERATURE

It seems that genetics teaching in its current form cannot effectively contribute to a robust conceptual understanding of contemporary genetics. Indeed, a recent comparative study of biology textbooks from 6 countries has shown that genetic determinism is found in all of them and that genetics concepts are presented in a way that does not take into account the reality and complexities of development (Gericke et al., 2014). Interestingly enough, even biology teachers may hold similar simplistic and inaccurate views, as a study with teachers from 23 countries has shown (Castera and Clement, 2014). Therefore, it is unsurprising to find that people may finish high school with deterministic view of genetics. It has been suggested that there should be significant changes in education (e.g. Kampourakis, Reydon et al., 2014). However, it may not be enough if genetic determinist conceptions stem from deeply rooted intuitions, such as psychological essentialism and design teleology. If this is the case, then it is necessary not only to challenge students’ genetic determinism conceptions, but also their essentialist and teleological conceptions.

Several research findings support that psychological essentialism is widespread among students: children seem to believe that organisms belonging to the same taxonomic group share some underlying, non-visible properties, and they rely on these properties to draw inferences about the characteristics of organisms. Thus, children apparently believe that organisms are characterized by



underlying, distinctive “essences” that make them what they are (Gelman, 2003). Recently, it has been suggested that essentialism also has a strong, specific impact on people’s understanding of genetics. In particular, it has been suggested that it may lead people to view genetically influenced traits as immutable and determined (Dar-Nimrod and Heine 2011). These findings suggest that essentialist conceptions could at least reinforce genetic determinist ones, and therefore they might be explicitly addressed in teaching.

Moreover, a large body of research suggests that people tend to intuitively provide teleological explanations for the characters of organisms from very early in childhood, as the parts of organisms may be perceived in the same way with the parts of human made artifacts. Design teleology has been shown to be a conceptual obstacle to understanding evolution (Kelemen, 2012; Kampourakis, 2014). The notions of design and purpose could enhance the idea of “genes for” traits, in the sense that genes exist for an intended use or purpose. In a study, it was shown that essentialist and teleological conceptions about inheritance are contrasting: traits with some function are either more heritable and less modifiable (essentialist stance) or less heritable and more modifiable (purpose-based stance) (Ware and Gelman, 2014). The question of correlation between essentialism and design teleology requires further empirical research.

## RESEARCH QUESTIONS

In this study, we investigate the nature and prevalence of essentialist, teleological and genetic determinist conceptions, as well as the correlations and implicit associations between them. The proposed study aims to provide answers to the following research questions:

- 1) *What kind of explanations do secondary students provide to questions about the origin of biological traits? Are their alternative explanations, and the respective conceptions, inaccurate with scientific knowledge?*
- 2) *Do students’ alternative explanations indicate that they hold essentialist, teleological or genetic determinist conceptions?*
- 3) *Are there any statistically significant correlations among students’ genetic determinist, essentialist and teleological conceptions?*
- 4) *Are there any implicit associations between students’ genetic determinist and essentialist or teleological conceptions?*

## RESEARCH DESIGN AND METHODS

The study documents and analyzes the explanations provided by secondary students during 2 years. The study consists of the following stages:

1. Develop a reliable and valid two-tier test to document students’ responses to questions asking for explanations, with distinct items focusing on design teleology, psychological essentialism and genetic determinism.
2. Develop a reliable and valid adaptation of the implicit association test to investigate possible associations between genetic determinism and psychological essentialism or design teleology.

3. Analyze students' responses to the two-tier test and identify any significant correlation between students' genetic determinist explanations, and teleological or essentialist ones, using classical test theory, item response theory and factor analysis.
4. Identify any implicit association between genetic determinist conceptions and essentialist or teleological ones, on the basis of the results of the implicit association test.

Compare the findings of the two-tier test and the implicit association test and conclude about possible associations between genetics determinist conceptions and essentialist or teleological ones.

## PRELIMINARY FINDINGS

Interviews with secondary students have been conducted with 50 students from three secondary schools in Geneva, in September and October 2016. Our presentation will highlight the main findings of this initial study and discuss how they are used to develop a two-tier test and the implicit association test that will be given to a larger number of students.

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# INVESTIGATING THE EFFECT OF FORMATIVE ASSESSMENT DESIGN ACTIVITIES ON SENIOR BIOLOGY STUDENT TEACHERS' UNDERSTANDING OF MODERN GENETICS AND PEDAGOGICAL CONTENT KNOWLEDGE

**Nazli Ruya Taskin**

Balikesir University, Turkey

## INTRODUCTION

Learning progressions (LPs) are defined as “empirically grounded and testable hypotheses about how students’ understanding of, and ability to use, core scientific concepts and explanations and related scientific practices grow and become more sophisticated over time, with appropriate instruction” (Corcoran et al., 2009, p.8). Gotwals and Alonzo (2012) argue the importance of understanding the growing interest in learning progressions (LPs) by addressing the promises and the challenges that LPs hold. LPs have the potential to be a bridge between curriculum, instruction, and assessment (NRC, 2007). Since learning progressions are inferential and hypothetical until some effort moves them from theory to practice, this potential creates a teacher professional development challenge. Scaffolding teachers to conduct the aligned activities and assessments is an integral part of LPs research for us to know that our findings are useful, practical and in as sense that realistic. Furtak, Thompson, Braaten and Windschitl (2012) describe the ways in which teachers’ professional development can be built through learning progressions. They argue that LPs for students may support students’ understanding in terms of content or/and practices, but these LPs do not describe the ways that teachers can improve as practitioners to scaffold student learning. They mainly address the effective use of formative assessments in classroom settings. Formative assessments aim to provide feedback to teachers and students throughout the learning process to understand the gap between students’ current and desired performance in any particular knowledge domain (Heritage, 2008). Assessment based on LPs could “provide information that is more easily interpreted by teachers and potentially allow them to make better informed and more precise decisions about student needs and how to respond them instructionally” (Corcoran et.al., 2009, p.23). However, designing appropriate formative assessments and providing useful feedback are also challenging for teachers (Heritage et al., 2009). Furtak and Heredia (2016) presented the research-based, four-step Formative Assessment Design Cycle (FADC) to meet this challenge. These steps are (1) Setting goals and exploring student ideas, (2) revising tools, (3) enacting and collecting data and (4) reflecting and identifying next steps. Following these steps with a group of teachers, teachers can design better formative assessments and develop activities to uncover student ideas and learning more about student thinking and their understanding of the topic they teach (Furtak & Heredia, 2016).

Understanding of students’ common prior ideas and “knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners” are elements of teachers’ pedagogical content knowledge (PCK) (Shulman, 1986, p.9-10). Teachers can use LPs to be aware of potential maps of the knowledge in a particular area to see the structure and relationships of students’ understanding and so that they could provide LPs based and targeted instruction. LPs have been developed in several science

topics such as the carbon cycle (Anderson, Mohan & Sharma, 2005) and components of evolution (Catley, Lehrer & Reiser, 2005), genetics (Duncan, Rogat & Yarden, 2009; Elmesky, 2012; Roseman, Caldwell, Gogos & Kurth, 2006). For every discipline, some critical areas can be considered as common areas of students' weakness. For example, Elmesky (2012) states that genetics are challenging to understand and students and adults hold many misconceptions in the field of genetics and heredity. Duncan et.al. (2009) believe that all students can develop deeper understandings of genetics through carefully designed instruction and with the support of competent teachers. They also suggest that identifying a limited set of core ideas in the domain provide students with a coherent framework for understanding phenomena and issues in genetics. Genetics is also challenging for teachers to learn and teach as many studies shown before (e.g. Gericke & Smith, 2014; Marbach-Ad & Stavy, 2000).

Given the challenges and premises that LPs hold for both students and teachers, student teachers also need to be informed about LPs; LP aligned formative assessments and instructional methods as future teachers. Learning how to design LP aligned formative assessments might be a useful way for student teachers to be aware of the content they will teach, assessments and instructional process. Genetics is chosen as a focus area in this study because it is a hard-to-teach-and-learn topic, genetics LPs are developed and revised in many studies to provide a background for this study (e.g. Duncan et.al., 2009; Elmesky, 2012; Roseman et.al., 2006), and genetics topics are also an integral part of the high school Biology curriculum in Turkey. Within this line, this study aims to investigate the effect of formative assessment design activities on senior biology student teachers' genetics learning progressions and pedagogical content knowledge.

## RESEARCH QUESTIONS

This study is going to be carried out to look for an answer to the following research question: What is the effect of formative assessment design activities on senior biology student teachers' genetics learning progressions and pedagogical content knowledge? The sub-problems of the study are:

- 1) *What is senior biology teachers' understanding of modern genetics?*
- 2) *What is the effect of the formative assessment design activities on senior student teachers' understanding of modern genetics?*

What is the effect of the formative assessment design activities on senior student teachers' pedagogical content knowledge (knowledge of students' understanding in modern genetics, knowledge of biology curriculum, knowledge of instructional strategies for teaching biology, knowledge of assessment of biology learning)?

## RESEARCH DESIGN AND METHODS

The present study has a double pre-test quasi-experimental design that senior biology student teachers are given the pre-test two times, one at the beginning of the fall semester and one at the beginning of the spring semester before the activities. The pre-test will be given two times because senior biology teachers have a Seminar course where the instructor covers some modern genetics topics by the student teachers' choice. The sample consists of 30 senior biology student teachers who will be taking "Teaching Practice" course in their last semester at the faculty of education. Data will be collected through various data gathering tools. Turkish version of Learning Progression-based Assessment of Modern Genetics (LPA-MG) (Todd & Romine, 2016) and an open-ended genetics LP based assessment will be used as pre-post-follow up tests of modern genetics understanding. Pre-post interviews, video records of the activities, reflective journals and the assessments which student teachers designed during the activities will be used to determine their pedagogical content knowledge levels. Gathered data will be analyzed statistically and qualitatively. The experiment and control groups will be randomly assigned. The experiment group (n=15) will have activities for 12 weeks (4 class hours a week). In each activity, student teachers will design formative assessments related to the constructs of the Genetics Learning Progression (Duncan, Rogat & Yarden, 2009) following the steps of Formative Assessment Design Cycle (Furtak & Heredia, 2016).

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## **SESSION C: CHEMISTRY EDUCATION**



# THE DEVELOPMENT OF CRITICAL THINKING SKILLS THROUGH CHEMISTRY FOR YEAR 9 AND YEAR 10 STUDENTS IN ENGLAND

**Panagiota Axelithioti**

University of Birmingham, United Kingdom

## FOCUS OF THE STUDY

The study focuses on Critical Thinking (CT) in secondary chemistry education in England. It is a study that follows the interpretive tradition in terms of data analysis. The reason the study focused on CT because it would appear to be a central skill for teaching and learning in primary and tertiary education but is not emphasised in mid-secondary education. Mid-secondary education, when students are between 13 and 15 years old, is content-ridden, the stage during which students are progressively prepared for external examinations that will lead to higher education. For chemistry, specifically, there is a common belief amongst students that it is a complex and often difficult subject to grasp; theory-heavy and based extensively on rigid, experimental procedures that do not leave room for CT. However, the history of chemistry is first and foremost a chain of stories of discoveries that have been based on observation, curiosity, experimentation and independent thinking and learning. It is therefore interesting to explore: on one hand whether the students' perception about chemistry can change with the implementation of CT opportunities and whether CT opportunities will fit into the teaching of chemistry.

## REVIEW OF LITERATURE

In 1990 the American Philosophical Association (APhA) stated the following definition for critical thinking (Facione, 1990, p. 3): CONSENSUS STATEMENT REGARDING CRITICAL THINKING AND THE IDEAL CRITICAL THINKER. We understand critical thinking to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based. CT is essential as a tool of inquiry. As such, CT is a liberating force in education and a powerful resource in one's personal and civic life. While not synonymous with good thinking, CT is a pervasive and self-rectifying human phenomenon. The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit. Thus, educating good critical thinkers means working toward this ideal. It combines developing CT skills with nurturing those dispositions which consistently yield useful insights and which are the basis of a rational and democratic society.

The Association's statement does not come in the form of a list of specific criteria and is not limited to a few descriptive lines. It is a complicated, meaning-heavy, yet, quite complete description

(rather than definition) not only of what critical thinking is but also what a critical thinker is expected to be able to do. The statement also explicitly supports the idea of independence of the individual in all stages of the process; from the emergence of a thought, notion or question to it becoming an opinion, decision or belief.

The tradition of critical thinking in education has been much more prominent in the US than in Europe. From the 1970s onwards US policies have been influenced by a number of distinguished scholars and movements that support CT as a subject study in its own right in schools, colleges and universities. These efforts have focused on teaching CT as a separate subject, and in that form, it is expected – though there is no way for it to be verified – that time is allocated to practise the good skills that have generally been agreed upon in using “criteria in making reasoned judgements” (Bensley, 2011, pp. 2-3). Many a philosopher of education and scholars of CT have endeavoured to ask and answer why is it important to teach CT to students? What is the best way to teach CT? What are the expected outcomes of such formal teaching and how might these outcomes could be best assessed?

The view of the study about the connection of critical thinking and chemistry education is influenced by two scholars whose different philosophies in combination overlook the hurdles of vagueness of defining or describing CT and offer a refreshing approach. On one hand Sharon Bailin (2002, p. 368) suggests that CT is seen beyond the intricacies of lists of skills that do not quite match, each list adding or subtracting an element from the previous list. The core of the argument Bailin makes contextualised CT gives meaning a purpose to the exercise so much so that outside a context it almost does not make sense (2002, p. 368). The author poses and counters the tools for CT and the practices of doing science to demonstrate how the two blueprints easily overlap (2002, p.370). Richard Paul, on the other hand, makes explicit reference on the aspect of emotional investment in engaging in CT (1996, p. 13). The reason why Paul’s emotional factor is important is because it highlights the independence and responsibility that CT encapsulates and therefore the self-assurance a critical thinker should command in order to practice CT. this aspect is relevant to the study bout chemistry education from the viewpoint of encouraging students to acquire a degree of independence via performing experiments, building models and explanations based on their own observations and data collection and relying on their own abilities and not merely the teachers’ expertise.

## RESEARCH QUESTIONS

The questions this study aims to address were:

- 1) *Can teaching practices encourage argumentation, development of explanations, development of models, observations and inferences, and reinforcement of positive attitude in the chemistry classroom effectively in the chemistry classroom?*
- 2) *How does the focus on enhancing CT affect the teachers’ practices and teachers’ attitudes towards CT? Did the study have a long-term effect?*

## RESEARCH DESIGN AND METHODS

The methodology used for the study was based on traditional classroom observations. Classroom observations have been used for teacher training purposes and initial teacher progress reports. The literature of classroom observations from the psychological point of view informs that classroom observations are used to record behaviours and infer emotional situations of the students. In the present study the classroom observations are used for description of actions and interactions between the teacher and the students and among the students using a coding of actions which presents more similarities with the psychological approach to observations but the observations and analysis were done using an education lens.

An observation sheet was devised that contains a grid of 60 lines, each representing one minute for a 60-minute lesson, and a panel of 20 codes that described in detail the pre-decided actions related to effective CT teaching. The actions and interactions were revised on basis of pilot observations at the beginning of the study.

The design for the study was differentiated for each age group of participants. Year 9 students (aged 13-14 years) received an action research approach; wherein the observations spread over several weeks. With the cooperation of their teachers, teaching for CT was incorporated into their lessons on atomic theories, the periodic table and electron distribution and movement. Revisions to teaching activities were made based on discussions before and after every lesson that was observed. Overall, 14 lessons were observed. The Year 10 study (students aged between 14-15 years old) was two weeks in duration and was experiment-oriented. Students explored the factors that affect the rate of reaction via performing different experiments. The short period for observations necessitated a more structured study; plans of the lessons were extensively discussed and revisions agreed with the teacher delivering the unit of work. This included the Year 10 cohort performing the different experiments during their classes. Each of the nine groups was given agents of different concentrations or temperatures so a different outcome would be expected for each group. The purpose of this design was to propel keener observation of results based on the differences and propel peer discussion and reflection of process to enhance attention to details and the generation of an explanation, possibly even argument-building and debate.

## PRELIMINARY FINDINGS

The results of the study will be delivered in two distinct categories: results from discussions and performance of the teachers and results based on the performance of the students against the codes of interactions from the observation tool.

As far as the teachers are concerned the preliminary results show that the teacher who chose to co-operate fully had the most significant results in terms of reflection on teaching practices and the philosophical approach of the study had a longer-lasting effect on the teacher and the teaching practices. The teacher who felt that enough CT opportunities were already provided in the lessons had some results. Finally, the cohort of the teacher who exhibited the greatest resistance in co-operating and made

no adjustment to the teaching practices had few results in terms of CT, which were all self-motivated and entirely independent to the influence of the study as there was no influence from the study.

The results show that there is high likelihood that the attitude of the teacher towards CT influences the attitude of the students to a further extend than originally. However, the analysis is not complete to say with certainty that this correlation is validated.

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# DEVELOPMENT AND EVALUATION OF LEARNING PROGRESSIONS ON CHEMICAL CONCEPTS FOR LOW-ACHIEVING STUDENTS

Kübra Nur Celik

University of Duisburg-Essen, Germany

## FOCUS OF THE STUDY

Germany has introduced educational standards which describe competencies the students have to acquire by the end of a particular grade (KMK, 2005). These national educational standards are formulated as general standards, i.e. as the middle performance level students have to reach in average (Klieme et al., 2007). However, the IQB national assessment study of 2012 revealed that German students, particularly in North Rhine-Westphalia, perform lowly on these standardized assessment tests in chemistry compared to other federal states of Germany (Pant et al., 2013).

The aim of the project is to develop and evaluate learning progressions which suggest potential learning pathways so that learners can continue to develop content knowledge, which is important for the development of scientific literacy (Duncan & Hmelo-Silver, 2009; Duschl, Schweingruber & Shouse, 2007).

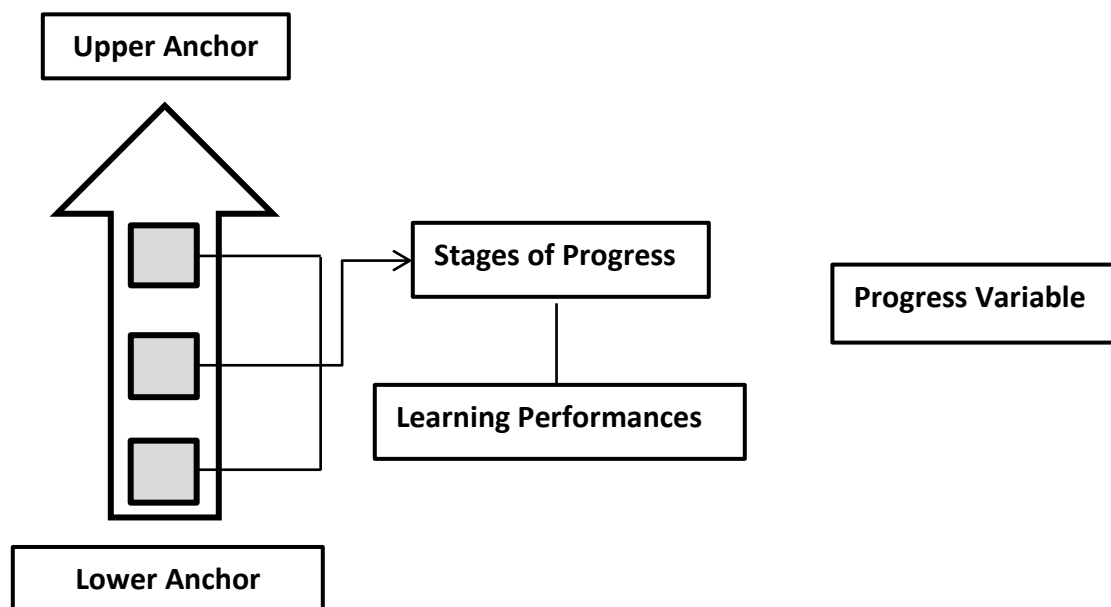
The development of learning progressions for the chemical concepts “Structure of Matter”, “Chemical Reaction” and “Energy” (c.f. MSW, 2011) focuses setting a minimal level to enable all students, particularly low-learning students to gain science proficiency. On the basis of a performance test that assesses students’ outcomes and surveys the development of chemical abilities it is possible to evaluate the hypothetical learning progression.

The study focuses two core aims: In the first step, learning progressions for the three chemical concepts “Structure of Matter”, “Chemical Reaction” and “Energy” (c.f. MSW, 2011) are developed. In a second step, the assumptions made in the learning progressions will be empirically evaluated. The strand maps which reproduce the learning progressions are linked to the chemical concepts. Each of these concepts consists of core ideas. The core ideas then are defined by several requirements. The learning progressions expect a logical sequence and a dependency of these core ideas, which will be the focus of the project.

## THEORETICAL FRAMEWORK

*“Learning progressions in science are empirically grounded and testable hypotheses about how students’ understanding of, and ability to use, core scientific concepts and explanations and related scientific practices grow and become more sophisticated over time, with appropriate instruction”* (National Research Council, 2007 in Corcoran, Mosher & Rogat, 2009, p. 15). The core idea of a learning progression is to arrange and depict the actual development of the learning progress of scientific concepts step by step to validate and evaluate the hypothetic learning progression empirically (Duit & Neumann, 2011).

Learning progressions consist of several characteristic elements (see figure 1). The end point of a learning progression, the learning targets or learning goals, are defined by the core concepts of a domain, which is pictured by an upper anchor and describes the skills and knowledge students have to achieve by the end of the progression. The lower anchor describes the abilities of the students who enter the progression. Between these two anchors are the stages of progress, which describe the learning pathways students have to get over successively (Corcoran, Mosher & Rogat, 2009). They represent the “varying levels of achievement” (Duncan & Hmelo-Silver, 2009, p. 607). These levels are defined by the learning performances which set the level of understanding and competences students would be able to perform (Corcoran, Mosher & Rogat, 2009; Duncan & Hmelo-Silver, 2009).



**Figure 1:** Components of a learning progression (cf. Corcoran, Mosher & Rogat, 2009; Duschl, Schweingruber & Shouse, 2007; Stevens, Delgado & Krajcik, 2010; Weber, 2015)

The development of scientific literacy is very important for lifelong learning and the understanding of core concepts in science (AAAS, 2007). The American Association for the Advancement of Science (AAAS, 2007) aspires in “Project 2061” the idea of developing scientific literacy for all students. The Atlas of Scientific Literacy describes the relation between learning targets and core ideas. Strand maps are used to visualize students’ growth of understanding of the core ideas and represent the link between core ideas and learning targets (AAAS, 2007).

A large part of the students in North Rhine-Westphalia does not even reach the necessary basic skills and chemical expertise in the IQB assessment study (Pant et al., 2013). A study from US assumes that low test results of students and the unfocused and disconnected science education might be related (Alonzo & Gotwals, 2012). Hence, learning progressions promise to build a better connecting point between standards, curriculum, instruction and assessment to improve science education and to promote scientific literacy (Alonzo & Gotwals, 2012; Duncan & Hmelo-Silver, 2009).

## RESEARCH QUESTIONS

The project is going to answer the following questions:

- 1) *Can the developed learning progressions for inefficient students be validated empirically?*
- 2) *Is there a difference in students' performance between classes which were taught according to the developed learning progression and classes which were not?*
- 3) *Is there an interdependency between the chemical concepts? Are requirements from one chemical concept necessary to achieve requirements from a different chemical concept?*

## RESEARCH DESIGN AND METHODS

In a first step, 56 core ideas are identified in cooperation with nine teachers. For each core idea we frame a description of what students are expected to know and be able to do, what they are not expected to know and typical misconceptions students have. After this, the chemical core ideas are brought into a logical sequence and are connected via strand map analogous to the project of AAAS (2007). In order to assess students' abilities items for each requirement within the core ideas are developed and administered to students from 2 different grades at the beginning and at the end of the school year. In the upcoming pilot phase the quality of the constructed items will be validated in a pre-post test with a Multi-Matrix design and selected assumption between core ideas will be exemplary calculated to evaluate the correlation. In the following main study all theoretical relations between the core ideas will be verified. The sample will consist of classes from nine teachers participating in the project and nine parallel classes from the same schools. The total sample size will be approximately 500 students from grades 7 and 9. The results of the performance test can be used as evidence about the necessity of one chemical core idea to understand the next one or if knowledge in one idea is just beneficial for the understanding of the others. Characterizing the relationship between the core ideas will finally help to construct valid learning progressions for low-achieving students.

Students' solution probabilities will be investigated with regard to the dependencies. Here one example for the methodical approach: Items represent two core ideas A and B. A is assumed to be required to understand B. Can it empirically be shown that the majority of students, who solve B can also answer the items for A correctly? Correlations, the McNemar test, cross lagged panel analyses, the Bayesian networks or cognitive diagnosis models can be applied to test this assumption.

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# **TEACHING AND LEARNING ABOUT THE NATURE AND BEHAVIOUR OF MATTER IN UPPER PRIMARY AND LOWER SECONDARY SCHOOL CLASSES IN ENGLAND. AN EXPLORATION OF THE RELATIONSHIP BETWEEN THE SPECIFIED, INTERPRETED, ENACTED AND EXPERIENCED CURRICULUM**

**Elizabeth Coppard**

Oxford Brookes University, United Kingdom

## **FOCUS OF STUDY**

Extensive research, as exemplified in the review by Hadenfeldt et al.(2014), has shown that a significant number of young people leave school and embark on their adult life without a meaningful understanding of the particulate nature of matter.

The concept that matter is made up of infinitesimally small particles is one of the fundamental ideas underpinning the humans understanding of the world. It is essential for any meaningful interaction with the science that is the foundation of most of our daily lives in the 21<sup>st</sup> century.

In the English school curriculum the study of matter and materials begins formally in key stage 1 (ages 5 – 7 years) and continues to the end of the statutory period of schooling at age 16. It is now well established (Braund, 2008) that there is a ‘dip’ in children’s attainment and interest in science as they transfer at age 11 from primary to secondary schools and there is evidence in the literature (Johnson, 2014) of a disconnect in the primary and secondary science curricula in the way that the concept of matter is treated.

Although wide-ranging research has been carried out on children’s conceptions of matter at different ages, literature which examines the materials used by teachers or studies the ideas, conceptualisations and pedagogy of the teachers themselves as they enact this material in the classroom is surprisingly sparse.

The purpose, therefore, of my study is to:

Explore the similarities and differences in the ways in which teachers interpret and enact, and children experience, the specified curriculum about the nature and behaviour of matter in key stage 2 (ages 7 – 11) and key stage 3 (ages 11 – 14) of the English School system.

## **SHORT REVIEW OF RELEVANT LITERATURE**

Much of the research carried out in the curriculum area of concepts of matter (Tsaparlis and Sevan, 2013) has been on elucidating children’s ideas about matter.

Children begin to form their own intuitive ideas about matter, several of which differ in significant ways from accepted scientific orthodoxy, from a very early age (Driver, 2000). Many of these ideas are tenaciously held and persist, in some cases, through all phases of schooling and into adulthood. Over recent years much of this evidence has been utilised to design ‘learning progressions’ which have informed curricula planning and against which assessment methods have been validated. (Alonzo and Gotwals, 2012).

In the learning progression suggested by Johnson, learners' ideas about matter begin with the notion that matter is continuous (Johnson and Papageorgiou, 2010). Gradually this changes to an acceptance of a particulate model, although initially one in which the particles are imagined to be inside some sort of continuous material. Their ideas slowly develop into one where the particles are accepted as the matter itself but at first the particles are ascribed macroscopic character. The final model is the accepted scientific one of matter as composed of particles and the properties of matter due to the collective behaviour of the particles.

It would appear (Braund, 2016) that a particularly problematic time for science learning in the English School system occurs at age 11 when children transfer from primary to secondary school. Much of the literature on primary to secondary transition in science suggests that teachers in secondary schools frequently fail to refer to learner's previous science learning experiences and reported assessment data and highlight the problems associated with students encountering significant differences in teaching approaches and language and repeating work without sufficient increase in challenge.

A significant amount of evidence in the recent literature (Johnson, 2014) points to students' understanding of the central concept of chemistry, the notion of 'substance', as a crucial feature in helping students comprehend the nature and behaviour of matter and chemical change. Johnson argues that teaching concepts of matter through a 'solids, liquids and gases' framework inadvertently encourages the development of alternative conceptions and suggests that children should be taught about 'substance' from the outset and that all teaching should instead be done through a 'substances' framework.

Taber (2015) stresses the importance of integrating concepts in the curriculum to ensure curriculum coherence. The shifting of concepts over time and chemistry's use of multiple models and representations to understand target concepts are highlighted by Taber as uniquely problematic in chemistry teaching.

## RESEARCH QUESTIONS

My study will try to answer the following research questions:

- 1) *How is progression, from KS2 to KS3, in learning about 'the nature and behaviour of matter' prescribed in the National Curriculum?*
- 2) *What do teachers, of classes prior to and immediately after entering secondary school, understand about the nature and behaviour of matter?*
- 3) *How do teachers of classes pre and post primary to secondary transition interpret and enact the curriculum designed to develop the understanding of the nature and behaviour of matter and what discontinuities appear to be evident?*
- 4) *How do children in pre and post transition classes experience the curriculum as it is interpreted and enacted by teachers and to what extent does there appear to be a disconnect between the key stages and between children's experience and teachers expectations?*

## RESEARCH DESIGN AND METHODS

To fully examine the multi-faceted nature of the research questions a pragmatic mixed methods approach will be used. The overarching approach of the study will be to triangulate data obtained from nested case studies with survey data and thematic content analysis of relevant documentary material. The methodological triangulation, possible through the application of different research instruments that will gather data through questionnaires, interviews, observations and documentary analyses, will be used to address issues of validity and reliability. The outline of my research design is as follows:

1. Examine the relevant section of the statutory national curriculum documents for teaching science at key stages 1,2 and 3 in English Schools prescribed by the British Government. This will take the form of a thematic content analysis. This process will be iterative, seeking major themes and interconnections and mapping the documents against research evidence from the literature.
2. Explore how teachers in upper primary classes and lower secondary school classes **interpret** the statutory requirements for teaching about the nature and behaviour of matter. This will be addressed by:
  - a) A survey of primary and secondary teachers administered using an online questionnaire tool. The school teachers chosen for the survey will be a non-probability sample chosen because of convenience.
  - b) A thematic content analysis of some of the key schemes of work utilised by teachers at KS2 and KS3.
  - c) Observation of lessons in primary and secondary schools. These will be largely unstructured and audio or video recorded where possible according to the schools circumstances
3. Explore the similarities and differences between teachers from three or four feeder primary schools, where the students will transfer to the local secondary school (informing the nested case studies of each teacher) in the way that they understand the nature and behaviour of matter and the way they **enact** the curriculum in this topic area. This will be addressed primarily by:
  - a) Audio and video recorded unstructured and semi-structured observations (of between six and twelve lessons).
  - b) Group or individual interviews of primary teachers and secondary school teachers. These will be audio recorded, transcribed then coded with the aid of CAQDAS software NVivo11.
4. Explore how the curriculum is actually experienced by the children in KS2 and KS3 classes. This will be addressed by:

Group interviews with primary and secondary school students. These will be stimulated recall interviews following video recorded lesson observations.

## PROPOSED TIMELINE AT THIS STAGE IN MY RESEARCH

My intention, by the timing of the summer school in June 2017, is to have completed the following:

1. Thematic analysis of the statutory documents
2. Thematic analysis of the relevant sections of key schemes of work
3. Collected and analysed survey data from primary and secondary teachers.

Obtained full ethical clearance from my university to enable me to start collecting observational and interview data from pupils and teachers

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# DEVELOPMENT OF A TRAINING TO PROMOTE THE ACADEMIC CONCEPT OF STRUCTURE OF MATTER

Andreas Jackowski

University of Duisburg-Essen, Germany

## THEORETICAL FRAMEWORK

The application of images plays a central role in education of scientific-related contents in chemistry. Learning processes are supported by the interaction of images and text (Mayer, 2009). The benefits of different multimedia learning materials depend on the skills of the individual learners (Hoeffler, Opfermann, & Schmeck, 2013). Nevertheless, an adequate teaching of scientific contents is not practicable without the use of illustrations (Gilbert & Boulter, Developing models in science education, 2000).

Especially in the field of structure of matter, a variety of different forms of representation is used. The term *structure of matter* deals with the basic characteristics of structures and the origin of matter. The different forms of representation vary depending on the intended objectives. It is important for learners to be aware of the presented form as well as to know how to deal properly with it. They must be able to identify the information of different parts of an image to capture the higher-level context (Weidenmann, 1994).

However, it is possible that the illustrations are misinterpreted due to confusion with alternative types of representation. To avoid misinterpretation, a great number of competitive types of representation, each with a specific vocabulary and different features, have to be known by the learners (Schnotz, Baadte, Müller, & Rasch, 2010).

Illustrations can be characterized either as decorative or instructional visualizations depending on the amount of information implied (Niegemann, Domagk, Hessel, Hein, Hupfer, & Zobel, 2008). Whereas decorative visualizations only serve the purpose to be visually appealing and thus are not meant to foster the acquisition of content knowledge, instructional visualizations contain relevant information for learning content knowledge.

Instructional visualizations themselves can be differentiated by their level of abstraction. A distinction can be made between purely iconic and symbolic representations and hybrid forms of them (Dickmann, Opfermann, Rumann, Dammann, Lang, & Schmuck, 2015). Iconic visualizations show a structural similarity to the real object. They are depictive representations of the reference object (Schnotz, An Integrated Model of Text and Picture Comprehension, 2005). In contrast, symbolic representations are descriptive representations. They present their information in a condensed and conceptional way and have no similarity to the real object (Schnotz, An Integrated Model of Text and Picture Comprehension, 2005). Additionally, there are hybrid types, containing symbolic as well as iconic attributes in various combinations.

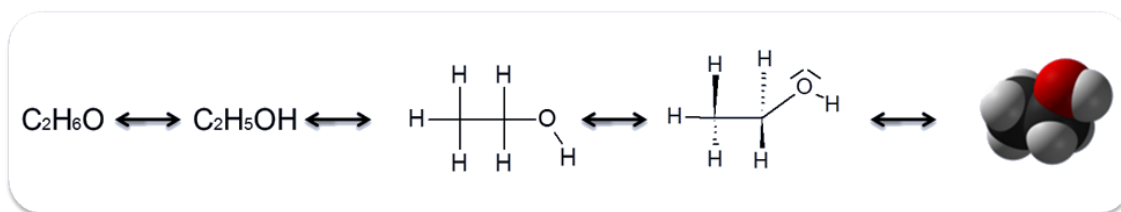


Figure 1: Different representations of an ethanol molecule. From the left to the right, the representations become more iconic and less symbolic.

## OBJECTIVE

Within this project, a training will be developed with the aim of improving the conceptual understanding of structure of matter. The project is divided in two phases.

At first, the influence of different competences of learners on the handling of illustrations with varying level of abstraction is evaluated. Particular attention will be paid on the mathematical ability and the spatial sense of the subjects.

Another goal of this phase is to examine whether a basic understanding of symbolic models is required to increase knowledge in an iconic domain or if both fields develop independently. In the second phase, a training for the learners will be designed on basis of the results of the first phase. The aim of this training is to increase the conceptual understanding of models of the structure of matter in the iconic and symbolic fields.

## RESEARCH QUESTIONS AND HYPOTHESES

Against the described background, the following research questions (RQ) and hypotheses (H) will be addressed in the first phase of the study:

- 1) *Which influence has the mathematical ability to the conceptual understanding of models of structure of matter in the symbolic field?*
  - H1: The mathematical ability is predictive for the conceptual understanding of models of structure of matter in the symbolic field.
- 2) *Which influence has the spatial sense to the conceptual understanding of models of structure of matter in the iconic field?*
  - H2: The spatial sense is predictive for the conceptual understanding of models of structure of matter in the iconic field.
- 3) *Is there a chronological order in the development of different fields of understanding of models of structure of matter?*

## RESEARCH DESIGN AND METHODS

The study is realized in a pre-post-design and the test-sample consists of first-year undergraduates in chemistry teacher training at the University of Duisburg-Essen ( $N = 122$ ) with an average age of 20.9 years ( $SD=3.1$ ).

Data is collected at the beginning of the first term and at its end. The pre-test has been carried out before the first lecture in order to record the prior knowledge at the beginning of the course



(10/2016). Finally, the increase of knowledge over the first term will be determined at the end of the lecture period with the post-test (02/2017).

Typical forms of representation to communicate contents in the field of general chemistry are identified to develop an extensive questionnaire for the evaluation of the academically understanding of models in the field of structure of matter. The tasks within this test include chemical content which is illustrated either in an iconic or symbolic form. The tasks vary in their level of complexity and the demand of different cognitive processes. The subjects have to reproduce, select, organise or integrate the given information to complete the tasks.

In addition to the developed test, a number of further test instruments are used. The mathematical ability is evaluated with a Mathtest (Kimpel & Sumfleth, 2015), the content knowledge is determined with a chemistry knowledge test (Freyer, 2013) and the spatial orientation is specified with a paper-folding-test (Ekstrom, French, Harman, & Dermen, 1976). Furthermore the cognitive capabilities are assessed with a cognitive ability test (Heller & Perleth, 2000), as a control variable.

An additional qualitative study will be carried out to investigate the impact of different competences on the work with different types of representations. Subjects will be selected based on the results of the first study. They will perform different tasks on the field of structure of matter with application of the thinking aloud method. A smart pen will be used to capture the thoughts and the intentions as well as written assignment.

## OUTLOOK

Extreme groups in terms of spatial sense and mathematic abilities have been identified from the results of the pre-test. As already mentioned, a qualitative study will be performed at the beginning of February 2017 in order to detect whether these skills have an influence on the handling of representations. After the performance and analysis of the post-test, the results of the investigations will be combined to develop the training. The training will increase the academically understanding of models in the symbolic and iconic field of the structure of matter.

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# DEVELOPING PRE-SERVICE SCIENCE TEACHERS' ABILITY TO DESIGN AND IMPLEMENT REPRESENTATIONS OF NATURE OF MATTER

Emine Sahin

Istanbul University, Hasan Ali Yücel Education Faculty, Turkey

The purpose of this study is to investigate how pre-service science teachers' represent the nature of matter through their personal external representations before and after the course and to investigate if and how pre-service science teachers' representations of the particulate nature of matter changes after the course that is designed to investigate the use of multiple representations. This study is designed to investigate the use of multiple representations to increase pedagogical content knowledge. Research questions address several components of pedagogical content knowledge.

## THEORETICAL FOUNDATIONS

### *Pedagogical Content Knowledge(PCK)*

Shulman (1986), who coined the term pedagogical content knowledge, argued that good teaching requires the integration of disciplinary and pedagogical knowledge.

PCK includes knowledge of how particular subject matter topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction (Magnusson et al., 1999). PCK is created through reflection, integration, and processing of all these necessary components. Since PCK is developed and shaped via teaching experience (Clermont et al., 1994; van Driel, Verloop, & de Jong, 1999, 2002) the best predictor of general PCK is experience, what the teacher learns by doing.

### *Representations*

**Internal Representations:** The cognitive science term for internal representation is mental representations. Internal representations are divided into three categories by cognitive psychologists (Rapp & Kurby, 2008). The first category is visual memory, which is made up of short lived copies of what we see, the second category is visual images which are visual experiences viewed through the mind's eye, the third category is knowledge representations (Rapp & Kurby, 2008).

**Knowledge Representations:** Thagard (1992, 2000) explains concepts as "mental structures representing what words on paper represent" (pg. 21). Rapp and Kurby (2008) defines knowledge representations for objects as including not only a visual image of the thing itself, but also relationships of the object, situations where the object is used, and emotions and beliefs about the object.

**External Representations:** External representations, are called inscriptions that those find outside the mind and in the environment (Rapp & Kurby, 2008)

**Personal External Representations:** I chose to define personal external representations from external representations because I will ask the participants to draw their ideas about PNM without any intervention.

## RESEARCH QUESTIONS

- 1) *How do pre-service science teachers represent their personal understanding of NOM?*
- 2) *How does experience with multiple representations of nature of matter(NOM) influence teachers' science content knowledge?*
- 3) *How does experience with multiple representations of nature of matter influence teachers' ability to design alternative representations of nature of matter?*
- 4) *How does experience with multiple representations of nature of matter influence teachers' ability to design alternative representations of NOM?*
- 5) *What do teachers' evaluations of the appropriateness of alternative representations reveal about their beliefs about the learning characteristics of children?*
- 6) *What do teachers' evaluations of the appropriateness of alternative representations reveal about their beliefs about the conditions under which children learn science?*
- 7) *How does experience with multiple representations of NOM influence teachers' ability to evaluate the appropriateness of alternative representations for children learning science?*

## RESEARCH DESIGN AND METHODS

Pre-service science teachers have been exposed to external representations of the particulate nature of matter (PNM) through their own schooling and teaching. These experiences with PNM have influenced the teachers' internal representations which include both visual and knowledge representations. Based on reviewed literature, it seems that there is a lack of research which concerns about science teachers' understanding of PNM by using multiple representations during the teacher training. So different than other studies, this study aims to enhance teachers' knowledge for using multiple representations in teaching PNM.

To explore the research questions I plan to use a mixed methods design (Robson, 2011). In this study, participants will be asked to create drawings to serve as their personal external representations of their views on the particulate nature of matter before and after the course. Drawings will be written words, symbols, pictures, diagrams etc. Participants will be asked to explain the representations of PNM to group members and evaluate the strengths and weaknesses of each representation and its appropriateness for children. Another data collection methods for this study includes observations, audio-visual recordings.

Purposeful sampling technique will be used to select participants. The criterion of participants is that they have to be enrolled in science teacher education program to become middle school science teachers. Since all the participants "meet some criterion (Patton, 2002), criterion method will be used to select participants.

## DATA ANALYSIS

Dual Coding approach will be taken to analyze the data for this study. According to Paivio (2007), using both images and verbal processes can provide a framework, which helps organize knowledge into the different cognitive domains, and this allows for better activation and retrieval of that knowledge. The Value of the Dual Coding approach is that it explains to some extent what happens in the brain while

learning (Gilbert, 2010). Clark & Paivio (1991) also proposed that comprehension and retention can be improved by using concrete examples and visual illustrations to activate concrete referents or connections and increase students' generation of their own mental images. One outcome of this study was that some of the participants generated more representations than were asked for on the post-test and proposed using all of the representations to teach the principle. More diagrams, models, concept maps, and verbal explanations were used in their representations. Component principles were linked with verbal connections to produce a logical progression leading to the larger overarching principle the representation was designed to demonstrate.

Recordings and observations will be used to check coding frameworks that will be developed by the researcher.

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# IMPLEMENTATION OF THE PRE-LEARNING STRATEGY IN CHEMISTRY EDUCATION

**Snježana Smerdel**

University of Split, Faculty of Science, Croatia

## FOCUS OF THE STUDY

Due to numerous abstract terms and contents of mathematical nature, students often regard chemistry as a difficult school subject (Taber, 2002). According to Johnstone (1984), the scientific nature itself makes chemistry unapproachable. However, difficulties entice both traditional teaching methods, as well as learning methods (Taber, 2002). According to the Cognitive Load Theory (CLT) (Sweller, 1988), information processing and knowledge acquisition are limited with work memory capacity. Not only does the work memory have to accommodate information received, but at the same time, it also needs to have enough space for their processing. When the requirements exceed the work memory capacity, overload ensues, and understanding of the subject matter drastically decreases (Alam, Zaman & Khan, 2014). A more efficient linkage of new information with the existing knowledge, and consequent decrease of work memory overload, is achieved with increasing the pre-knowledge level by application of pre-lecture activities (PLAs).

In the Croatian education system, there are no relevant researches which refer to the importance of using PLAs with the goal to reduce students' cognitive overload. Although significant researches indicate the advantages of these activities, it is important to determine with empirical findings their suitability for implementation into our education system. The focus of this study is to investigate the use of novel, web-based pre-lecture materials in chemistry classes at Croatian secondary schools in order to determine how they can be both designed and implemented into real classroom situations to reduce students' cognitive overload.

## REVIEW OF RELEVANT LITERATURE

PLAs were carried out before a block of lectures, designed to ensure that the essential background knowledge is established and accessible so that new learning can be built up on a sound foundation (Sirhan & Reid, 2001). This concept was based particularly on ideas developed by Ausubel (1968) (preparing the mind for learning) and Sweller (1988) (CLT). This could take a form of reading a textbook extract or Word document, listening to a podcast, performing an online activity, or completing a quiz. The key aspect is that PLAs are integrated into the lecture itself, so that they have an attributed sense of value by the student and teacher (Seery, 2010).

The efficient practice of PLAs was researched in detail at the undergraduate level (Collard, Girardot & Deutsch, 2002; Kolari & Savander-Ranne, 2007; Kristine, 1985; Seery & Donnelly, 2011; Sirhan & Reid, 2001). Previous studies reveal that such activities, in different contexts of application, can significantly facilitate learning since the students, prior to teaching itself, prepare their minds with introduction of key terms, which helps them recognize misconceptions and activate pre-knowledge. In addition, it is more probable they will be more engaged in the lecture if they are familiar with the

material and feel confident in their understanding (Dindia, 2013). Based on these findings, in chemistry secondary education, a relation between three variables: using PLAs, the knowledge quality and the knowledge retention can be hypothesized, however, this relation has not been investigated.

## RESEARCH AIM AND RESEARCH QUESTIONS

The purpose of this study is to investigate the use of PLAs in the Croatian secondary chemistry education, and determine their effect on students' achievements. The first part of the study aims at exploring current real situation in Croatian schools regarding the application of PLAs in chemistry education. The second part's preliminary research questions are the following:

- 1) *How does the use of pre-learning materials in chemistry education affect students' knowledge quality?*
- 2) *How does the use of pre-learning materials in chemistry education affect students' knowledge retention?*
- 3) *Is there a connection between students' attention and quality of the acquired knowledge regarding the use of pre-learning materials?*

## RESEARCH DESIGN AND METHODS

The study is based on the quasi-experimental research design (Campbel & Stanley, 1963). The first part of the study will be carried out through a nationwide questionnaire on a sample of 200 chemistry teachers of Croatian secondary schools. The second and main part will comprise three secondary schools from various regions in the country with a non-random convenient sample of 200 fourth-grade students (18-19 years) divided into a treatment and control group.

This study will use an explanatory sequential mixed methods design in which quantitative data collection and analysis will be supplemented by qualitative data collection and analysis (Creswell, 2013). By qualitative data collection (semi-structured interviews with teachers and questionnaires for students of the treatment group), an attempt will be made to obtain additional information on preparing an analysis of higher quality, and accommodating the obtained results of all tests into a wider context.

For the first part of the study, the instrument will be validated in a pilot study (March, 2017) in order to control the questionnaire quality and gather data for its optimization. The main research for the first part will be conducted May – July 2017. Learning environments for both examined groups are designed on processing the same chemistry subject matter with the *traditional* teaching method according to the same lecture design. Teachers with approximately the same teaching experience, who achieve optimal educational results in their work, will participate in the study. The compared groups will be in different schools so the students and teachers of the control group could not have the access to the pre-lecture material.

The influence of PLAs application will be determined with three tests of knowledge. One week before the application of pre-lecture materials, all students will take a pre-test to equal the pre-knowledge of students in the treatment and control group. Simultaneously with the pre-test, the students will take a D2 Test of Attention with a psychologist. Class intervention is planned through six



chemistry lessons (January – February 2018). The materials will be available online to students of the treatment group by Edmodo (LMS software) in the days after their previous lecture and before the subsequent one. The time students spend completing PLAs will not extend much beyond 15 minutes. The lecture itself will build on the key terms introduced in the pre-lecture material, and at the beginning of the lecture, the students will discuss what they were asked to review (Seery, 2010).

Novel pre-learning materials will be developed based on the Cognitive Theory of Multimedia Learning principles (Mayer, 2002), *previous research findings*, results from the first part of the study, personal experience researches, and in accordance with anticipated learning outcomes of the Croatian chemistry curriculum. A pilot study will test the suitability of pre-lecture materials, as well as the *validity* and reliability of measurement *instruments*. At the end of class intervention, the students in both groups will take a post-test, equal to the pre-test. Five weeks later, the students of both groups will take a retention test, which will assess students' capability to recall knowledge.

The analysis of the collected quantity data will be carried out with SPSS program package. Test reliability will be determined with Cronbach's alpha coefficient (after pilot study). Statistical difference between the average test of knowledge results for students of both groups will be determined with the independent samples t-test and the effect size Cohenov d. In addition, statistical difference between average results of different tests of knowledge within each group will be determined with the dependent samples t-test. Students' answers to the questionnaire items, as well as connections between the students' attention and results in tests of knowledge will be analysed with Pearson's correlation coefficient (for interval variables), i.e. with Spearman's correlation coefficient (for ordinary variables).

## PRELIMINARY FINDINGS

At the summer school, the results of the pilot study from the first part of the study will be available as a basis for discussion.

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## **SESSION D: EDUCATIONAL TECHNOLOGY**

# **BUILDING OF INTERPERSONAL COMMUNICATION SKILLS OF NEW GENERATION STUDENTS EMPLOYING RESPONSIBLE RESEARCH AND INNOVATION**

**Audrius Ivanauskas**

Lithuanian University of Education Sciences, Lithuania

## **AN OUTLINE OF THE STUDY**

The rapid development of information and communication technologies and changing economic, social and political conditions have resulted in transformations in education as well. Traditional teaching that focuses purely on knowledge transmission and reception has already lost its significance preparing an individual for unknown future activities. Memorising of knowledge is not emphasised any more (Čiūžas, 2013). The significance of the virtual space in the process of education has been increasing. The virtual space for of the new generation learners is becoming the world they are living in (Targamadžė, Girdzijauskienė et al., 2015). Lithuanian higher education schools are changing forms and methods of specialist training. Information technologies have been making their way to the process of education on a larger and larger scale. The teaching methods are also undergoing changes (Bankauskienė, Masaitytė, 2015).

The relevance of this work is predetermined by the fact that few authors reveal a pedagogical and psychological characteristics of the new (Z) generation school learners, disclose peculiarities of their interpersonal communication and highlight the role of virtual environments in communication of new generation learners (Targamadžė, Girdzijauskienė et al., 2015). The peculiarities of interpersonal communication of the new generation school learners in Lithuania have not been exhaustively investigated in Lithuania. Lithuanian authors have concentrated on the following aspects: S. Mikulionienė (2012) focuses on the problems of the dialogue of generations, P. Pečiuliauskienė, I. Valantinaitė, V. Malonaitienė (2013) discuss didactic aspects, V. Petrikaitė (2012) concentrates on personal features, J. Čeikytė, M. Petraitė (2014) emphasise the importance of responsible innovations. The lack of research studies on new generation learners' interpersonal communication competence in the process of education, which would reveal emotional areas of new generation school students, components that promote collaboration, abilities of initiation of interpersonal relations, maintenance of personal position, conflict management, provision of emotional support, is clearly felt.

The aim of the work is to identify peculiarities of improvement of interpersonal peculiarities of the new generation school learners using RRI.

## **REVIEW OF RELEVANT LITERATURE**

Changing society results in changes in the systems of values and emergence of new generations. Generation gaps are preconditioned by different value systems of separate generations (Howe, Strauss, 1991). In the second decade of the 21<sup>st</sup> century, the Z generation learners attend schools of general education, whereas the Z generation is referred to as the generation of technology (Cross-Bystrom, 2010). The children born from 1995 to 2012 are assigned to the Z generation (McClindle, Wollinger,

2010). The children of the new generation grew using internet before they were able to speak. The mobile phone replaced toys for them. The Z generation means technologies (Cross- Bystrom, 2010). The children of digital generation are creators, aggressive, both victims of bullying and torturers themselves. Therefore, educators have to assist them in development of their system of values (Targamadzė, Girdzijauskienė et al., 2015). The growth rates of the 21<sup>st</sup> c. generation are rapid. According to A. Tulgan (2013), the pace of growth of the new generation greatly overpasses the growth of the previous generations. Learning, information search as well as communication substantially differ from those of the previous generations. The school learners choose search systems rather than a library. The new generation school children get access to extensive knowledge on internet. Acquisition of knowledge is different compared to other generations. J. Palfrey, U. Gasser (2011) point out that the research studies, which would confirm or deny the efficiency of knowledge acquisition of digital generation compared to other generations, are scarce.

The importance of communication is unquestionable in today's world. It is one of the necessary conditions for individual's existence and improvement. According to A. Maslow, the need to communicate is ranked third in the hierarchy of needs (after physiological and safety needs).

Communication is defined in a hundred ways and represented by over two hundred communication theories. This shows that understanding of communication differs.

After their research, D. Burmester, W. Furman, M. T. Wittenberg, H. T. Reis (2008) offered a model of interpersonal communication, which consists of three components: behaviour, emotional and cognitive domains.

The first study on advantages and disadvantages of communication in social networks was conducted by R. Kraut, M. Patterson, V. Lundmark, S. Kiesler, T. Mukophadhyay, W. Scheri (1998). It aimed to identify social involvement and psychological well-being on internet.

The concept of responsible innovations was investigated by the authors T. Helstrom (2003), R. Owen (2009), K. Pandza, P. Ellwood (2013), B.C. Sthal (2013), B.C. Stahl, N. McBride et al. (2013), who focused on research on innovations. The research on responsible innovations is needed and developed in the European Union. The European Commission initiates scientific research, prepare guidelines and draft legal documents on issues of responsible investment (Hellstrom, 2003; Owen, Stilgoe et al., 2013; Pavie, Carthy, 2013). The biggest efforts are concentrated on evaluation of the influence of innovations with regard to social, economic, ecological and ethnic dimensions (Stahl, 2013). Some researchers define responsible innovations as a cultural and undefined phenomenon (Owen, Stilgoe et al., 2013; Pandza, Ellwood, 2013; Pavie, Egal, 2012). Other researchers approach them as a systemic management process, which is applied creating innovations (Stahl, 2013; Stilgoje, Owen et al., 2013).

The understanding of responsible innovations is related to principles and criteria of decision-making about innovation development in business environment. They also embrace management of decision-making processes related to innovative applied research. B. C. Sthalt, N. McBride et al. (2013) point out that responsible innovations refer to the process, whereof result (innovation) has to be a positive criterion of all the (social, economic, ecological and ethnic) dimensions to achieve an efficient

and positive progress. J. A. Schumpeter (1998) points out that the word “responsible” is time-consuming and “innovation” refers to the progress, rapidity and growth.

The research by J. Bessant (2013), Pavie X., Egal J. (2012), Pavie X., Scholten V., Carthy D. (2014) shows that organisations, which apply conception of responsible innovations, tend to achieve more stable and long-lasting successful results.

According to D.I.T. Hegerr, G. Spaargaren (2011), involvement of society in development of innovations leads to new business insights and better decisions predetermining success in case of commercialisation.

R. Owen, J. Stilgoe et al. (2013) conducted research on the criteria of responsible innovation dimensions. They distinguished the principles of anticipation, reflexivity, and inclusion and their application creates an aggregate of necessary processes, which guarantee targeted and responsible development of innovations.

## RESEARCH QUESTIONS

The **aim** of the research is to identify peculiarities of improvement of interpersonal peculiarities of the new generation school learners using RRI.

The following **objectives** were formulated to attain the abovementioned aim: to compare the differences in the averages of interpersonal communication skills of the new generation school learners applying socially significant scientific innovations according to the gender (1). To identify peculiarities of interpersonal communication skills of the new generation school learners (2). To reveal influence of socially significant scientific innovations on school learners’ communication (3). To reveal influence of socially significant scientific innovations (innovative methods) on dynamics of school learners communication skills over a year (4). The **object** of the research: communication skills of the new generation school learners, innovative methods.

The theoretical part of the work presents an overview of scholarly literature, which analyses peculiarities of the new generation learners, didactic principles of teaching new generation, communication competency, responsible innovations, peculiarities of interpersonal communication skills of new generation applying socially significant scientific innovations. The empirical part determines the object of the research, the aim and objectives of the research, statistical analysis of results.

## RESEARCH DESIGN AND METHODS

The quantitative research will be conducted using the research methodology (The Interpersonal Competence Questionnaire (ICQ)) (Buhrmester, Furman, et al., 1988), which aims to establish initiation, negative assertion, disclosure, emotional support and conflict management.

On experimental basis attempts will be made to identify the changes in communication skills of 7<sup>th</sup>-8<sup>th</sup> formers employing RRI (Responsible Research and Innovations).

In the beginning the questionnaire for establishment of school learners’ interpersonal competence will be distributed. Then during lessons of biology responsible scientific research and innovations will be applied for a year (following the Engage Project: [www.engagingscience.eu](http://www.engagingscience.eu)). The project aims to train teachers using the Program. A big number of teachers have already been trained to

work according to it in Lithuania. Having agreed with teachers that they are going to work with their learners following the abovementioned specifics, the learners will be given the questions without one correct answer (dilemma questions) while introducing a new topic: e.g. Mosquitoes are the world's most dangerous killer. The diseases they transmit, malaria, Zika and dengue fever, cause more than a million deaths per year. Some scientists have suggested exterminate all dangerous mosquito species. One method is to release genetically modified (GM) male mosquitoes which prevent further breeding. In this project, students investigate whether exterminating mosquitoes is a good idea, using scientific knowledge about interdependence". This is one of the example topics, which will be given to learners by the teacher. During lessons school learners will discuss, collect information in libraries, communicate with researchers (who will be invited), then they will discuss the topic with their peers and teachers. The conducted work will be generalised in the last stage.

Thus, school learners, teachers and researchers will work according to this model. At the end of the year, the questionnaires on identification of interpersonal competency will be distributed again. The aim will be to identify changes in children's communication skills after a year and whether the use of the method RRI (dilemma) has influence on children's communication skills.

## PRELIMINARY FINDINGS

The theoretical part has not been finished yet. The empirical part is planned to be started in September 2017.

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## **SESSION E: ENVIRONMENTAL EDUCATION**

# THE IMPLEMENTATION AND EFFECTIVENESS OF WHOLE SCHOOL ESD IN SWEDEN

Daniel Olsson

Karlstad University, Department of Environmental and Life Sciences, Sweden

## THE FOCUS OF THE STUDY

Perhaps the most important issue in our times is how to sustain our planet's resources, while increasing the welfare of a growing population. This monumental task has been defined in the concept of sustainable development (SD). In response, Education for Sustainable Development (ESD) has been launched as a teaching approach to solve this dilemma (UNESCO, 2006). The underlying idea is that ESD should foster young people into knowledgeable, reflecting, critical and active citizens who will make rational decisions, thus, in the long run, transforming the world into a more sustainable place (Lotz-Sitiska, Wals, Kronlid, & McGarry, 2015).

ESD has been adopted globally as a consequence of the UN Decade for Education for Sustainable Development 2005-2014, which has reshaped curricula worldwide. In the years to come, it is suggested that the Global Action Programme (GAP) on ESD will generate and scale-up concrete actions implementing ESD globally and locally thorough so-called *whole school approaches*, which implies that all levels of the school organization should be included in the process implementing ESD in educational practices (UNESCO, 2014). However, empirical studies are a missing link in the discourse around ESD, where decisions and implementation strategies are heavily based on policy recommendations and practitioners' gut feelings (Scott, 2013). The focus of this study is therefore to longitudinally research implementation of a whole school ESD, as suggested in the GAP, with focus on how students are informed, empowered, and motivated to act. The study will be a part of larger longitudinal research project, where teachers will be guided in the development process by a TPD-program on the implementation of a whole school approach on ESD.

## LITERATURE REVIEW

ESD is defined as consisting of two essential features: a holistic view of the subject content taught, and a pluralistic view of the teaching methods used (Hopkins, 2012). Boeve-de Pauw, Gericke, Olsson & Berglund (2015) refer to these two major aspects of ESD as *holism* and *pluralism*. Holism concerns the multiple perspectives on content based on the idea that environmental problems cannot be solved in isolation; instead solutions to such problems need to be made in accordance with economic and social needs together with the perspectives of the local-global and the past-present-future. As a consequence, interdisciplinary is crucial in ESD education for students to understand the complexity of sustainability issues (Vare & Scott, 2007). The pluralistic approach of ESD deals with the process of teaching and learning that focuses on the development of skills and action competence for sustainability (Mogensen & Schnack, 2010). This pedagogy has been labeled pluralism (Rudsberg & Öhman, 2010) and is characterized by an ambition to acknowledge and engage multiple perspectives and values when dealing with SD. Thus, instead of teaching the "right" answers ESD focuses on learner-centered teaching

strategies such as critical thinking, participatory decision-making, value-based learning, and multi-method approaches (Lijmbach et al., 2002).

Often the effects of educational practices in the field of ESD are studies in terms of changes in the students' environmental learning outcomes (such as knowledges, attitudes, behavioral intents etc.). Within our research group we have developed and operationalized the concept of sustainability consciousness (SC) to extend previous environmental education research and to establish a more holistic approach towards SD, (e.g. Olsson, Gericke and Chang Rundgren, 2016). The concept of SC links the action competence process in ESD with the SD content. The development of students' SC can therefore be assumed to reflect the development of students' action competence regarding sustainability issues (Olsson, Gericke & Chang Rundgren, 2016).

In several large-scale studies in Sweden, the student outcomes were investigated in terms of their SC and their experiences of ESD teaching (e.g. Boeve de-Pauw, Gericke, Olsson & Berglund, 2015; Olsson, Gericke & Chang Rundgren, 2016; Olsson & Gericke, 2016). Students in schools participating in ESD-certification programmes were compared with students in reference schools. The main finding of these Swedish studies was that ESD-certified schools had none or only small effects on students' SC in grade 6 and 12, and even negative effects in grade 9 (Berglund, Gericke & Chang Rundgren, 2014; Olsson et al., 2016). Furthermore, the students in grade 6 and 9 at ESD-certified schools did not experience more holistic or pluralistic teaching approaches, while the students in grade 12 did (Boeve de-Pauw et al., 2015). These results are somewhat disappointing since it shows that the efforts of the past decade to implement ESD in the Swedish school system seem to have failed to provide much of the changes urged for in the UN Decade. However, when comparing student outcomes (their SC) with their experiences of ESD teaching (holism and pluralism), regardless of whether their schools have ESD-certifications, it was found that when pluralism and holism are included in teaching, a higher sustainability consciousness among students is found (Boeve de-Pauw et al., 2015). Thus, it can be empirically concluded that ESD can be effective. However, the problem is that ESD-certified schools (and schools in general) do not necessarily practice these approaches.

Therefore, in the current experimental study the focus will be to create a longitudinal school development research project based on the framework of Desimone (2009) (see the section research design and methods) in how to reach the goals of the GAP. This will be done by adjusting an ESD school development project in a Swedish municipality to the findings of ESD research described above.

## **AIM OF THE CURRENT STUDY**

The aim of this study is to contribute a novel research approach in the field of ESD since the vast bulk of interventions previously suggested are based on theoretical standpoints rather than empirical evidence. The study will be a part of larger longitudinal research project on the implementation of whole schools approaches on ESD, where all actors of a school (students, teachers and school leaders) should work together towards a common goal (UNESCO, 2014). However, this current study will focus on whether a whole school approach implementation program (can) contribute to effects on students' SC.

Furthermore, the study will also investigate if and in what ways students develop their experiences of ESD teaching and their self-perceived action competence by centering on the following questions:

- 1) *What is the effect of the ESD implementation process on students' sustainability consciousness?*
- 2) *In what ways do students' experiences of ESD-teaching (holism and pluralism) develop during the ESD implementation process at their school.*
- 3) *In what ways do students' self-perceived action competence towards SD develop during the ESD implementation process at their school.*

## RESEARCH DESIGN AND METHODS

Desimone (2009) has developed a research framework for studying the effectiveness of teacher professional development (TPD)-programmes. According to Desimone, the research should investigate (I) teacher outcomes, (II) change in teacher instruction, (III) student outcomes and (IV) the school context outside the classroom including leadership, organization etc. In the larger research project, which this study is a part of, the intention is to follow Desimone's (2009) research framework for developing and investigating the implementation process and effectiveness of the whole school approach on ESD. A TPD-programme will be designed in collaboration with a Swedish municipality to support schools in the ESD implementation process. However, for this current study specifically, the focus will be on the student outcomes (III above) in terms of their SC, how they experience the teaching due to changes in teachers' teaching practices throughout the ESD TPD-programme, and in what ways they develop their self-perceived action competence towards ESD.

Student outcomes (from grade 6-12) will be studied by collecting survey data using instruments covering students' SC, their experiences of holism and pluralism and self-perceived action competence (Olsson et al., 2016; Boeve-de Pauw et al., 2015). The first baseline data will be collected in the spring 2017 followed by data collections in the autumn 2017, 2018 and in the late spring 2019. Data will be analyzed using structural equation modelling (SEM)) growth analysis and the software Mplus. The descriptive statistics (means and standard deviations) will be analyzed using the software SPSS. The results of the student outcomes will be discussed in the light of the TPD-design.

## PRELIMINARY FINDINGS

At this stage there is not possible to present findings from the study. However, by the time of the ESERA summer school it should be possible to present some early descriptive findings from the baseline data collected in the spring 2017. So far, the present study is limited to longitudinal, quantitative data. There is also a possibility to collect longitudinal qualitative data within the larger research project. The participants and coaches at the summer school could contribute important input and discussions regarding the research design, methodology and analyze methods, but also on how to combine the statistical approach of the present study with more qualitative data to develop the research further.

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# INVESTIGATING THE GAP BETWEEN TEACHERS' BELIEFS AND PRACTICES IN EDUCATION FOR SUSTAINABLE DEVELOPMENT TEACHING

Eleni Sinakou

University of Antwerp, Department of Training and Education Sciences, Belgium

## INTRODUCTION

Although an abundance of ESD initiatives have been applied at classroom during The United Nations Decade for ESD (DESD, 2005-2014) (Lambrechts & Hindson, 2016), their effectiveness has not been examined enough. Teachers' teaching practices are influenced by their beliefs (Cotton, 2006; Grace & Sharp, 2000). From this perspective, this thesis investigates elementary Flemish teachers' beliefs about ESD effective teaching as well as their self-reported practices in ESD teaching. It also focuses on factors that enable or hinder the enactment of teachers' beliefs about ESD effective teaching in practice. The aim of the thesis is to support teachers in ESD teaching, since their role is of high importance for the successful implementation of ESD (UNESCO, 2014).

## THEORETICAL BACKGROUND

The role of ESD is to equip students with sustainability competences through a holistic understanding of the SD issues and by applying pluralistic teaching methods (Boeve-de Pauw, Gericke, Olsson & Berglund, 2015; Walshe, 2016). ESD should teach students to take part in decision-making processes related to SD issues now and in the future through social learning experiences (Wals, 2011). Teaching programmes adopting a holistic approach of ESD deal with the implications of SD issues within the three dimensions regarding conflicting interests (Berglund, Gericke & Chang Rundgren, 2014). In this way, students conceive SD issues in an integrate way (Berglund et al, 2014). Also, students should examine SD issues from many different perspectives in order to be able to address the complex SD issues (Boeve-de Pauw et al, 2015). Such a pluralistic ESD approach allows students to actively take part in societal debate, and thus, it leaves room for action and autonomous thinking (e.g. Jickling and Wals 2008; Öhman and Öhman 2013). Boeve-de Pauw and Van Petegem (2011) found that teachers in eco-schools in Flanders accomplish SD activities but they do not apply a pluralistic EE approach.

Teachers' beliefs and perceived competencies have been found to be important predictors of teachers' practices in the context of environmental education (Zint & Peyton, 2001; Hsu & Roth, 1999; Plevyak et al., 2001; Forbes & Zint, 2010). Therefore, when studying teachers' classroom practices at elementary school, it is important to study first their beliefs (Forbes & Zint, 2010). Research in Environmental Education (EE) shows that although teachers support the implementation of effective EE practices at school, they do not apply their ideals in practice (Tan & Pedretti, 2010; Pedretti & Nazir, 2014; Forbes & Zint, 2010). It is not surprising that there is a gap between what teachers believe and what they do in practice (Korthagen, Kessels, Koster, Lagerwerf & Wubbels, 2001). This is because elementary teachers face challenges when trying to put their beliefs about effective EE practices into practice (e.g. Tan & Pedretti, 2010; Pedretti & Nazir, 2014; Forbes & Zint, 2010). In order for elementary

teachers to be better supported to cope with the everyday challenges at school, ESER should learn more about their beliefs, self-efficacy beliefs and self-reported teaching practices in EE (Forbes & Zint, 2010).

While ESD is being applied in formal education, empirical research on its effects and effectiveness are scarce (Boeve-de Pauw et al., 2015). The above research refers to teachers' beliefs and practices from a EE perspective rather from an ESD perspective. To our best knowledge, no research has previously been done in the field of ESD. EE and ESD are distinct but complementary (McKeown & Hopkins, 2003). EE focuses more on environmental protection, whereas ESD takes into consideration both economic and human development related to environmental protection (McKeown and Hopkins 2003).

## PURPOSE, AIM AND RESEARCH QUESTIONS

The purpose of this thesis is to explore teachers' beliefs and practices regarding ESD teaching and the gap between them, if any. The thesis aims at finding potential barriers and facilitators, which teachers face, regarding the implementation of an effective ESD approach. The research questions are the following:

- 1) What are teachers' beliefs about ESD effective practices?
- 2) *What their actual practices during ESD teaching?*
- 3) *Is there any gap between their beliefs about ESD effective practices and their own practices?*
- 4) *What are the barriers that explain this gap?*
- 5) *What are the facilitators which support teachers in applying effective ESD teaching practices?*

## METHODOLOGY

### *Data collection*

This study employs a mixed methodology approach (Creswell & Plano Clark, 2007). The first two studies examine academics' and teachers' SD conceptions, respectively. The first study, which is already conducted, is a survey which explores SD conceptions of academics' in the field of ESD worldwide. The aim of the study was to determine the degree up to which academics in the field of ESD hold a holistic view of the SD concept. The instrument consists of 16 statements and each statement focuses on different aspects of the SD concept in terms of the three dimensions (environment, society & economy). Based on the implementation of the Bradley-Terry-Luce statistical model, a rank order which presents the statements from the least chosen to most chosen ones, have been generated (Lesterhuis, Verhavert, Coertjens, Donche & De Maeyer, 2016). The purpose of this study is to develop a basis so as to make it possible to assess teachers' SD conceptions. This is necessary, since there is no consensus in the field on the definition of the SD concept.

What it will follow is a second survey to investigate teachers' SD conceptions in Flanders, Belgium in terms of the three dimensions of the SD concept. Based, again, on the implementation of the Bradley-Terry-Luce statistical model, a rank order will present the statements from the least chosen to most chosen ones (Lesterhuis, Verhavert, Coertjens, Donche & De Maeyer, 2016). The third study is also a survey which explores (a) teachers' beliefs about effective ESD teaching and (b) their self-reported practices in ESD teaching based on whether teachers believe that developing students' holistic

understanding of SD and pluralistic thinking with regards to SD issues, and action competence with regards to SD issues. This study will also examine internal (within the teacher) and external (residing in the environment) factors according to teachers' views. For this study, Cronbach's  $\alpha$  will be estimated and confirmatory factor analysis as well as structural equation modelling will be applied. This study will reveal if there is a gap between teachers' beliefs and practices as well as factors that influence positively or negatively the enactment of teachers' beliefs. The instruments of the two surveys with teachers will be pilot tested with 4-5 teachers each via the process of cognitive interviews to ensure the content validity of the instruments. The fourth study examines in-depth teachers' views on barriers and facilitators through individual interviews. For the fifth study of the thesis, I will organise 4-5 focus groups with the teachers to find out their own views on solutions regarding the barriers revealed in the individual interviews. Both the interviews and the focus groups will be pilot-tested with 3-4 individual and one focus group, respectively. The interviews will be analysed in terms of their content related to barriers and facilitators and the focus group related to teachers' view for solutions. Pilot testing interviews and focus groups.

### *Participants*

For the first study, I have considered the participants based on two criteria. They (a) mainly do research in the field of education for sustainable development/ education for sustainability or ESD/EfS is one of their research interests; and (b) hold an academic position at a higher education institution for educational sciences (e.g. Department of Educational Sciences) worldwide.

As for the rest of the studies, the sample will consist of teachers in primary schools in Flanders, Belgium. For both surveys, 3-4 teachers interested in ESD from 100 elementary schools in Flanders, randomly selected, will be invited to take part in. The teachers who show a large or no gap between their beliefs and practices in ESD teaching, as this revealed by the second and third survey, will be invited for an interview. 10 teachers will be invite in each case. As for the focus group, I will consider the teachers who will have taken part in the individual interviews and their colleagues at school. For each focus groups, 8-10 teachers will be invited to participate.

### **PRELIMINARY FINDINGS**

The first study has already been conducted. The rank order of the statement from the least to the most chosen ones allowed us to identify the most emphasized aspects of the SD concept. The findings of the first study show that academics in the field of ESD worldwide do not hold a holistic view of the SD concept. There is a tendency towards social and economic aspects of SD. The second study will reveal whether this is the case also for teachers in Flanders. As literature show (e.g. Stevenson, 2006), teachers understanding of the SD concept is a factor that influences ESD teaching.



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## ACKNOWLEDGEMENT

This study is supported by a grant from the Alexander S. Onassis Public Benefit Foundation, Greece awarded to Eleni Sinakou.

## **SESSION G: CULTURAL, SOCIAL, AND GENDER ISSUES**

# ANALYSIS OF INTERACTIONS IN A MULTILINGUAL SCIENCE CLASSROOM IN LUXEMBOURG

**Anna Gorges**

University of Luxembourg, Luxembourg

## FOCUS OF STUDY

The focus of my PhD research examines how students in a multilingual classroom construct meaning in dialogue with each other to reach a common or mutual understanding about notions of sustainability (Vygotsky, 1978), in order to better understand the practices of teaching and learning science in Luxembourg's multilingual schools. Specifically, I am exploring how students' authentic ways of expressing their understanding can be used as a resource for the construction of meaning in the science class.

These 'authentic ways of expressing understanding', or *modes*, which are "socially shaped and culturally given resources for making meaning" (Kress, 2009a, p. 54), include both verbal and non-verbal means of communication. The verbal means of expression in a multilingual context include the students' unique set of lexical features, grammatical features and individual ways of pronunciation, or the students' idiolect (Otheguy, García & Reid, 2015), which is shaped by features from multiple national languages and changes according to the context (e.g. formal vs. informal, English vs. French etc.). The non-verbal means of expression include gestures, body movement, texts, pictures and many more. All of these modes express different meanings (Kress, 2001), which is why I am analysing the interplay of all these modes together, in order to better understand students' meaning making process.

My research is situated in Luxembourg, a small country in the heart of Europe bordering on Germany, France and Belgium. Luxembourg has the highest immigration rate in Europe with 46.7 %. On top of that, every day 167.000 border workers from the neighbouring countries commute to Luxembourg for work (Statec, 2015). As a result, Luxembourg's society is highly multilingual as well as multicultural, which is reflected in the students in our classrooms. The three state languages, Luxembourgish, German and French, are successively used as language of instruction at school, starting in kindergarten with Luxembourgish. In primary school, students are alphabetized in German, which is also used as language of instruction. French is introduced in second grade and used as language of instruction in secondary school in an increasing number of subjects, also in those subjects, which were formerly instructed in German. Despite this highly multilingual society, instruction in the multilingual schools remains strictly monolingual. Consequently, students are only allowed to use parts of their idiolect to make meaning, e.g. only the formal features appropriate in the institution school and only those formal features that belong to the 'right' national language according to school policies, which is not meaningful to them and restricts them in their meaning making, when exchanging ideas with others. Furthermore, assessment in Luxembourg is focused on the written and spoken language(s) alone (MENJE, 2015). However, especially multilingual students with other home languages than the ones required at school draw on a variety of resources to express their science understanding, which are not being honoured due to the

linguistic policies of the school. These restrictions for students to express their understandings play an important part in contributing to the high dropout rates in our country of 11.6% in 2012/13 (Luxemburger Wort, 2015).

For my research, I collected data in a multilingual alternative high school in Luxembourg city (Luxembourg's capital), where students at the age of 18 to 30, who failed in the traditional school system, have the chance to attain a school leaving certificate. This school employs a resource-rich approach to learning and by that, supporting not only students' use of their full linguistic repertoire for the co-construction of knowledge, but also apply multimodal ways of assessing students (Kress, 2009b).

## LITERATURE REVIEW

Grounded in socio-cultural theories of learning (Tobin & Roth, 2006), I understand the learning process as a dialogic and highly contextualized process, which is why I am looking at plurilingual students' meaning making through the lense of Ofelia García's concept of *translanguaging* (2009) – a common practice of students in their everyday lives in Luxembourg. Translanguaging represents students' authentic ways of making use of their full linguistic repertoire, which means of all the language experiences they have made during their life trajectories. The term hereby "refers not simply to a shift or a shuttle between two [or more] languages, but to the speakers' construction and use of original and complex interrelated discursive practices that cannot be easily assigned to one or another traditional definition of language, but that make up the speakers' complete language repertoire" (García & Wei, 2014, p. 22). But the concept does not only focus on the verbal means of communication alone. It includes all "the different ways multilingual speakers employ, create and interpret different kinds of linguistic signs to communicate across contexts and participants" and thus, views spoken and written 'languaging' in different national languages only as a part of a much wider repertoire of resources for meaning making (García & Wei, 2014, pp. 28-29). As Kress stresses, language is only one mode amongst many that are all capable of creating distinct, full meanings in themselves and at the same time, none of them is able to express all meanings alone (Kress, 2009a).

## RESEARCH QUESTIONS

Through my research, I hope to draw a detailed picture of using research rich approaches in science education. The specific research questions I explore include:

- 1) *Which resources are available to students and teachers when engaging in science learning?*
- 2) *How are these resources employed?*
- 3) *How do these resources support students' exploration of science concepts?*

My goal is to reveal what students learn from exchanging about science in small-group situations, with the intention of developing a framework for science classroom methods to be tested in future research and considered by Luxembourgish teachers.

## RESEARCH DESIGN AND METHODS

Conducting a video-based ethnographic study, I accompanied a class of 12 students in a project about sustainability on eight three-hours-sessions over the period of one month. In the project, the students were first introduced to the concept of sustainability and then had the time to exchange and conduct research about a topic which they were supposed to present with a poster at a 'mini-research-colloquium', organized for all the classes involved in the project. I collected the individual voices of each student with individual audio recorders, three cameras captured the three group tables the students were working on (24 h of video), I conducted informal interviews with the students and the classroom teacher, I took field notes, collected student artefacts and asked the students to draw language identity self-portraits (Prasad, 2014). In my role as co-teacher of the project, co-planned the lessons with the teacher, taught parts of the lessons and supported students with language and content questions. With the data of 5 focus students being transcribed, I am now conducting a case study examining the ways one student uses her full multimodal repertoire to ensure understanding in a group of five plurilingual students through the lenses of multimodal discourse analysis (Kress, 2001) and sociocultural perspectives (Tobin & Roth, 2006).

## PRELIMINARY FINDINGS

Sandra is one student in the class I have collected my data in. Her linguistic repertoire contains features from seven different languages. In a safe space, created by the classroom teacher, Sandra, as expert of her topic, shares the findings of her internet research with her peers. This safe space enables Sandra to make use of her full linguistic as well as semiotic repertoire. While presenting her work, she orchestrates all the resources she has in order to transmit her messages as fully and as clearly as possible. She uses both, her linguistic repertoire and her semiotic repertoire to structure the conversation and facilitate understanding between the plurilingual members of the small group. In that way, Sandra is able to initiate a discussion in her group, which helps her to test her ideas about her own topic, adapt the same during the interaction and thus, create new meaning and broaden her understanding about sustainability. This means that, if given the opportunity, students draw on their full linguistic as well as semiotic repertoire in order to more fully represent their conceptual understanding in their exchange with others and to move towards a more scientific understanding.

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# **SUBJECT CHOICE IN SECONDARY SCHOOLING: A COMPARATIVE STUDY OF THE FACTORS IMPACTING SUBJECT CHOICE IN POST-COMPULSORY EDUCATION FOR PHYSICS AND MODERN FOREIGN LANGUAGES IN ENGLAND**

**Sandra Takei**

King's College London, United Kingdom

## **BACKGROUND**

Recently in England there has been concern over the decline in uptake of certain 'difficult' subjects including sciences, mathematics and languages during post-compulsory education (Bell et al. 2005). This can be placed within the wider concern that participation in STEM careers, particularly physical science and engineering, is especially low for women, students from lower socio-economic backgrounds and certain ethnic minority groups. However, while there has been considerable resources invested in understanding the underlying causes of declining participation in STEM subjects there has been relatively little research in other problem subjects such as modern foreign languages (MFL).

This project aims to address a gap in knowledge by comparing the major factors influencing subject choice in post-compulsory education for physics and modern foreign languages. This study will take place in England where most students are entered for national General Certificate of Secondary Education (GCSE) examinations by the end of compulsory schooling at age 16 in at least ten subjects including the required core subjects: mathematics, English and science. Learning a foreign language was compulsory between the ages of 11 and 16 until 2004 but while state-maintained secondary schools must currently offer at least one foreign language option it is not a requirement for all students (DfE 2014). In post-compulsory education (or post-16), students may specialise in up to four subjects including a wide array of academic and vocational options, the most common of which are the academic 'A Level' exams. Both physics and modern foreign languages are considered to be 'difficult subjects' and have been reported as the subjects with the highest level of grade severity at both GCSE and A Level (Fitz-Gibbon & Vincent 1994). Since the late-1990s A Level entries in modern foreign languages have continued to decline each year from 39,554 students or 6.4% of total A Level entries in 1996 to 27,732 students or 3.7% in 2015 (Long & Bolton 2016). In addition, disparities in performance between boys and girls have been reported to be significantly greater in modern languages than in other areas of the curriculum (Clark & Trafford 1996; Davies 2004) and girls are more likely than boys to study modern foreign languages at both GCSE and A Level (Vidal Rodeiro 2007; Gill 2014). A comparative study of the factors shaping student A Level subject choice in both physics and MFL would allow me to explore whether findings relating to students' attitudes and subject choice in science are subject specific or reflect broader trends across all subjects.

This research will use a sociological lens to investigate how subject choice is shaped both by individual factors relating to learners' identities and structural factors relating to their school, family background and broader social context. In this instance, I am theorising identity from a social

constructionist perspective where identity is understood to be something that is dynamic, not fixed, and produced within and through discourse (e.g. Gee 2000). In other words, identity is not something that you 'have' or 'are' but a fluid process that you are constantly 'doing' through day-to-day interactions. I will also draw upon the work of Foucault (1978) which theorises that identity is structured through relations of power to understand how patterns of inequality can persist in which some subject choices are seen to have value and some do not, or students who choose those subjects some count as 'normal' and some do not such as boys choosing STEM subjects or girls choosing to study modern foreign languages. Through using these theoretical frameworks, I hope to contribute to a better understanding of how certain groups of students may be excluded from particular subjects (or are able to persist despite being excluded).

## RESEARCH QUESTIONS

- 1) *To what extent are the factors shaping student A Level subject choice similar or different for physics and modern foreign languages (MFL)?*
- 2) *How do these factors vary in terms of*
  - *(i) school and teacher factors and*
  - *(ii) interactions of gender, ethnicity and social class?*
- 3) *What role do student and teacher constructions of subject 'difficulty' and student confidence play for each subject area? And how are those variables shaped by interactions with gender, ethnicity, social class and school type?*

## RESEARCH DESIGN AND METHODS

This investigation is interested in comparing the major factors shaping student A Level choice between different subjects. As there is very little work which compares the research findings between subjects, a first step will be to conduct a review of existing literature to identify similarities and differences between the research on participation in STEM and modern foreign languages. A mixed methods approach was selected to explore these research questions to uncover broader trends in subject participation through secondary analysis of existing datasets (e.g. ASPIRES and National Pupil Database) and examine these patterns on a deeper level through primary qualitative data collection including focus groups and one-on-one interviews with students and teachers.

### *Secondary data analysis*

Two existing datasets, ASPIRES and the National Pupil Database (NPD), will be analysed and used to form a foundation for subsequent primary data analysis. ASPIRES is an Economic and Social Research Council (ESRC) funded ten-year longitudinal research project which studies young people's science and career aspirations with a cohort of students who were ages 10 to 11 in 2009. ASPIRES combines quantitative online surveys of a student cohort and repeat (longitudinal) interviews with a selected sub-sample of students and their parents. My study will examine the interview ASPIRES data from the cohort who are currently aged 17-18 (Year 13) choosing to study physics and modern foreign languages, directed by the research questions to identify themes among the reasons expressed by students for



choosing those options. I will also explore the survey data to identify patterns among students choosing physics and modern foreign language subjects by gender, ethnicity, social class and school type.

The National Pupil Database (NPD) is a longitudinal database for all children in schools in England compiled by the Department for Education. The NPD holds pupil and school characteristics such as age, gender, ethnicity, level of deprivation, attendance and exclusion, matched to pupil level attainment data on national assessments and other external examinations. Similar to my analysis of the ASPIRES survey data states above, I will explore how A Level subject choice varies by gender, ethnicity, social class and school type to build on ongoing work at Cambridge Assessment (e.g. Vidal Rodeiro 2007).

### *Primary data collection*

The research sample will include teachers and students in Year 12 (age 16) at 6 different schools including a single-sex girls' school, a single-sex boys' school, a mixed independent school and three mixed state schools. Collecting data at a variety of different schools will help to provide a better understanding of how single-sex and coeducational environments impact student A Level subject choice. The number of schools was selected to provide wide variation in school types while being realistic goal within an average PhD course. Schools will be identified using publicly available data on A Level course offerings and exam results for previous years as well as accessibility given time and travel constraints for the researcher. For example, single-sex girls' schools that have recently demonstrated high uptake of STEM subjects will be recruited for participation as girls are typically underrepresented in STEM subjects. Likewise, single-sex boys' schools that have higher than average uptake of modern foreign languages will be recruited to participate. Mixed independent (fee-paying) and state-maintained schools are included in the sample for comparison to account for differences in the student populations at each school such as socio-economic status and prior attainment.

Data collection methods will include one-on-one interviews with teachers as well as focus groups and one-on-one interviews with students. I will interview physics and modern foreign language teachers each of the schools about their constructions of each subject and of the students who study them. Students in Year 12 will be recruited to participate in focus groups based on their current enrolment in physics, one or more modern foreign language and students who are enrolled in neither physics nor a foreign language. During these focus groups, I will ask students to discuss how they selected their current subjects and what subjects they intend to continue into Year 13. At the end of the year, the research sample will be narrowed down to a few purposefully selected students at each school for in depth one-on-one interviews where I will ask students to elaborate on themes which emerge during focus groups and analysis of secondary datasets in earlier stages of the study. Data collected during focus groups and interviews will be transcribed and analysed using a thematic analysis with NVivo software using themes identified both from the literature and ASPIRES interview data.

### *Timeline for data collection and analysis*

Recruitment for one coeducational state-maintained school to participate in a pilot study began in May 2017 with focus groups and interviews to be completed by the end of the academic year in July 2017. Recruitment for schools to participate in the main portion of the study will begin in summer 2017 with the aim of commencing data collection in autumn 2017.

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## **SESSION H: HISTORY, PHILOSOPHY, AND SOCIOLOGY OF SCIENCE**

# **A SELF-STUDY ON DEVELOPMENT OF STUDENTS IN STEM CAREERS BY ENRICHED APPLICATIONS WITHIN HISTORY OF SCIENCE**

**İsmail Dönmez**

Gazi University, Institute of Educational Sciences, Turkey

## **OUTLINE**

It seems that there has been a shift from science literacy to STEM literacy for the last 10 years (Bybee, 2010; Zollman, 2012). STEM literacy is an approach aiming to give individual, interdisciplinary perspective, knowledge and skills to individual problems (Toulmin and Meghan, 2007) from the individual literacy of science, technology, engineering and mathematics. The involvement of STEM pedagogy in curricula (Gomez and Albrecht, 2013) with a multidisciplinary education will play a key role in meeting future workforce needs and providing job opportunities for STEM members to all segments of the society.

In my research, I would like to use the enriched STEM lesson plans by history of science which I have developed to improve the STEM career awareness of 7th grade students and consider this process via self-study. The aim of this research is to try to understand how I can achieve class practices, as a science teacher, through self-study methodology and discovering myself on this account.

## **LITERATURE REVIEW**

The conceptual framework of the research consists four parts: STEM education, history of science, children's career development model, and pedagogical content knowledge. The common definition of STEM is that an interdisciplinary approach establishing the relationship between academic content and real-world situations in science, technology, engineering and mathematics, including STEM literacy and new economic competitive conditions, including school, community, business and global initiatives (Tsupros et al. 2009). STEM education should support the care of students in the science, technology, mathematics and engineering fields. Educators, businessman, managers and all segments of society need self-educated individuals in these areas (Craig, Thomas, Hou, & Mathur, 2011). Allchin (2011) stated in his work that science can be taught as a instructive history, illustrating the development of concepts throughout history, explaining why and how concepts evolve and highlighting key events in history with the help of the scientists with their discoveries and important achievements. Combining science, technology, engineering and mathematics integration with the history of science within my science course would create role models for students and develop STEM career consciousness. TPAB includes meaningful and high skill knowledge in technology teaching (Mishra and Koehler, 2008).

This study include self-study methodology. I will evaluate the development of my own practice. For this reason the use of pedagogical and technological knowledge as a teacher is essential to the nature of the content area in order to be able to describe my knowledge and beliefs. "Career is the activities, behaviors and related attitudes, values and activities of the individual concerning his / her work" (Bernardin, 2003). Bandura, Lent and Ginzberg show that various researches have been conducted on

the development of individual career plans. Super has developed the first theoretical model based on career maturity for children at the growth stage (1990) and emphasized children's career development needs to be examined. These dimensions; Curiosity, research (exploration), knowledge, key figures, information, control focus, time sense, self-concept and plan. In this study, the model indicated by Super (1990) will be used (Appendix A).

## RESEARCH QUESTIONS

The primary research question is: *How I can describe my classroom practices as a science teacher?* The supporting question helping to answer the primary question is *'How I can use enriched STEM applications via the history of science to improve STEM career awareness of the 7th grade students?* Sub-questions are A) *How can I describe the STEM classroom practices enriched with the history of science in order to improve my understanding of career consciousness in STEM fields?* B) *Will STEM applications enriched with the history of science cause any change in the students' career consciousness?*

## SIGNIFICANCE OF THE STUDY

In the literature, there is no study enriched with the history of science for the formation of career consciousness in STEM fields of middle school students. Although similar researches have been criticized by the teacher himself, it has been shared with the society, rarely (Schulte, 2009). In this context, it is thought that this self-study will bring a different dimension to the teaching of science history in science education.

## RESEARCH DESIGN AND METHODS

Qualitative research method was preferred in this study. The question of why we prefer the qualitative research model answer's is that this method is one of the process of producing information about people's lifestyles, stories, behaviors, social and organizational structures changes. (Strauss and Corbin, 1990). The self-study methodology has a differentiated structure in the world of qualitative research (Manke, 2005; Laboskey, 2004). The self-study is a research involving narrative research from qualitative research designs and is influenced by action research linking research design according to Creswell (2012). It is a qualitative research consisting of self-study, narrative research and action research. Qualitative research requires a description of trends in a research problem or relational explanation between variables (Creswell, 2012). It is a qualitative research consisting of self-study, narrative research and action research. Self-study is a systematic research method that attempts to develop and examine professional classroom practices (Hamilton and Pinnegar, 1998a).

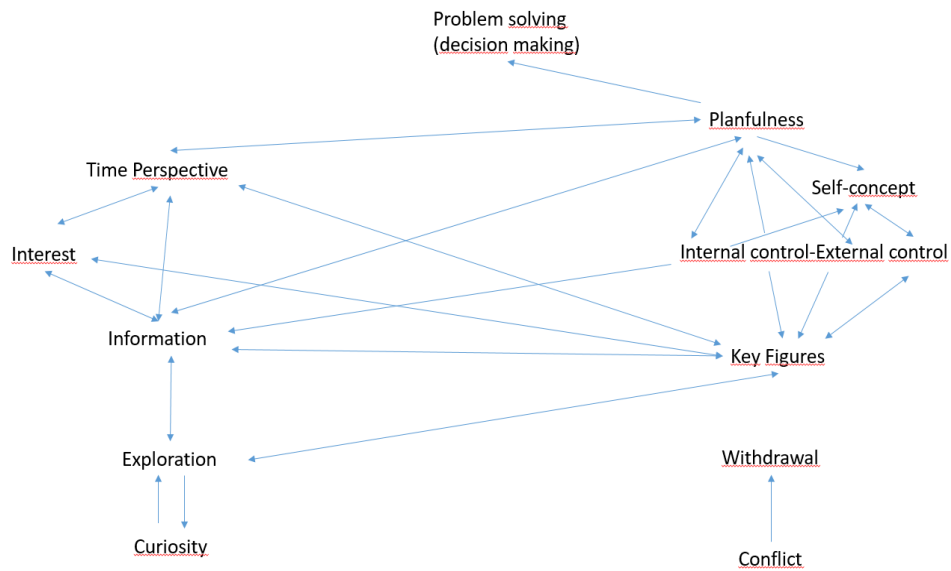
Interview, life story, video recording, diaries, colleagues opinions, STEM activities, vocabulary attachment test and drawings will be used (Appendix B) in my self-study methodology. As Labosky (2004) mentioned the conceptual framework guiding principles my self-study methodology. The validity of the self-study in the qualitative research means the observation as much as possible and as unbiased as possible (Kirk and Miller, 1986). Validity in qualitative research means that the researcher is looking at the phenomenon as much as possible and as unbiased as possible.

In this research, narrative and coding technique will be used to analyze the data (Appendix C). As a narrative method, individuals start to tell their experiences they express with their lives. (Creswell, 2012).

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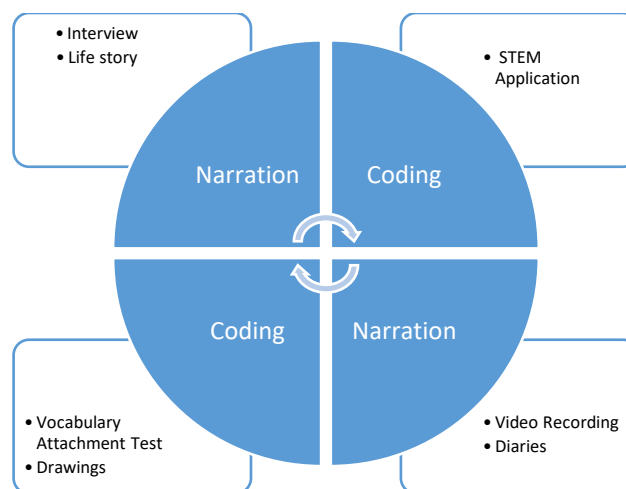
## Appendix A: Super's Child Career Development Model (Watts, Super and Kidd, 1981)



## Appendix B: Research Process And Research Method



## Appendix C: Coding Of Datas



# **HISTORY AND NATURE OF SCIENCE: SCIENCE LESSONS IN MULTICULTURAL CONTEXTS IN THE UK**

**Haira Emanuela Gandolfi**

UCL, Institute of Education, United Kingdom

## **OUTLINE**

In this project, I will reflect on the contributions of History, Philosophy and Sociology of Science (HPSS) to school science, especially to teaching about Nature of Science (NOS) in urban multicultural schools. It is my intention to draw on perspectives from Post-colonial studies of Science to explore how HPSS can inform the development of activities dedicated to the teaching about how science works and its intercultural roots. This research is being developed through an exploratory phase in 2 London urban secondary schools, with attention to science teachers' intercultural practices. Later, a case study will be held to examine the implementation of HPSS activities (based on intercultural historical cases) in order to understand how they can foster science lessons committed to the teaching about science from an intercultural perspective.

## **LITERATURE REVIEW**

Recently, the expansion of school science curricula has stimulated several research and reflections about its teaching in multicultural contexts. However, in this scenario of cultural exchanges, where a wide range of students from different backgrounds are gaining access to scientific knowledge, the nature of the relationship between mainstream science and culture and worldviews does not need to be adverse, at least in the school science setting (Jegede & Aikenhead, 1999; Nola & Irzik, 2005).

In this scenario, the goals of school science should not be to indoctrinate students, but to equip them with skills to critically make their own assessments regarding modern science. Furthermore, they should also be given the opportunity, with the aid of HPSS, to understand science as a result of historical processes of intercultural exchanges and contributions from different people, communities and ways of seeing the world – an “intercultural” view of science (Matthews, 2014; Sarukkai, 2014).

Therefore, there seems to be an interesting connection between this intercultural view of science informed by HPSS and the teaching about how science works (NOS). Long advocated as an important part of Science Education, learning about NOS can include discussions about its epistemic (theories, experimentation, etc.) and social-institutional (ethics, certification and negotiation of knowledge, etc.) dimensions (Driver et al., 1996; Erduran & Dagher, 2014). Thus, the study of NOS may help students from different backgrounds not only to understand modern science (the ways it produces its knowledge), but also to clarify its origins, claims, assumptions, boundaries, weaknesses and strengths in reasoning about the natural world.

However, while these urban classrooms have become more diverse, very few changes have been observed in relation to how science is taught and to how scientists, scientific work and communities are portrayed to these multicultural groups of students (Krugly-Smolka, 2013; Sarukkai, 2014). In this



scenario, some authors (Christidou, 2011; DeWitt et al., 2011; Sarukkai, 2014) argue that the examples we use to teach scientific content, often associated with specific images of scientists (male, white, etc.) conveyed by these lessons, and the lack of discussions about NOS can have a relevant impact on how students understand scientific work and also on their views about who can participate in this scientific world (Christidou, 2011; DeWitt et al., 2011).

Therefore, in this project, I aim to investigate the possibilities presented by the field of HPSS to the development of an “intercultural” approach towards science teaching (Matthews, 2014; Sarukkai, 2014). Since, according to Krugly-Smolska (2013) and Sarukkai (2014), few investigations have been carried out about the impacts of the integration of intercultural examples into science lessons in urban multicultural schools, this project pays special attention to whether and how the usage of diverse scientific contexts from History of Science can foster students’ learning about how science works.

## RESEARCH QUESTIONS

- 1) *How do current science education practices deal with intercultural aspects of modern science? Are teachers taking these aspects into account when teaching about NOS?*
- 2) *In which ways are secondary students aware of the history of scientific development carried out by different people in different places of the world? And how do they respond when confronted with this kind of knowledge?*
- 3) *What are students’ views and understandings about NOS? Which aspects are influencing and shaping these views and understandings in urban secondary schools?*
- 4) *Can the study of the contributions of different cultures to modern science be successfully integrated into science learning through HPSS? In which ways can this type of activity promote a wider understanding of NOS in multicultural classrooms?*
- 5) *How can a collaborative approach between science teacher and researcher foster the development and implementation of these innovative activities?*

## RESEARCH DESIGN AND METHODS

The methodology proposed to this research is based on a qualitative and interpretive perspective (Charmaz, 2014) towards the study of science lessons in two secondary schools (years 8-10, students aged 12-15) in London/UK. This investigation comprises two phases (exploratory and intervention) related to teaching practices in relation to an intercultural view of science and based on an ethnographic approach.

The exploratory phase consisted of following-up science lessons (5 teachers; 9 classrooms from years 8-10, different ability groups, and topics in Biology, Chemistry and Physics), and paid specific attention to the way science teachers work alongside cultural diversity in their lessons. My aim was to reflect on practices developed by them in their urban and multicultural classrooms (RQ1), especially in relation to teaching about NOS, and to the use of examples from different cultures. Therefore, around 50 sessions of participant observation were carried out (field notes and audio-recording of the lessons) and are currently being analysed under an interpretive perspective, inspired by Grounded-theory

approach (Charmaz, 2014). Follow-up interviews with the teachers about their practices will be triangulated with the data generated by these observations.

Furthermore, two different open-ended questionnaires (RQ2 and 3) were applied to the participant students to investigate their knowledge on History of Science (based on Gurgel et al., 2014) and on NOS (based on Driver et al., 1996; and Erduran & Dagher, 2014). Their answers to the History of Science questionnaire were tabulated and counted in a simple quantitative approach, leading to an interpretive analysis of the patterns found. Meanwhile, their answers to the NOS questionnaire will be qualitatively coded and inspired by Peters-Burton's (2015) work on "Epistemic Network Analysis". Based on these results, follow-up group interviews will be carried out with a sample of students to cross-check their answers and to establish possible relationships between these those and their teachers' practices.

Informed by the exploratory phase, the intervention phase (July/2017-June/2018) will consist of a case study on the implementation of lesson plans intended to teach about NOS from an intercultural-historical perspective, with diverse examples of scientific work and development from different cultures. Through a collaborative work, I will help the teachers to produce teaching sequences to be implemented throughout 1 academic year in year 8 and 10 classrooms. These sequences will follow the regular science curriculum adopted by the school, taking into account the official requirements for science lessons, working alongside the scientific content expected to be taught.

This study will encompass observations of the lessons where the designed teaching sequence will be taught, and the reapplication of the NOS questionnaires (pre and post-intervention) to evaluate the overall impact of the intervention on students' views about science (RQ4). A sample of students involved here will be interviewed to cross-check some of their answers to the instruments, and to get a deeper understanding of some interesting points that can raise from my observations. A post-intervention interview will be also conducted with the participant teachers in order to address their impressions about the process of designing the activities and expectations of impacts on students' knowledge about and attitudes towards science (RQ5). All the data gathered from this case study will be analysed under a qualitative and interpretive perspective.

## **PRELIMINARY FINDINGS**

Preliminary results from the exploratory phase will be presented, with focus on:

- Teachers' practices in relation to intercultural perspectives and teaching about NOS (implicit approach towards how science works; use of students' own interests and previous knowledge during the lessons, but emphasis on scientific content/assessment; decontextualised use of HPSS; lack of diversity in how scientists are portrayed; etc.).
- Students' views about NOS and who usually participates in science (lack of diversity in scientific role models and lack of knowledge about science being done in different places; focus on the importance of evidence to science, but not on collaboration, communication and other social-cultural aspects; etc.).

In addition, during the Summer School I plan to discuss my ideas for the intervention phase, including some initial teaching sequences (drafts) that I am developing and how they can be informed by the results from my exploratory phase.

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## **SESSION I: SCIENCE LEARNING IN INFORMAL CONTEXTS**

# **A CASE STUDY EXPLORING HIGH SCHOOL STUDENTS' ENGAGEMENT WITH CITIZEN SCIENCE PROJECTS**

**Lubabalo Albert Bhulana**

University of the Witwatersrand, Johannesburg, South Africa

## **INTRODUCTION**

Citizen science is an informal learning approach that is expanding. Most citizen science projects that have enjoyed success with data and interpretation of data lie in the environmental sciences. There has also been success in the field of astronomy for those interested in stargazing through participation in projects that are online like the Galaxy Zoo (Raddick et al., 2010). A trend that is on the rise now in the field, is looking at how technology can be integrated in citizen science for accurate data collection and communication, and also to increase enthusiasm by participants through games created (Newman et al., 2012). With the age of computers evolving, and schools having access to computers, it also makes it possible for students at school to get involved in citizen science projects so as to gain firsthand experience with working with real scientific data. Also with telephone networks producing smart phones that are affordable, students have the advantage of participating in citizen science projects after school hours, where convenience is afforded.

## **AIM OF THE STUDY**

Citizen science projects do involve volunteers doing 'real science' where their contributions aid in helping to answer a research question. It is the nature of doing real scientific work and possible positive impacts that citizen science projects have on volunteers that has had most schools to consider getting involved in citizen science projects.

Schools in Europe and South America that have incorporated citizen science projects into their curriculum have had positive results with their students (Eastman, Hidalgo-Ruz, Macaya-Caquilpan, Nunez, & Thiel, 2014; Ruiz-Mallen et al., 2016; Silva et al., 2016). Not only were their educational outcomes achieved, but students gained experience on the processes involved when conducting real scientific investigations.

It never is easy to have a citizen science project where both educational and scientific objectives & outcomes are achieved (Zoellick, Nelson, & Schauffler, 2012). At the same time, it also is not an impossible task. For the school students in Europe and South America where educational outcomes were achieved, the teacher and scientist have had to come together to create a citizen science project that could ensure that objectives and outcomes of the scientist and teacher are covered in the project. This however is a process that is often complicated, and thus may take time to create a suitable project that school students could get involved in.

With a growing number of citizen science projects, it becomes more possible for teachers having the possibility of selecting a citizen science project that can be incorporated into their existing curriculum, than having a long process of creating a citizen science project from scratch with a scientist.

Therefore, the purpose of this qualitative study will be to explore how an online citizen science project chosen for high school students involved in a science enrichment programme impacts them.

## **PROBLEM STATEMENT**

### ***Research problem***

In South African schools, a reality that exists is that many schools do not conduct practical work. Motlhabane (2014) and Heeralal (2014) conducted research on the use of practical work in schools. They found that the science apparatus supplied to the various schools in their studies was not used. When probing teachers on why the apparatus was not used, the reason supplied was that there was not enough time, as most time is spent on administration. With practical work being sacrificed at the expense of covering work needed for assessment in different terms, or to catch up on administration, specific outcomes set out by the curriculum to be achieved by practical work become neglected.

There is however, a way to get students involved in practical work so as to enhance scientific literacy and an interest in the sciences; and that is getting students involved in a citizen science project. Citizen science projects do not necessarily need students to have lab apparatus or to be restricted in doing the work in a classroom environment.

With technology evolving, students can access citizen science projects using their phone devices, or school computers. What is of benefit for both teachers and students with citizen science projects, is that they can be done at the students own free time.

## **LITERATURE REVIEW**

### ***Citizen science***

Citizen science is becoming increasingly popular in fields that require observation as a means of data collection (Silvertown, 2009). Usually, research assistants would help scientists in the administration of the data collection; but there are now many projects that are emerging that require a large amount of data to be collected. Such projects cannot be done by research assistants due to the magnitude of data required (Bonney et al., 2014). This is where citizen science comes in. With citizen science projects, volunteers are used to gather information over larger geographical areas, and over longer periods of time (Cohn, 2008).

### ***Online Citizen Science Projects and Technology***

On a daily basis, more citizen science projects are becoming available online so that more people are able to access these projects. There is a website called sci-starter that has a list of over 600 citizen science projects which are put into different topics (Malykhina, 2013). What is also an added benefit about this website is that the citizen science projects are listed according to subject area. This helps with visitors to the website to quickly access citizen science projects in topics they are interested in. With more citizen science projects being available online, there are opportunities for educators to use available citizen science projects and incorporate them into their curriculum or pedagogy, so as to allow students the opportunity to be involved in “real science.”

## RESEARCH QUESTIONS

Most citizen science projects that have been done have had positive impacts on the participants based on the fact that the volunteers had an interest in the topic the citizen science project was investigating (Raddick et al., 2010; Zoellick et al., 2012). In this project, to see whether citizen science projects do generally have an impact on participants, a citizen science project will be chosen for the students. If indeed the citizen science project chosen has positive impacts on participants irrespective of topic interest, then it would be noteworthy to explore the feasibility of introducing these projects in schools to enhance science literacy amongst school students. For my study, the following research question will be explored:

- *What impact do selected online citizen science projects have on students that participate in them?*

To further interrogate the main research question, there are five sub-questions that will investigate the following impacts: knowledge gain, interest and perceptions of science, and practical skills. The sub-questions are:

- 1) *What do students know about the topic presented by the online citizen science project before and after they participate in the project?*
- 2) *How does the students' interest in science change (if at all) by participating on the online citizen science project activity?*
- 3) *How do the students' perceptions of science change (if at all) by participating on the online citizen science project activity?*
- 4) *What were students' experiences of participating in a citizen science project?*
- 5) *What practical work is involved in the citizen science project activity and what practical skills (if any) do students gain by participating in the citizen science project activity?*

It is important to investigate testable impacts, especially on volunteers that consist of school students, as there is a very limited knowledge on what impacts citizen science has on school students (Bonney, Phillips, Enck, Shirk, & Trautmann, 2015)

## THEORETICAL FRAMEWORK

I had to look at a theory that incorporates constructivism (as constructivism plays a major role in my study), and at the same time, incorporates the activities that students will do when participating in the study. The theory that satisfies these conditions is the theory called Experiential Learning Theory (ELT) developed by David Kolb.

This theory emphasizes that experience plays a central role in the learning process, and also stresses an important note that incorporates constructivism, that being in experiential learning, it is the individual learner that constructs knowledge due to the learning experience offered in the environment they find themselves in (Carver, 1996; Kolb, 1984). For the benefit of understanding this theory, it is important to define what is meant by learning through experience in the context of my study.

Learning by experience will be looked at as a process where learning takes place outside a traditional academic classroom, where participants learn through having a firsthand experience of participating in real science research, as opposed to them reading books on how scientist go about doing scientific research.

Kolb (1984) presented a cycle of four elements necessary for effective learning to take place. The cycle is presented below:

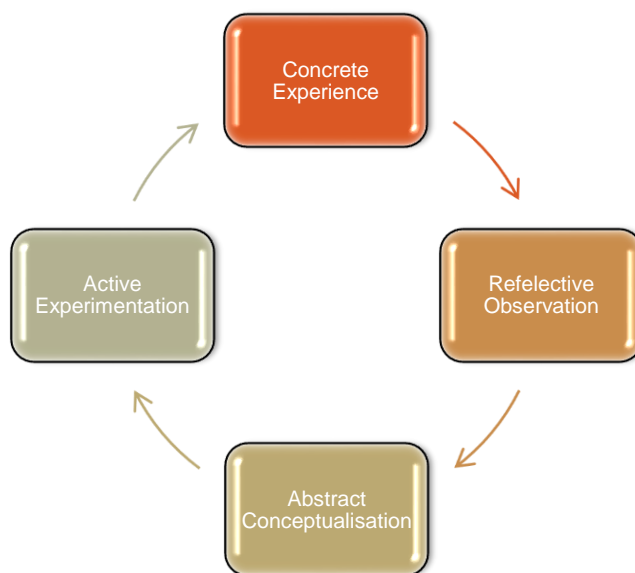


Figure 1: Kolb's Cycle of Experiential Learning

The research approach that I have decided to use is that of a case study. Opie defines a case study as “an in- depth study of interactions of a single instance in an enclosed system” (Opie, 2004, p. 74). Students that are involved in a science enrichment programme will be the group chosen to participate in my study. The reason for choosing such a group is because activities surrounding enrichment are done after school hours. In this way, students would not be disadvantaged in their learning at school, as in most schools, teachers do complain about time constraints in finishing certain curricula during school hours. In 2017 in the month of May, my research instruments will be piloted so as to make necessary changes if needs be to collect needed data for analysis.

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## **SESSION O: OTHER**

# **EXAMINING ELEMENTS OF PHYSICS STUDENT ATTRITION IN A FINNISH UNIVERSITY: THE PERCEIVED MEANINGS AND INTERACTION IN TEACHER TUTOR SYSTEM**

**Laura Timonen**

University of Oulu, Finland

## **AN OUTLINE**

Physics is one of the degree programs in Europe, in which there are fewer graduates than there are students choosing it as their major subject at the beginning of their studies in the tertiary level of education (Eurostat, 2016). This is also true in Finland, the country often praised for its education system. For example, only one third of the physics students in my home university have graduated in recent years, the rest drop or opt out after year or two. This should worry both the politicians hoping for new innovations and the staff of the tertiary level education institutions trying to pass on the knowledge and renew the science community.

Vincent Tinto's interactionalist model (1975; 1982; 1994) emphasizes the meaning of interaction between the students and the educational institution in fighting student attrition. The students' interaction with faculty staff is important (Pascarella & Chapman, 1983; Walsh, Larsen, & Parry, 2009), but as the teaching is still mostly one-way lecturing, other opportunities to communicate become critical.

The University of Oulu has developed a teacher tutor system, in which for every student enrolling to the university a teacher tutor from his/her major is appointed. In short: the teacher tutors should be like personal guidance counselors, first contacts to the staff of the university, advisors and even mentors for the newcomers, according to the university's official instructions. Teacher tutors are not meant to be private content teachers for the students. The physics degree program's own sub-instructions emphasize conversation as the main means of interaction and good study habits and use of time the most important topics to cover in meeting with the student.

All the above sounds wonderful, in thinking the student's integration to a new educational environment. The teacher tutor system of the physics degree program has been going on unchanged for the last six years. For all this time, there has been no scientific research or even a follow up questionnaire about how it is holding up and is it working as it should. According to Tinto (2006) all support programs for students should be monitored, as it is easier to design one than to implement it.

My thesis focuses on the perceived meanings of and the perceived interaction in the teacher tutor activity, the interfaces between the parties of the activity and the possible connections with the theory and reality of student attrition phenomenon. The focus group is the physics degree program students and their teacher tutors from my home university. The general aim is to provide new information about student attrition in a field of pure natural science and locally benefit the physics degree program with knowledge they can utilize in evaluating and developing the teacher tutor system.

## **LITERATURE REVIEW**

Vincent Tinto (1975; 1982; 1994) has developed a very influential (Ulriksen, Madsen, & Holmegaard, 2010) interactionist model, in which students' initial attributions and initial commitments are affected by all the interactions the student experiences in the institutions domain, the result is academic and social integration. These shape the students' commitments and leads to a decision either to continue or quit studies. The process is longitudinal in time and cyclic by nature: new interactions affect time after time and the commitments shift shape continuously. This connects well with the aim of the teacher tutor activity to go on for the first three years of studies.

Validity for Tinto's model (1975; 1982; 1994) has been presented (Braxton, Shaw Sullivan, & Johnson, 1997): the students' initial attributions and initial commitments, the deepening commitment to the institution after beginning studying and social integration do affect student retention. Also, the academic integration has validity in circumstances similar to our research (Braxton & Lien, 2000).

Lähteenoja and Pirttilä-Backman (2005) have researched Finnish university teachers' views of student integration through group interviews. They found the views varied from beneficial to even harmful, which is interesting considering Tinto's model (1975; 1982; 1994) sees integration as a key feature. The research of Lähteenoja and Pirttilä-Backman (2005) with its qualitative point of view is an exception to the vast quantitative research mass there is about student attrition and relating phenomena (Ulriksen et al., 2010). In teacher tutoring, university teachers need to take a whole different role than just teacher's and might have different views on the topic of integration. Lähteenoja and Pirttilä-Backman (2005) suggest the research on university staff's perceptions of student integration should be carried on.

Stephen, O'Connell and Hall (2008) compare the views of students and personal tutors about tutoring-relationships, concluding that both parties see the importance of creating stronger academic community and wish their relationship was more meaningful. Stephen et al. (Stephen et al., 2008) recognize the need to do more research on personal tutoring within mass higher education.

The goal of my research is to broaden the view and knowledge of the aforementioned topics by finding answer to following questions.

## RESEARCH QUESTIONS

- 1) *What kind of meanings do teacher tutors give to the teacher tutoring activity?*
- 2) *How do the teacher tutors describe interaction between the teacher tutor and the student?*
- 3) *What kind of meanings do students give to the teacher tutoring activity?*
- 4) *How do the physics students describe interaction between the teacher tutor and the student?*
- 5) *What is the perceived meaning and interaction interfaces of students and teacher tutors like?*

## RESEARCH DESIGN AND METHODS

My research takes the socio-constructive view, where all meanings are constructed in interactions between the parties of this reality. Therefore, I've chosen qualitative methods in which teacher tutors and students get to share their views and their voices will be heard. So far, I've

interviewed physics teacher tutors and collected written narratives from physics students from the University of Oulu about their views of the teacher tutor system.

The interviews were volunteer-based, semi structured and had only open-ended questions. Questions were designed for this research and piloted with a member of the focus group. 8 teacher tutors participated, which is 38 % of the focus group. This data has been analyzed with abductive content analysis using researcher triangulation and we've answered *RQ1*. The analysis will continue to get answers to *RQ2*.

The data collecting from physics students begun in Spring 2017. Students were asked to write an informal text about their views on teacher tutor system. Five questions were provided to help the writing process. When returning the text, they were asked to fill a background questionnaire and give their student ID. Everything was voluntary. During a period of four weeks of data collecting we got four written narratives, all those who answered also filled a background questionnaire and gave a permission to use their student record as a research material. As we expected more responses, the data collection was decided to be continued in the Fall 2017.

As a supportive data, all the university's official material concerning the teacher tutor system will be reviewed as well. The research findings' concurrent validity will be estimated along the way by comparing the emerging results with existing theory and research.

## PRELIMINARY FINDINGS

For *RQ1*: the perceived meanings teacher tutors have can be divided in 5 categories: Encountering, Study techniques, Integration, Guidance counselling and General advising. These had 11 subcategories in combined. They all are descriptions of either a holistic encountering of two persons or a more traditional guidance counselling in different forms. Also, we found sixth category named Questioning, in which the teacher tutors question the meaning of the system.

There is a definite connection with the concepts of academic and social integration (Tinto, 1975; 1982; 1994): the meaning subcategories were assigned either to academic or social integration, three subcategories were left out. There were more subcategories on the side of academic integration and these subcategories were relatively less questioned than those on the side of social integration.

This is to say that the teacher tutor system has actual validity in preventing student attrition and in developing the system there should be a focus on increasing the social integration. A manuscript of a scientific article of this has been written and is in process.

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# PRIMARY SCIENCE SUBJECT LEADERS: THE STORIES THEY LIVE BY. A STUDY OF THE IMPACT OF THE PSQM PROGRAMME ON TEACHER IDENTITY AND AGENCY

Clare Warren

University of Hertfordshire, United Kingdom

## OUTLINE OF THE STUDY

Introduced throughout the UK in 2010, “The Primary Science Quality Mark (PSQM) is an award programme to develop and celebrate the quality of science teaching in primary schools” (Turner et al, 2013, p3). Ofsted (2011) noted the positive impact of PSQM in pupils’ performance, engagement and enjoyment as a result of teachers’ improving confidence and ability to teach science. Over 2000 schools have now completed the PSQM award (PSQM, 2016). The aim of my study is to explore the development of the science subject leaders (SSLs) who take part in the PSQM programme.

## REVIEW OF THE LITERATURE

### *Subject leadership*

Busher et al (2007) point out the sparsity of research concerned specifically with middle leaders in primary schools. The limited literature available highlights the benefits of devolved leadership but also identifies conflicts which arise (Bell and Ritchie, 1999). The resistance of colleagues and the lack of supportiveness of the head teacher, were potential barriers to effective subject leadership noted by Hammersley-Fletcher and Brundrett (2005). Thus, the school context in which SSLs work may impact on their potential to develop through the PSQM process.

In terms of leadership more generally, Zaleznik (1963) stated, “the exercise of leadership requires a strong sense of identity – knowing who one is and who one is not – a sense of autonomy, separateness, or identity, permits a freedom of action or thinking necessary for leadership”. Thus steering me to consideration of identity.

### *Identity*

Despite the fact that since the 1990s, there has been a growing interest in researching teacher identity (Akkerman and Meijer, 2011), few have examined the identity of primary subject leaders, so the wider literature on teacher identity has been explored.

There is no agreement on a single definition of identity, however, three common threads have been noted among many of the definitions: a multiplicity of identities which vary with context; a discontinuity of identity and the social or relational nature of identity (Akkerman and Meijer, 2011). The concept of identity therefore feels very elusive (Rogers and Scott, 2008). One way to resolve the issue of multiple identities changing across both time and context is using dialogical self-theory which weaves together the concepts of self and dialogue (Akkerman and Meijer, 2011).

Rogers and Scott (2008) suggest that identity, “is both interpreted and constructed through the stories that one tells oneself and that others tell. These stories change over time, across contexts, and depend on relationships” (p737). “In effect, the self can be seen as the meaning maker, or teller of

stories. If our identities are stories then our selves might be the storytellers” (p738). Connelly and Clandinin (1999) also explain a teacher’s identity as “a unique embodiment of his/her stories to live by, stories shaped by the landscapes past and present in which s/he lives and works”.

### **Agency**

Vähäsantanen (2015) argues that an “agency centred approach” (p2) is required to understand developing teacher identity. Beijaard (2009) also links agency and identity suggesting that without agency teachers will find it difficult to develop and maintain a professional identity. Hence the need to study identity and agency together.

As with identity, recent years have seen a marked increase in the quantity of research around teacher agency, much of it set in the context of educational reforms (Philpott and Oates, 2016). Agency is also similar to identity in that it is dependent on social and individual resources and is “temporal and dependent on the situation” (Vähäsantanen, 2015, p10). Like identity, there are multiple definitions of agency. Philpott and Oates (2016) state that some researchers study the contexts in which teachers are able to exert agency while other researchers seek personal attributes which support agentic behaviours. Rogers and Wetzel (2013) combine both elements, defining agency as, “the capacity of people to act purposefully and reflectively in their world”.

A number of authors relate structure, which Beijaard et al (2004) describe as “the socially given” (p113), to their conceptions of agency. For example, Lasky (2005) notes the relationship between agency, identity and structure when she states that, “Structures [...] are both an expression of agency and shared identity while also being elements that shape agency and professional identity” (p902).

### **RESEARCH QUESTIONS**

I wish to explore both the identity and agency of the Science Subject Leaders (SSLs) over the course of the PSQM year. Further, I want to consider the elements of the PSQM programme and the contextual background which influences any changes. This leads to three questions:

- 1) *Is SSL identity changed during the PSQM year and if so, how, and in what ways?*
- 2) *Is SSL agency changed during the PSQM year and if so, how, and in what ways?*
- 3) *If there are changes to SSL identity and agency, which contextual features have influenced the change?*

I will view identity as embodied in the stories teachers live by (Connelly & Clandinin, 1999) and I posit that agency as “an unfolding process of knowing, acting and being-in-the-world” (Leach & Moon, 2008, p144) can be woven into the preceding concept of identity.

### **RESEARCH DESIGN AND METHODS**

Tamboukou et al (2013) state that, “researchers who are interested in narratives as individualised accounts of experience tend to be most convinced of the significance of stories as ways of expression and building personal identity and agency” (p7). Chase (2008) points out that narrators have



opportunities to learn and reflect as they tell their stories. I therefore plan to use a series of six interviews over the course of a year to collect stories from SSLs.

Using PSQM hub leaders as gatekeepers I will recruit two participants for a pilot study. This will be used to test and refine the research instruments and data analysis techniques. A further six participants will be recruited for the main study. Interviews will be recorded and transcribed in full. Participants will also be offered the opportunity to make a visual map of their PSQM year as a 'river of experience' (Pope and Denicolo, 2001).

Narrative analysis covers a range of approaches which may be used to analyse stories that individuals tell to understand themselves and the world they live in (Bryman, 2004). I intend to trial some narrative analysis approaches using my pilot study data to see which best answer my research questions. Throughout, it is important to recognise that my interpretation of events is only one of a number of possible interpretations (Mischler, 1986) and in a similar way to Meijer et al (2009), who viewed narrative research as an act of dialogue, I shall also involve the teachers in the process of analysis and interpretation.

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## **SESSION P: PHYSICS EDUCATION**

# WHAT DO STUDENTS' REPORTS OF SCIENTIFIC INVESTIGATIONS TELL US ABOUT THEIR UNDERSTANDING OF SCIENTIFIC INQUIRY?

Katharina Gierl

University of Koblenz-Landau, Germany

## RESEARCH FOCUS

The study examines the development of student's *reporting-competence* from kindergarten to mid-secondary school. *Reporting-competence* is essential for recording scientific inquiry processes and making results objectively. Therefore, reporting scientific inquiry processes can be described as the communication processes for analyzing scientific report. Following this description, two main focuses can be identified: first, the actual inquiry process, and second, the receiver of the report. Such focuses can be used to assess reporting competence across different school levels.

## THEORETICAL BACKGROUND

Scientific inquiry is an important component of many education standards and curricula ranging from preschool to secondary school (e.g. USA: NRC 1996; Germany: KMK, 2005). Scientific inquiry encompasses the development of scientific questions, to design and conduct suitable investigations, and using evidence for answering questions (Lederman, 2009). Within scientific inquiry, traditional process skills in science, such as, observing, predicting, measuring, interpreting and analyzing data, are as essential to have an understanding of these scientific methods (AAAS, 2000). In order to develop cumulatively competencies and scientific inquiry understanding along the entire school career (Weinert et al 2011; Shavelson & Towne, 2002), students need to be promoted appropriately accordingly to their age. Therefore, the study focuses on the development of these skills from preschool to mid-secondary school. The traditional skills in scientific inquiry have been investigated by diverse studies (e.g. Schecker et al, 2016; Hammann et al., 2015; Lunetta et al., 2007; Wellnitz & Mayer, 2013; Mayer 2012, Kohlhauf et al. 2011). Each study has a different focus on specific skills and addresses different age-groups ranging from preschool to secondary school. All studies have divided the scientific inquiry process into sub-dimensions - what couldn't be empirically confirmed in all cases (e.g. Hammann & Phan, 2008). Besides valuable information about the structure of scientific inquiry processes, the studies provide valuable conclusions. Although the skills in scientific inquiry are assessable in every school stage, the studies have drawn inconsistent results regarding the differentiation (structure of the skill), graduation and development of these skills. Because of the presupposed sub-dimensions, the studies can't provide information about the quality of the scientific inquiry process as a whole. More importantly, the scientific inquiry processes are generally not linear (Klahr, 2000; Heine 2014). Scientific inquiry is a complex interaction of steps, and the coherence of this interaction provides understanding on how one must use and work with them. This important interaction becomes obvious, because it has been highlighted that these steps seem to be closely related (e.g. Wellnitz & Mayer, 2013; Kohlhauf et al. 2011). How the process is reported can be a way to assess scientific inquiry process as a whole. This is due to the fact

that the last step of every scientific process is to make a report on it as a way to produce replicability of scientific results. Hence, reporting scientific results can be defined as a communication process between scientists, where models are taken into consideration (Kulgemeyer et al. 2013; Shannon, 1949).

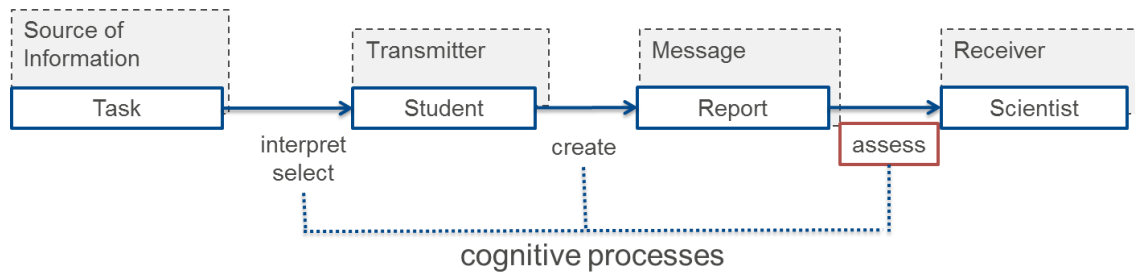


Figure 2. Modell of scientific report process

The first step of the report process is the information provided by the task. Based on empirical models of scientific inquiry, such tasks are constructed according to certain steps in the inquiry process (e.g. Wellnitz & Mayer 2013; Schecker et al., 2016). The steps are: developing scientific questions, developing scientific hypotheses, testing hypotheses and using evidence for answering the question. The transmitter (student) needs to interpret the task, select relevant information and create the message (report) based on the inquiry process. The receiver (scientist) assesses the message following the three quality criteria of objectivity, validity and reliability. An adequate report obtains the necessary information to assess the scientific inquiry process based on these quality criteria in order to ensure replicability of results. The transfer of these criteria to science education is only applicable to a limited extent. They contain specific principles: e.g. theoretically and empirically coherence, objectivity and transparency, and lastly, generalizability (Shavelson & Towne, 2002). Based on these principles, it could be possible to assess the quality of scientific inquiry processes.

The report is influenced by person-specific characteristic and skills. Kohlhauf et al (2011) developed a competency model for skills in biological observation suitable for school grades ranging from kindergarten up to university. Analysis showed that prior-knowledge and language skills predicted observation competency and the description skills. Due to the vast resources to assess prior-knowledge in mechanics from preschool up to secondary school (Vosniadou, 2009), we focus on the subject of mechanics in our investigations. Furthermore, Mayer et al. (2014) could identify elements that have an influence on scientific reasoning skills in elementary school. Certain subscales of intelligence, problem-solving skills, visual thinking and reading literacy have an impact on scientific reasoning. Moreover, motivational factors as 'interest in science' and 'self-concept' can predict scientific reasoning. Such studies show that all predictors increase until the last year of elementary school. On this account, while assessing the *reporting-competence*, these predictors should be controlled in a large scale study.

## RESEARCH QUESTIONS

This background motivates the research questions of this paper:

- 1) *How can different levels of reporting-competence be assessed from preschool to secondary school?*
- 2) *What is the effect of cognitive development and schooling, and how do intelligence, self-concept, pre-knowledge, language skills and current motivation interfere with these levels?*

## RESEARCH DESIGN AND SAMPLE

In this study participants (N=180) from preschool, elementary and mid-secondary (up to 8<sup>th</sup> grade) school will be tested, having 60 students in each case. The points of data collection will be set between transitions from preschool to elementary school and secondary school in order to have a longitudinal perspective. This allows us to provide valuable information on the development status of *report competence* in regards to the grade level. The students from preschool and primary school will be tested in the last school year before the transition (age 5-6 and age 9-10) to avoid impacts of the transition itself (e.g. caused by new teachers and environment). The mid-secondary students will be tested at the end of grade eight (age 13-14).

## METHODS AND INSTRUMENTS

Each participant will be asked to perform selected experiments from mechanics, structured by videotaped interview (standardized questionnaire adapted from Kohlhauf, 2012) session. The students have to report the investigation so that the person who give the task could replicate the investigation and obtain the same conclusions. The videotaped descriptions of the students will be analyzed by a theoretically based (Wellnitz & Mayer, 2013; Kohlhauf, 2013) and an inductively adjusted observation system. In addition, current motivation (Vollmeyer & Rheinberg, 2006) including self-concept will be tested immediately after each experiment. Pre-knowledge, subscales of intelligence, and language skills are tested in a pre-test. New test instruments for pre-knowledge and language skills that are suitable from preschool to mid-secondary school, have to be adapted or developed.

## STATE OF THE STUDY

The development of the experiments will be finished on February 2017. The adaptation of the test instruments and interview questionnaire will be finished and pretested for each type of school (N = 30) until April 2017. Data available at the time of the summer school and consequences for the main study could be discussed. The main study will start in autumn 2017.

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# DEVELOPING STUDENTS' PROBLEM SOLVING ABILITY: HOW DO PHYSICS LESSONS CONTRIBUTE?

Florian Gigl

University of Koblenz-Landau, Germany

## OUTLINE OF THE PROJECT

From the perspective of the PISA Consortium, in physics lessons problem solving is taught as part of scientific literacy. Accordingly, the presented study investigates the relationship between the outcome of learning opportunities in physics class and assessment of problem solving ability in PISA.

Therefore, the connections between the possible outcome of prominent learning opportunities in physics classrooms at school – problem-oriented text-based exercises and experiments, and adjacent domain-general problems – analytical and complex - will be assessed. Both differ in the influence of domain-specific knowledge and strategies. Additionally, experiments and complex, domain-general problems are incongruent in manner and diversity of provided system response. An additional instrument will be developed to assess complex problem solving ability in tasks which require the use of physical knowledge and strategies.

## LITERATURE REVIEW

Problem solving can be defined as “the capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious” (OECD, 2014b, p. 2) and has been explicitly assessed in the large scale assessments of PISA 2000, 2003, 2012 and 2015 without confirming its curricular and ecological validity (Greiff, Holt, & Funke, 2013; Klieme, Funke, Leutner, Reimann, & Wirth, 2001; Leutner, Fleischer, Wirth, Greiff, & Funke, 2012; OECD, 2014a). The operationalization of the PISA study considers problem solving abilities as part of the construct *scientific literacy as a life skill* (Klieme et al., 2001; Leutner et al., 2012) with part of its core competencies to be acquired within scholar education in Germany (KMK, 2004).

In physics education, the most prominent opportunities for developing scientific inquiry skills – and thereby probably also problem solving abilities (Mayer, 2007) – are text-based exercises with a problematic aspect and experiments – which take up about 70% of teaching time (Börlin, 2012; Duit, 2010; Friege, 2001).

Text-based problem tasks are a common part of textbooks at the end of a learning unit where students can practice and apply newly learned knowledge (Reinhold, Lind, & Friege, 1999). Their target is to increase the practical use of content knowledge, by transferring it to new contexts. Those tasks are characterized by a verbalized description of the problem and situation including all information necessary to solve the problem (Friege & Lind, 2003).

Student experiments provide a problem description but the problem solver has to generate an experimental setting by himself in order to gain the data necessary to solve the problem (Hopf, 2007). The subsequent (manual) interaction with the experiment, selection of relevant data, analysis, and final



knowledge gain from the experiment differ fundamentally from the text-based exercises. A general problem-fit scheme for the course of an experiment is the model of scientific discovery as dual search, which distinguishes three stages of an experiment: search in the space of hypotheses, testing the hypotheses, and analysis of evidence (Hammann, Phan, & Bayrhuber, 2008).

In contrast to problem solving in science education, in general educational research, two fundamental measuring types of problem situations have been established (*analytical* and *complex*). They can be distinguished by the amount of information given in the problem description as well as the need for interaction necessary to solve the problem (Leutner et al., 2012). Both problem types have been researched from a domain-general point of view, assuming that domain-specific problem solving ability can be explained by combining general problem solving ability and content knowledge, disregarding the probable influence of domain-specific strategies (Klieme et al., 2001).

Analytical problems in PISA (APS) consist of a domain-general, text-based problem description and optional pictures for further explanation. The tasks include all information needed to solve the problem, while an interaction to gather further information is not possible or necessary (Leutner et al., 2012).

Complex problems (CPS) usually consist of a problem description and a computer-based interactive problem system, which contains most of the information necessary to solve the problem. Students must solve such problems in two phases: First exploring the system systematically – i.e. generating information about the connections of the system – and then representing the causal structure in a map (Funke, 2001; Greiff & Fischer, 2013). In the second phase, the acquired knowledge about the system has to be applied to solve the problem (Funke, 2001). In current domain-general instruments (i.e. MicroDYN, MicroFIN; Greiff, Stadler, Sonnleitner, Wolff, & Martin, 2015) for the assessment of complex problem solving ability, students have to work on multiple items, each consisting of an arbitrary, domain-general context covering independent and dependent variables, which can be connected by either linear or Boolean relationships (Funke, 2001). Validation studies showed medium correlations between CPS and reasoning ability, partly mediated by students' need for cognition. Altogether the model explained 78% of CPS variance (Rudolph, Greiff, Strobel, & Preckel, submitted).

The connection between learning opportunities in physics education and domain-general assessment in large scale assessments can be classified based on the categories *domain-specificity*, *information content*, *need for interaction* (Mayer, 2007) and additionally also *type of system response*. Accordingly, on the one hand, text-based problem tasks in physics education and APS are linked containing full information, with no further possibility to interact with the problem. They only differ in the need for domain-specific knowledge and strategies to solve the problem. On the other hand, both experiments and CPS give incomplete information and require an interaction with a problem system in order to obtain missing information. They differ in need for domain-specific knowledge and type of system response: Complex problems are computer-based and therefore only provide a prescribed set of responses. In contrast, experiments' responses are not limited in such a way. To properly assess the relationship between learning outcome from experiments and CPS, it is necessary to distinguish between influence of deviating system response quality and of domain-specific knowledge and strategies. This

distinction requires physical complex problems that combine characteristics of the described CPS instruments and of physical problems.

## RESEARCH QUESTIONS

The connection between the above learning opportunities to domain-general assessment is questionable. Therefore, the study will deal with the following research questions: *How is the outcome of school-related learning opportunities in physics related to (1) physical and (2) domain-general problem solving ability?* and (3) *How is the ability to solve physical complex problems connected to domain-general problem solving ability?*

## METHODS AND INSTRUMENTS

For measuring physical problem solving ability, a computer-based instrument with equal item pairs – text-based and complex problem solving tasks regarding mechanics – is developed. To ensure comparability, each pair will carry an identical context and problem. Additionally, content knowledge (self-development), experimentation ability (Theyßen, Schecker, Neumann, Eickhorst, & Dickmann, 2016), reasoning (Baudson & Preckel, 2015), need for cognition (Preckel, 2016), domain-general problem solving ability will be assessed using the PISA 2003 instrument for APS (Klieme, Hartig, & Wirth, 2005) and MicroDYN (PISA 2012, Greiff & Fischer, 2013) for CPS.

## RESEARCH DESIGN AND SAMPLE

The instruments will be piloted in Spring 2017 with  $N \geq 150$  10<sup>th</sup> grade students of the German Gymnasium (secondary school). The main study will take place in Summer 2017 and assess a structural model with 17 parameters and  $N \geq 170$  10<sup>th</sup> grade students per instrument ( $\cong$  model parameters) utilizing a planned-missings-design (Kline, 2011). As a result, we will receive regressions from learning outcomes to physical and domain-general problem solving, taking into account the influence of covariates. Thereby, we learn about the influence of domain-specific knowledge and strategies on physical complex problem solving.

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# INCREASING MOTIVATION OF PHYSICS EDUCATION STUDENTS BY FOCUSING ON SCHOOL-RELATED CONTENT KNOWLEDGE IN UNIVERSITY PHYSICS COURSES

**Joost Massolt**

Universität Potsdam, Germany

## OUTLINE OF FOCUS OF STUDY

In this study, problem sets discussed in tutorial groups, part of first year university physics courses for physics majors and pre-service physics teachers, are modified in such a way, that some of the problems will increase the perceived relevance of the university content knowledge and therefore the motivation of the physics education students. To achieve this goal, the content knowledge category that describes the content knowledge relevant for teachers has been further developed. Problems based on this category have been developed and introduced in weekly tutorials. Using a weekly questionnaire, students have rated these problems with respect to relevance, difficulty and other constructs.

## SHORT REVIEW OF RELEVANT LITERATURE

### *Motivation*

Dropout rates in university physics and physics education courses are consistently high (e.g. Heublein et al. 2014). At the same time, a particularly high physics teacher shortage is expected in Germany (Klemm 2015). Part of the problem is the learning motivation of pre-service physics teachers. They often have difficulties seeing the connection between the content knowledge that has been taught in university courses and the content knowledge they will need in their future teaching career. In addition, evaluations of the teacher education courses at the University of Potsdam showed, that students wish for a more pronounced connection between the content knowledge courses and the pedagogical content knowledge courses (AG Studienqualität 2011). Surveys at other universities show that this problem has a general validity (e.g. Koponen et al. 2016). As perceived relevance correlates positively with learning outcomes, the level of conceptual understanding (Deci et al. 1991, 1994) and motivation (e.g. Keller 1983) and because separation from the professional field and lack of motivation are seen as reasons for study discontinuation (Heublein et al. 2010), there is a need for action.

### *Professional knowledge*

Shulman (1986) already described the professional knowledge of (prospective) teachers. He differentiated content knowledge (CK) from pedagogical content knowledge (PCK) and pedagogical knowledge (PK). In multiple studies of the professional knowledge of (prospective) teachers (e.g. Loch 2015; Riese 2009), CK has been further specified. A third category has been established, next to school knowledge and university content knowledge: *school-related content knowledge* (SRCK). This category describes the content knowledge that is teacher-specific. SRCK has been modelled for several subjects in a multi-disciplinary group within the project PSI-Potsdam (Woehlecke et al., in preparation), see figure 1. SRCK is characterized by networked knowledge and describes a conceptual knowledge that enables an overview of physics; it is university content knowledge reflected on school-related contexts. SRCK is

necessary for a deeper understanding of content relevant in school-situations; it prepares for planning, teaching and analysing physics lessons.

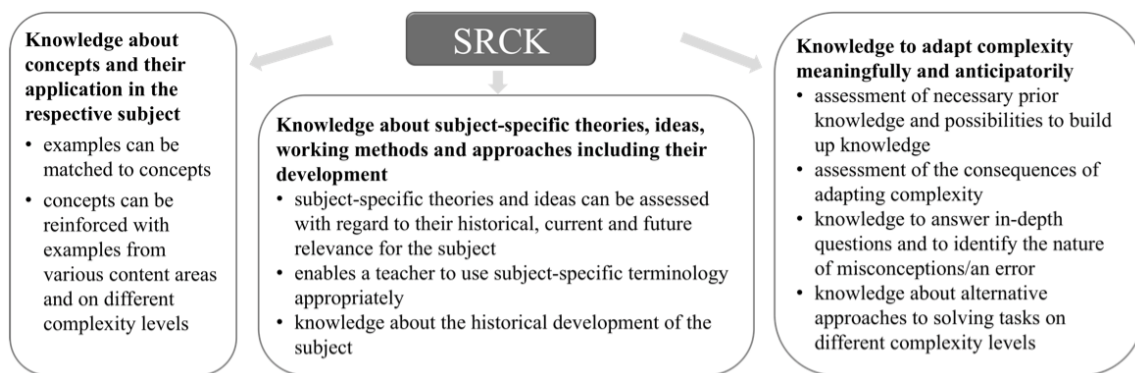


Figure 1: Facets of the School-Related Content Knowledge (SRCK)

## STATEMENT OF RESEARCH QUESTIONS

The university physics courses in Germany consist of lectures, tutorial groups and laboratory experiments. In the tutorial groups, weekly problem sets are discussed. These tutorials form a very important preparation for the final exams. We have modified regular problem sets discussed in tutorial groups part of first year physics courses for physics majors and pre-service physics teachers in such a way, that some of the problems are based on SRCK. Both physics majors and pre-service physics teachers solve the problems on these problem sets in preparation of the weekly tutorial groups. This leads to the following research question: to what extent do problems that base on SRCK increase the perceived relevance of the problem sets by pre-service physics teachers and therefore their motivation? The expectation is that a focus on SRCK in these problems will increase the perceived relevance of the university content knowledge (e.g. Keller 1983) and therefore the motivation of the pre-service physics teachers.

## OUTLINE OF RESEARCH DESIGN AND METHODS

Two out of five of the regular problems on weekly problem sets, part of a first semester experimental physics course (Winter semester 2016/2017, N=28 physics students, N=47 physics education students), are replaced. One of the new problems is based on the SRCK-model and therefore connects university physics with school physics; the other problem also focuses on conceptual knowledge, but without a connection to school physics. The problems based on SRCK are constructed using a validated problem-construction manual. As a further validation, experts will be asked to judge the problems based on SRCK with respect to their relevance for prospective physics teachers.

On equal terms, both the new problems and the regular problems are solved at home and discussed in several tutorial groups. Every week (for a total of 13 weeks), the students are asked to fill out a questionnaire in which they have to rate the problems with regard to relevance for their later career, difficulty, satisfaction with their problem solving performance and enjoyment in solving the problems. These items were adapted from the Intrinsic Motivation Inventory (Deci and Ryan 2003). In

order to avoid any influence of the problem discussion in the different tutorial groups (with different instructors), the students are asked to fill out the questionnaire at the start of the tutorial group.

Since the problem sets are such an important preparation for the final exam and the problem sets are aimed at both physics majors and pre-service physics teachers, the developed problems should be at the same level as the problems they replace.

## PRELIMINARY FINDINGS

An analysis using an *unpaired two-sample t-test* shows, that the questions based on SRCK are perceived as more relevant ( $M = 4.07$ ;  $SD = 0.28$ ) by pre-service physics teachers than by physics majors ( $M = 3.33$ ;  $SD = 0.36$ ),  $t(23) = 5.75$ ;  $p < .0001$ ;  $d = 2.25$ . Both groups do not consider these problems to be easier ( $M = 3.12$ ;  $SD = 0.56$ ) than the regular questions ( $M = 3.32$ ;  $SD = 0.67$ ),  $t(24) = -1.92$ ;  $p = 0.068$ .

The pre-service physics teachers perceive the problems based on SRCK ( $M = 4.07$ ;  $SD = 0.28$ ) as more relevant than the regular questions ( $M = 3.86$ ;  $SD = 0.39$ ;  $t(28) = 2.05$ ;  $p = .049$ ;  $d = 0.56$ ). The physics of the last part of the semester is more distant to school physics; here, the significance level and effect size of the difference between the problems based on SRCK ( $M = 4.31$ ;  $SD = 0.20$ ) and the regular problems ( $M = 3.86$ ;  $SD = 0.46$ ) is more significant  $t(16) = 3.35$ ;  $p = .0040$ ;  $d = 1.06$ , without the problems being significantly easier ( $M = 3.21$ ;  $SD = 0.46$  vs  $M = 3.53$ ;  $SD = 0.63$ ,  $t(8) = -1.27$ ;  $p = .24$ ).

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# COMPUTER-SUPPORTED COLLABORATIVE LEARNING ENHANCING PHYSICS STUDYING IN HIGHER EDUCATION: THE VIEW POINT OF STUDENT-STUDENT INTERACTION

Joni Lämsä

University of Jyväskylä, Faculty of Education and Psychology, Finland

## FOCUS OF THE STUDY

The focus of this study is to understand inquiry-based learning (IBL) processes (Pedaste et al., 2015) of undergraduate physics students when enhancing collaborative learning with new technologies as part of so-called primetime-learning model, shown in Figure 3. In primetime-learning, the learning process can be described with four different phases repeating every week: self-studying key concepts, applying the concepts in small groups, full-length problem solving independently or in small groups and a primetime between a teacher and a small group (see

Table 1). This study focuses especially on Practice-phase (shaded in

Table 1). From the group working sessions, I have analysed collaborative inquiry-based learning (CIBL) processes at different levels. The analysis has been qualitative aiming to visualize and capture temporality aspects of CIBL processes.

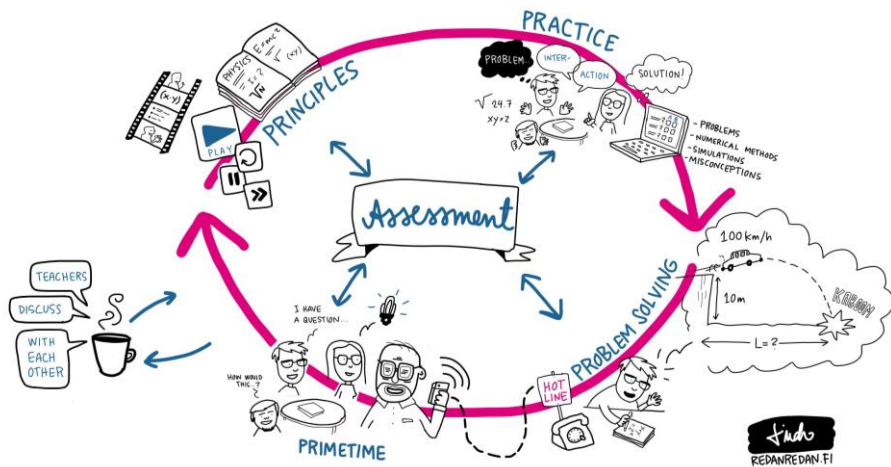


Figure 3. Weekly rhythm of primetime-learning model.

Table 1. The phases of primetime-learning model.

	Principles	Practice	Problems	Primetime
How?	Independently	In small groups	Independently or in small groups	In small groups with a teacher
What?	Short YouTube-video clips in a technology-enhanced learning (TEL) environment; a course book	Short, qualitative problems including e.g. simulations or numerical methods in the TEL-environment	Full-length, quantitative physics problems which were submitted to the TEL-environment	Challenges the group has faced during the previous phases

How often?	Twice a week	Twice a week	Once a week	Once a week
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In this study, I used the framework of IBL made by Pedaste et al. (2015). Based on the framework, the IBL processes can be described with five phases engaging students in an authentic scientific process: during the inquiry cycle, students orientate, conceptualize, investigate, conclude and discuss about the topic under study (Pedaste et al., 2015). Advantages of IBL are well known also in higher education: for instance, Alfieri, Brooks, Aldrich and Tenenbaum (2011) found that adults benefit even more from enhanced IBL than children. Especially, inquiry-based approaches may improve high-level reasoning skills compared to the traditional lecture-based teaching (Jensen & Lawson, 2011).

When enhancing IBL with a TEL-environment, technology-enhancement can both provide computerized tools for scientific inquiry (Bell, Urhahne, Schanze & Ploetzner, 2010) and foster social interaction (Stahl, Koschmann & Suthers, 2014). As collaboration between students is beneficial for learning both science and how to do science (Jensen & Lawson, 2011), it can be argued that computer-supported CIBL may answer the many challenges (e.g. low engagement and retention rate of students (Freeman et al., 2014)) the fields of science, technology, engineering and mathematics (STEM) have faced in higher education. Indeed, a growing number of studies have suggested that in STEM-subjects lecture-based instruction and teaching should be developed towards active learning methods (e.g. Freeman et al., 2014).

Despite of positive impacts of computer-supported collaborative learning in STEM, also negative effects have been reported (e.g. Hmelo-Silver, Jeong, Faulkner & Hartley, 2017). According to Stahl (2017), for instance, collaborative learning research needs ways to investigate and visualize the group processes that bring about group practices. Therefore, it is important to study the dynamics and temporality aspects of CIBL processes, and find out what may promote or hinder the collaborative learning situations in different phases of computer-supported CIBL.

## RESEARCH QUESTIONS

This study addresses to the following research questions: *How temporality aspects of CIBL processes can be captured and visualized in technology-enhanced physics learning?*

## RESEARCH DESIGN AND METHODS

I collected data in the autumn 2016 from a seven-week introductory course of thermodynamics and optics ( $N = 70$ ) where primetime-learning model (Figure 3 and

Table 1) was put into practice. Primetime-learning model will be used in that course also in the autumn 2017 when I will collect the same set of data. I followed four small groups ( $n = 20$ ) during the whole course by screen capturing and audio recording their group working sessions in Practice-phase. Totally, there are 56 screen capture videos (14 per group, totally 60 hours). There is also log-data available from the TEL-environment. The permission to participate in the study was asked from each of the students. The anonymity of the students will be maintained when reporting about the results. In addition, the data will be stored at least five years so that only the people necessary relative to the study have access to it.



To answer the research question, I chose couple of tasks from the group working sessions that fostered the groups to computer-supported CIBL. Especially, the focus is on a problem that was about finding out how the displacement of a gas molecule depends on the number of collisions with other molecules. Relating to the problem, I studied CIBL processes of two different groups more in depth. The technological tools given were a YouTube video clip and a platform for numerical analysis. I analysed the screen capture videos and the audio recordings by using theory-based thematic analysis (Braun & Clarke, 2006) followed by data-based content analysis (Krippendorff, 2004) methods. The themes were based on the phases of the IBL (Pedaste et al., 2015). This enabled to study the dynamics of the CIBL processes when the phases of IBL were presented over time. After this, I studied the differences and similarities in the dynamics by content analysis methods. I focused on how the groups used the technological tools as an external resource during CIBL. In addition, I analysed the impact (Kapur et al., 2008) of different students to the joint CIBL process. The reliability of coding was increased by using two coders: one of which was involved in the study, and the other outside from the study who is familiar with the technology-enhanced inquiry-based framework.

## PRELIMINARY FINDINGS

Preliminary findings show the dynamics of CIBL process differs significantly between two groups under study. First, group 1 did not use the technological tools collaboratively as an external resource. Instead, they proceeded from a phase of inquiry cycle (Pedaste et al., 2015) to another without planning research questions or methods explicitly. Because of that, they had to go back to orientation phase four times after they had already proceeded to other phases, for instance. On the other hand, group 2 solved the problem in a more systematic way: beginning with orientation, then moving to conceptualisation and investigation phases while discussing with each other's, and finally making conclusions based on the technology-enhanced investigation and discussion. In the end, only group 2 succeeded to get the correct answer to the problem.

Even though the CIBL process of group 2 had the clear focus at the group level, emerged challenges of both groups were similar at the student level. When it comes to the participation inequity (Kapur et al., 2008) of the groups, there were students in both groups who did not impact nearly at all to the CIBL processes. The role of these students decreases further if considering only the utterances where the technological tools were used as an external resource. In addition, based on our findings and literature (e.g. Kapur et al., 2008), the students' roles seemed to be rather stable during the whole CIBL process. Therefore, to increase participation equity it may be beneficial to support the beginning of the CIBL processes by implementing e.g. computer-based scaffolding (Belland, Walker, Kim & Lefler, 2017) or collaborative scripts (Kobbe et al., 2007) to the TEL environment.

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# ENHANCING STUDENT DATA ANALYSIS SKILLS IN PRACTICAL WORK

**Freek Pols**

University of Technology Delft, Netherlands

## PROBLEM DEFINITION

Although practical work is part of most science curricula and courses, the role of practical work in secondary schools is still subject of debate as the learning outcomes are limited (Lunetta, Hofstein, & Clough, 2007). Many studies show that similar results often can be achieved in less time and with less costly methods. Still educators and educationalists maintain their belief in the importance and value of practical work as a way to help science students, *e.g.*, link theory to practice, develop investigative and scientific skills, appreciate the work of scientists and the nature of scientific knowledge, and motivate them to become scientists themselves. Therefore the question is how we can plan and guide practical work in such way that the learning outcomes are improved (Lunetta et al., 2007). This study focuses on the role of the teachers as, according to Tamir (1991), teachers are the key factor for success, but many studies fail to take their role into account (Hofstein & Lunetta, 1982, 2004). Furthermore, we focus on the development of data-analysis skills as analysing data is a major part of practical work (Barton, 1998), and new ICT tools are available to enhance these skills.

## LITERATURE REVIEW

Activities in science courses in which students handle or observe the objects or materials they are studying, can be categorized as practical work (Millar, Le Maréchal, & Tiberghien, 1999). These activities ought to, *i.a.*, enhance student learning and motivate students to choose science as a major subject. However, many studies show that the learning outcomes are very limited (Abrahams & Millar, 2008; Hodson, 1990; Hofstein & Lunetta, 1982; Jenkins, 1998; Lunetta et al., 2007; Millar et al., 1999; Van den Berg, 2013). Multiple explanations have been adduced for these disappointing results:

- It appears that students see practical work as separate events with little connection to theory taught in class (Tamir, 1991).
- Students might be cognitively overloaded when they have to produce, observe and explain a phenomenon using unfamiliar equipment (Johnstone & Wham, 1982).
- The learning goal is often unclear, students hardly know what the essence of the practical is and pursue other goals than the teacher has set (Chang & Lederman, 1994; Jenkins, 1998; Tamir, 1991; Watson, Swain, & McRobbie, 1999).
- Students do not see patterns and trends in data (Millar et al., 1999).

Even when the students are capable of producing the phenomenon or the desired dataset, it is questionable whether they are capable of drawing valid conclusions from these observations (Millar et al., 1999). Students often just draw straight lines through data points, even when the graph shows a curved trend (Barton, 1997; Gunstone, 1991). To draw conclusions out of a dataset, data should be

analysed, represented and interpreted in different ways. Scientists take years to interpret and explain a phenomenon based on observed data, so it would be a tall order for students to do this in a 50-minute practical (Sutton, 1994). As Wellington (1998) adds, we cannot expect students to discover theory from producing and observing the mere phenomenon alone. Students should consult, discuss, work with ideas, concepts and scientific principles in order to ‘discover’ such scientific theories. Intervention of a teacher is essential in this process (Driver, 1995). However, often the focus of practical work is usually on the manipulation of equipment instead of ideas (Abrahams & Millar, 2008) while analysing and interpreting the data is set as homework and addressed by each student on his own (Barton, 1998).

Many of the problems with practicals are related to the role of the teacher who may discuss the learning goal, highlight important aspects in procedures and observations, and guide the analysis of the obtained results. Therefore it is not surprising that Tamir (1991) argues that the teacher is the key factor for success in practical work. However, the exact role of the teacher during practical work has hardly been studied. The factors that constitute the guiding role of the teacher have so far not been identified, and the extent to which these promote or prevent student learning has not been studied. One goal of this study is to describe precisely what teachers do during practical work, and to identify what factors of the teacher’s role contribute, in what way, to the attainment of its full learning potential.

The use of modern educational technology such as the interactive whiteboard (IWB) may provide new ways for the teacher to optimise his role in stimulating student learning. Barton (1997) already showed that computers can be used to enhance students’ discussions about graphs. The intervention of the teacher was thereby crucial. The IWB can be used in a similar way as the computers. Displaying multiple datasets allows the students to compare and discuss the differences and similarities between these. By jointly analysing the results, manipulating the data, discussing anomalies and trends, the students may learn collaboratively how to analyse and describe graphs and to interpret the meanings of these data representations.

## RESEARCH QUESTIONS

The IWB offers the teacher additional possibilities to achieve learning goals during practical work. The extent to which the additional possibilities contribute in achieving these goals, depend on the way the IWB is used and the teachers’ role during the practical work. To find out how the IWB can contribute to the role of the teacher, we have to know first out of which facets the teachers’ role constitutes and how to describe this role. However, not much research is done concerning the role of the teacher during practical work and we are unaware of a typology of teacher roles. This leads to the following question:

1. *Which typology allows for a description of the actual teacher roles during small group practical work in physics in secondary education?*

With a focus on enhancing the data-analysis skills, this leads to two interwoven questions:

2. *How can the use of the IWB in physics practicals contribute to (optimise) student learning of data-analysis skills?*

3. *Which factors in the role of the teacher during physics practicals contribute to (optimise) students learning data-analysis skills, and in what way?*

## RESEARCH DESIGN

A typology of the teachers role during practical work demands three things: 1) A description of the different facets that constitute the teachers' role; 2) An instrument capable of describing these facets, *i.e.* describing the actual role; 3) Validation in practice of the typology and applicability of the instrument.

The analysis of the teachers' role into its constituting factors is determined using a literature study. An instrument capable of mapping the teachers' role during a practical work is based on extension of existing instruments, such as the Practical Activity Analysis Inventory (Millar, Le Maréchal, & Tiberghien, 1998), that each describe only a part of the teachers role. Validation in practice is based on participatory observation in a multiple case study. Twentyfive teachers are observed during a regular practical in their ordinary teaching practice. Mapping of the teacher's role is based on analyses of audio and video recordings, and pre- and post-interviews. In order to explore the relation between the teacher role and the learning outcomes, exit cards are used to allow students to demonstrate what they have learned and reflect upon the practical work. This allows us to partly answer the third research question.

Educational design research is used to approach the second research question. An intervention is developed, tested, evaluated and adjusted cyclically towards an approach that optimizes student learning (Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006). Thus the design itself, by constituting an effective approach towards attaining learning outcomes that can be understood and predicted, provides both a practical and a theoretical answer to the research question.

In evaluating the effectiveness of the practical work, to interpret and explain the observed effects and obtain design principles it is necessary to extensively monitor the teacher as well as the students. Audio- and video recordings are used to observe teacher and students actions and dialogues unobtrusively (passive observant) and analyse whether the learning goals are attained. A pre- and post-test provides a measure of the effectiveness of the practical and triangulate the data from the recordings.

## PRELIMINARY FINDINGS

The literature study shows that the extent of teacher control is one of the key factors in the teachers' role. The nature and degree of control in turn, depends on the learning goals set by the teacher. In the first case studies we started to identify which goals teachers set, how they intend to guide students and whether this intentions are realized.

The extent to which the teacher is focussing on attaining the goals, indeed seems an important part of the teachers' role. However, stated goals might change during the course as teachers try to differentiate between students or try to better match the goals to the appropriate cognitive level of the students. This makes it harder to compare the learning outcomes with the learning goals set, but gives a much better understanding of the role of the teacher and the choices that are made during the execution of the practical.

To what extent above findings are valid for different teachers with different abilities and what other factors influence the success of practical work is being investigated presently.

For the development of data-analysis skills, we developed an intervention and tested the practical in a pilot. In the practical, water is heated showing at first a linear increase in temperature. However, the data points seem to deviate from this linear trend as the temperature rises. In this practical, the interaction between students mutually and between the students and the teacher is important. This interaction, focussed on analysing the obtained data and drawing preliminary conclusions, is strengthened by the IWB as the teacher has the opportunity to ask specific questions about trends, anomalies, and interpretation of the data. Two more cycles of testing, evaluating and redesigning are planned in 2017 and 2018.

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# TEACHING THE CONCEPT OF FIELD IN PHYSICS: HISTORICAL AND DIDACTICAL APPROACHES

**Zakaria Saadi**

Université Paris Diderot, Laboratoire de Didactique André Revuz, France

## OUTLINE

The main objective of our research is to design, experiment and analyze an educational tool inspired by history of science for teaching the concept of field in physics. For this purpose we adopt an over-viewing approach of the concept of field in physics focusing on interaction fields. Earlier research has been carried out to show the specific misconceptions and difficulties linked to magnetic, gravitational or electric field. Indeed many papers report students' interpretation of fields' behavior in a given medium or their conceptions about the field lines representations. It seems that the multiple uses and the level of abstraction needed to apprehend this notion for describing, interpreting and predicting physical phenomena justifies our choice to make a comprehensive study. Moreover the question of the intervening medium of interactions retained our attention. From a historical perspective the first use of the term field applied to a field concept in physics is attributed to Faraday during the XIXth century (Darrigol, 2003). From then on, the field view gave a powerful explanatory framework to face the problem of action-at-a-distance – a question that has been feeding a rich controversy among scientists and philosophers through history. From an educational perspective, the introduction of the concept of field in France at grade 11 (age 16-17) does not meet clear conceptual needs. The French national curriculum provides several recommendations stating that pupils should be able to *“describe the field associated with the physical properties that occur at a point in space”* and *“understand how the notion of field has historically emerged from experimental observations”* (BOEN, 2010). In continuation of this classical physics courses, the field concept is mainly reused during electromagnetism courses at university level while introducing Maxwell's equations. And the gravitational field is mainly presented in the framework of classical physics until the introduction of general relativity at a Master degree level. While we should be careful with any attempt to make a broad parallel between students' conceptions and scientists' concerns, our research aims to design a teaching sequence based on historical materials able to provide conceptual arguments to students and prospective teachers when dealing with the concept of field.

## LITERATURE REVIEW

Research in physics education abounds with studies on the difficulties encountered by students when facing the concept of field, its representations, its formalism in mechanics and electromagnetism (Bagheri-Crosson et al., 2002). Venturini et Albe (2002) show that students have difficulty giving a physical meaning to the fundamental concepts of electromagnetism and establishing links between them. Tarisco et al. (1998) conducted a study on the mental models about magnetism and identified obstacles in using the magnetic field concept. The authors also showed that students used their

knowledge in electricity to reason about magnetism problem. In the case of the electric field and students' associated reasoning, Rainson et Viennot (1992) show that when placed in situations where the influence of several factors on the electric field must be taken into account, students follow a "linear causal reasoning" and often believe that a cause exist only in cases of obvious effect. There are also problems in students' interpretation of graphical representations of the field lines, (which shows) showing the existence of deep misconceptions (Törnkvist et al., 1993). In their research, Chabay et Sherwood (2006) who argue for a clarification in the way the field concept is introduced, found a mean to use suitably the field line representations by relying on 3D representations. According to Galili (1995), the presence of an electromagnetic field can affect the interpretation and use of mechanical concepts previously taught in class. He thus observed a difficulty for students to apply 3rd Newton's law in the presence of an electromagnetic field. The author also suggests to make a clarification in introducing the concept of field especially in its historical aspects. Further research try to draw parallels between students' reasoning and historically introduced models (Bar et Zinn 1998). By the way, in accordance with the french national curriculum on the role of science and questions related to Nature of Science, history of science is presented by Matthews (1994) as a motivating and useful teaching tool able to give explanatory levers linked to the students' scientific questioning. Earlier research has been carried out and found evidences for a possible didactical efficiency of teaching sequences based on history of science. A framework in particular - the *didactical reconstruction* - will be useful to design our sequence (de Hosson, 2011; Duit et al., 2005; Mäntylä et al., 2011).

## RESEARCH QUESTIONS

The overall objective presented in the "Outline" part involves specific research questions (RQ). We manage a first (preliminary) epistemological work in order to give a definition of what underlies the concept of field in physics that could be formulated as following:

- 1) *What kind of field's characteristics should we retain for a teaching sequence designed for first year university students?*

In the same time, we answer the nature of students' conceptions when starting a general physics cursus:

- 2) *What do current teaching promotes regarding the field in physics? What kind of implicit model underlies the teaching/learning processes of the field concept at a high school and university level?*

Through a dialectic relation between these two concerns, we try to identify historical materials that should be relevant for a teaching sequence:

- 3) *To what extent arguments, representations, models identifiable in history of science are likely to fill conceptual difficulties at a given level, and remediate misconceptions and difficulties related to the field concept?*



## RESEARCH DESIGN AND METHODS

In order to address RQ1 we performed an epistemological inquiry that included a content analysis of university level and grade 11-12 textbooks. We interviewed a member of the physics' national curriculum designers and analyzed the scientific or experts' speech regarding the concept of field. We managed at the same time a first historical inquiry aiming at enlightening our reflexion on the epistemology surrounding the emergence of the field concept. We tried to identify the constraints and requirements that have historically led to the concept of field and their possible use as didactical key-arguments integrated into a teaching sequence (Darrigol, 2003 ; Hesse, 1962 ; McMullin, 20002). RQ2 requires an accurate knowledge of the conceptual difficulties reported in the research. A meta-analysis of the results helped us design a questionnaire that has been submitted to 147 first year university students enrolled in a general physics cursus. After a first open question asking them what is a field for them in physics, the survey evaluates their understanding of field representations and static field interactions with matter, vacuum and detectors such as compasses. The preliminary results and the analysis that is still in progress will help us identify and restrain our historical material. Then we plan to perform a *didactical reconstruction* and develop (up to April 2017) a teaching sequence for first year physics university students. We expect to experiment the sequence with students who have not yet followed Electromagnetism courses. For this purpose we are currently working on the sequence ergonomics. Our dataset should include paper tests and audiovisual recording of the sessions that will be analyzed.

## PRELIMINARY FINDINGS

The origin of the difficulties showed up in earlier researches may stand in the conceptual complexity and the level of abstraction of the concept of field itself. In addition to possible confusions attributable to the authors, the conceptual networks inferred from the textbooks at high school level seems to indicate a lack in the generalization processes that is confirmed with our sample of students. We found that there is a tension between declared intentions that present the field concept as a unifying and generalizing concept and the ostensive approach adopted by the textbooks and the national curriculum. Then, the vectorial/scalar subclassification seems to have screened the explanatory interest of the field concept. At any level (university or high school) we see a separation between different kind of fields that could be correlated to an underestimation of transversal and general features that they have in common (interaction-at-distance, propagation, nonlocality, interaction with matter, etc.). The analysis of the survey shows that students attribute a different role to electric fields in comparison with magnetic and gravitational fields. Our sample of students tends to have a newtonian-like representation of bodies acting at-a-distance. While research shows the difficulty for students to understand that there is an electric field between field lines (Törnkvist et al., 1993), we observe on the contrary that the existence of a gravitational field between field lines is well assimilated by the students.

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# SELF-REGULATED LEARNING IN A PHYSIC EXPERIMENTAL ENVIRONMENT

Vanessa Schad

University of Koblenz-Landau, Germany

## RESEARCH FOCUS

The aim of this study is to investigate how students can be encouraged to use their physic content knowledge while experimenting self-regulated in an experimental learning environment. A successful self-regulated learning process requests students to structure their problem-solving process and to apply their prior knowledge to the new situation. To that students need to be supported. In this study, students receive a strategy training where they should learn strategies for structuring and linking their knowledge before starting to work in the experimental environment. Moreover, while working in small groups with the experiments, they are prompted in order to stimulate them to apply these strategies. In this study, the self-generated structure of the problem-solving process and the use of physic knowledge are captured and the influences of the training and prompts on both are investigated.

## THEORETICAL BACKGROUND

Studies show that students neither work systematically and strategically on experiments (Walpuski & Sumfleth, 2007; de Jong & van Joolingen, 1998) nor do they use their prior content knowledge to explain new situations (Klauer, 1992), as it is required in an succesful experimental problem-solving process. Because a teacher cannot support the learning processes of every student group at the same time, is is important to enable students to work self-regulated in such settings. Self-regulated learning in experimental environments supports two aims: *scientific* experimenting as well as activating and involving prior knowledge (Wirth & Leutner, 2006). An adequat process to reach the first aim can be described by a scientific problem-solving process according to the SDDS-Model (Klahr & Dunbar, 1988) with the “absolutely necessary operational elements”: perceiving and understanding the problem, developing hypotheses, testing hypotheses and evaluating applying solutions (Oser & Baeriswyl, 2001, p. 1053). It includes that students use appropriate strategies, as for example the variable control strategy (Klahr, Dunbar & Fay, 1991). Reaching the second aim also requires the use of appropriate strategies, such as revision strategies, elaboration strategies and organisation strategies (Weinstein & Mayer, 1986). The german curriculum already defines an organisation strategy for structuring physical knowledge and suggest that students learn to use the four *basic concepts* (system, interaction, energy, particle-matter) when approaching new situations and linking them to previously learned knowledge (Ministerium für Bildung, Wissenschaft, Weiterbildung und Kultur, 2014). However, Thillmann, Künstig and Leutner (2009) describe a *production deficiency*: Although the students have strategic knowledge they don’t use it appropriately in a self-regulated experimental situation (Flavell, 1976; Veenmann, Kerseboom, & Imthorn, 2000). A supportive and interactive learning environment could help to solve this dilemma (Pintrich, Marx & Boyle, 1993). Accordingly, the problem-solving process is seen as an interaction of external support und internal regulation (Koedinger & Aleven, 2007). Strategy

trainings are a successful way of direct external support (Klauer, 1988). However, although they support learning they don't ensure strategy use (Friedrich & Mandl, 1992). Indirect support can be successfully provided by prompts which activate already existing strategic knowledge (Lin & Lehman, 1999). Prompts help to overcome the production deficiency and promote the strategy use. So far, however, the positive effect of prompts on self-regulated learning could only be shown for scientific experimenting, because students had no strategies for integrating their knowledge and, therefore, couldn't be prompted to use them (Thillmann, 2008; With, 2009). The question is open, if a combination of strategy training and prompts could promote student's use of strategies for integrating prior knowledge while experimenting.

To sum up, self-regulated learning in experimental environments supports two aims, scientific experimenting and activating and integrating knowledge. In this study it will be investigated how students can be encouraged to reach the second aim. Therefore, the experimental environment includes direct and indirect support. Students learn an organisation strategy in a strategy training before experimenting and get prompts while working in the experimental environment in order to activate them to use this strategy. In the strategy training, the students learn to map their knowledge scheme using the before mentioned basis concepts. These knowledge schemes give an external structure aid and support the integration and remembering of knowledge (Kopp & Mandl, 2006). Thus, the students should be able to use the basic concepts to apply their knowledge in new situations.

## **RESEARCH QUESTION**

How does a combination of strategy training and prompts affect students in integrating their knowledge in a scientific problem-solving process in small groups? Is the influence of strategy training and prompting on integrating knowledge mediated by students' actual use of basic concepts during the solving process?

## **STUDY DESIGN AND SAMPLE**

In a pre-study data from students in 5 classes in grade 10 at German upper secondary school was collected to explore and elaborate the training, prompts, and observation tools. Students were videotaped while experimenting in groups of four in a barely structured environment on the problem "Why do airplanes fly?" (adapted from INTeB, Wagner, 2016). In this experimental environment the students have to pass three experiments. Each gives a partial solution for the main problem "Why do airplanes fly?" based on two basic concepts (system, interaction). After experimenting, students presented a solution for the set problem. Using the videos from the pre-study, a coding manual of Heine and Kauertz (2013) is adapted to describe the structuring of the problem-solving process and a coding manual of Knobloch (2011) is adapted to describe how students integrate their content knowledge in the process. In a second study, data from a total sample size of about 255 students in grade 10 at German Gymnasium, which means 85 groups of three students, is collected in a similar way. The second study follows an experimental control group design with the support in experimental environment as the independent variable. The experimental group will perform strategy training before experimenting (Kopp & Mandl, 2006) and will receive prompts while experimenting (Lin & Lehmann, 1999). The control group will work the same time on task while the experimental group receive the strategy training. In the

experimental environment, the control group doesn't receive external support. Both groups receive a brief written introduction to the physical concepts needed to explain why airplanes fly.

## METHODS AND INSTRUMENTS

Video data will provide information on the two dependent variables: 1) how the student's structure the problem-solving process, gathered by a coding manual based on Heine and Kauertz (2013); and 2) how students integrate new information from the experiments into their existing knowledge structure, observed with categories from Knobloch (2011) describing the complexity of knowledge. Additionally three control variables are considered: prior knowledge, strategic knowledge (Thillmann, 2008), and interest and motivation (Blumberg, 2008). Knowledge and strategic knowledge is tested in a pre-post design while interest and motivation is only gathered in the first measurement.

## STATUS OF THE STUDY

Data collection for the first study was finished in April 2016. The development of a coding manual to analyse the videos with regard to structuring of the problem-solving process and integrating of knowledge is almost finished, but still in progress. Data collection for the second study will take place from February till April 2017. At the summer school data from the first and partly second study are available and the interpretation and limitations of the study could be discussed.

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## **SESSION L: SCIENCE LEARNING**

# THE EFFECTS OF LEARNING ACTIVITIES BASED ON ARGUMENTATION ON CONCEPTUAL UNDERSTANDING OF 7TH GRADERS ABOUT “FORCE AND MOTION” UNIT AND ESTABLISHING THINKING FRIENDLY CLASSROOM ENVIRONMENT

**Ayşe Buber**

Dokuz Eylül University, Turkey

## INTRODUCTION

Argumentation is a process in which different opinions are evaluated by individuals (in same or different viewpoints) to solve a problem, understand a phenomenon, decide on an issue or put forward opinions, criticize and evaluate these opinions and it is also all of the operations in this process and cognitive products as a result of evaluation of the process (Kuhn 1993, 1992, 1991; van Eemeren 1996, 1995; Simon, Erduran and Osborne 2006). This concept is explicitly stated in 2013 Turkish Science Curriculum as a new approach, and helps to explain the inquiry process not only “discovery and experiment” but also “explain and create argument” (Turkish Ministry of National Education Board of Education and Discipline Primary Science Curriculum [MEB] 2013). In the argumentation process students not only learn the science concepts and identify the knowledge, but also construct old knowledge and scientific rules to new conditions by asking questions, make contact between own knowledge and environmental phenomenon, create arguments and claims and also use reasoning skills (Dori and et al. 2000). When the argumentation is examined as a part of thinking process, it can be seen that it takes an active role in construction of knowledge (Kuhn 1993; Lawson 2003). Because argumentation includes process of rebutting opposite opinions and making run the opinions in the practice stage, it is related to conceptual change and higher order thinking skills closely (Dole and Sinitra 1998). Perkins (1992) emphasized that ‘learning is a consequence of thinking’ which can be interpreted as learners are active thinkers about what they are learning and when it is thought that argumentation process consisted of different thinking ways, argumentation is one of key to learn scientific concepts by using thinking.

In this respect it is believed that the activities for this research contribute students’ conceptual understandings and teachers and student’s behaviors which are indicative of thinking. Therefore, this study aims to answer following research questions:

- 1) *Is the learning activities based on argumentation in seventh grade “Force and Motion” unit effective on students’ conceptual understandings?*
- 2) *Is the learning activities based on argumentation in seventh grade “Force and Motion” unit effective on establishing thinking friendly classroom environment?*

## RESEARCH DESIGN

This study is based on pretest-posttest control group quasi-experimental research design in which the researcher seeks out effects of treatment on the independent groups which are assigned as



experimental and control groups (Cothari 2004). The control and experimental groups are assigned randomly. The experimental design of study is presented in Table 1.

Table 1. Experimental Design of the Research

<i>Groups</i>	<i>Pre-tests</i>	<i>Treatment</i>	<i>Post-tests</i>
Experimental Group (N=19)	T1, T2	Learning Activities Based on Argumentation	T1, T2
Control Group (N=20)	T1, T2	Regular Science Education depending on Turkish Science and Technology Curriculum (2005)	T1, T2
T1: Force and Motion Concept Test, T2:Thinking Friendly Classroom Scale			

### *Participants*

The participants of this research are 7<sup>th</sup> graders of a secondary school in one of the cities located on the north west of Turkey. A total of thirty nine 7<sup>th</sup> grade students (N=19 in experimental and N=20 in control groups) took place in the research. Before the research, experimental group students had argumentation preparation courses about how to conduct practices in the activities and also how to use components of argumentation process.

### *Instruments*

The instruments which were mentioned below were given to students at the beginning and at the end of the “Force and Motion” unit.

*Force and Motion Concept Test:* In order to determine students’ conceptual understanding levels before and after the treatment, 7<sup>th</sup> Grade Force and Motion Unit Concept Test (FMCT) which was developed by Yıldız (2008) was used in the research. FMCT has 18 two-tier item with KR-20 reliability coefficient of .77 originally. The highest score of this test is 18 point and the lowest score is 0 point. While the higher score shows that student has high misconceptions, the lower score shows that student has low misconceptions.

*Thinking Friendly Classroom Scale:* In this research, the purpose of using ‘Thinking Friendly Classroom Scale (TFCS)’ is to figure out student’s behaviors about learning thinking and how teaching strategies, methods and techniques support thinking in their science courses and was developed Doğanay and Sarı (2012) and internal consistency is 0.89 for whole scale. TFCS is likert-type rating scale and has 30 items. The highest score of test is 120 and the least score of test is 30. The higher score of scale shows that the classroom environment has positive features about student’s thinking.

### *Analyses*

The analysis of data collected through each quantitative data collection tool was analyzed by Shapiro-Wilk Test in order to test whether the data display normal probability plots (Tabachnick and Fidell 2013). Therefore Independent Samples T-Test was used comparing experimental and control groups’ pre and posttests and Paired Samples T-Test was used comparing experimental group’s pre and posttests and control group’s pre and posttests.

## PRELIMINARY FINDINGS

The current study investigated the effectiveness of learning activities based on argumentation on students' conceptual understanding and establishing thinking friendly classroom environment. The descriptive statistics results showed that the learning activities based on argumentation improved the mean FMCT scores of experiment group more than control group as both groups were increased their scores to some degree from the pretest to posttest and the mean increase was higher for the experimental group. And also the mean TFCS scores of experiment group is developed more than control group however, while experiment group increase their score to some degree from the pretest to posttest, control group decreased their score to some degree from pretest to posttest. It may be claimed that, learning activities based on argumentation made increase experiment group's FMCT and TFCS scores.

Following the descriptive statistics, when the comparison for scores of FMCT and TFCS are examined for statistical significance, it is seen that learning activities based on argumentation made significant effect on establishing thinking friendly classroom environment but no significant effect on students' conceptual understandings. The effect size is .167 and so 17% (large effect size) of the variance which is found in TFCS is bound up with learning activities based on argumentation approximately. Moreover, Cohen d coefficient is .87 which shows that the difference between TFCS means scores of experimental and control groups' standard deviation is .87. In other words, learning activities based on argumentation significantly affected the experimental group's TFCS scores by comparison with control group.

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# STUDENTS' LEARNING PROCESSES OF SCIENTIFIC INQUIRY KNOWLEDGE AND ABILITIES

Jörn J. Hägele

Justus-Liebig-Universität Gießen, Germany

## FOCUS OF THE STUDY

Researchers and policymakers agree that science education should foster students' knowledge and abilities of scientific inquiry (Crawford, 2014; National Research Council, 2012). A number of studies have investigated in which ways students' knowledge and abilities of scientific inquiry (SI) can be promoted effectively. A question that has been discussed in the context of these studies is whether students develop SI knowledge and abilities solely by engaging in inquiry activities (implicit instructional approach) or if knowledge and abilities of SI have to be targeted explicitly (explicit instructional approach; e.g., Dean & Kuhn, 2007; Klahr & Nigam, 2004). In order to investigate students' learning in such instructional approaches, students' learning gains are typically compared pre and post to instruction. In the study reported in this paper, a process-oriented perspective is added: Using video recordings of students working in small groups on an explicit and an implicit instruction that targets three facets of inquiry (formulating questions and hypotheses, planning investigations, and analyzing and interpreting scientific data), we seek to explore how the instruction promotes students to develop and use SI knowledge and abilities. Additional pre- and post-test data can be used to analyze the relationship between process data and learning gains.

## THEORETICAL FRAMEWORK

SI is conceptualized in several different ways (Crawford, 2014); some approaches assume that it has (at least) a procedural component (i.e., knowledge and abilities of SI) and an epistemic component (i.e., knowledge about the nature of SI). It has to be stressed that the procedural component not only comprises abilities (and skills), it also includes knowledge; *both* are necessary to engage successfully in inquiry activities (see Osborne, 2014, p. 189). In order to, for instance, correctly analyze and interpret data, students may need the ability of tabulating these data appropriately. In order to create tables and corresponding graphs, students need to know about the concepts of independent and dependent variables and in which columns, respectively axes, these should be inserted. The epistemic component comprises knowledge *about* procedures, e.g., knowing that there is no single scientific method followed by all scientists (Lederman et al., 2014). Despite the relevance of the epistemic component, this study concentrates on the procedural component of SI.

Some instructional approaches stress that not only are inquiry activities relevant to promote students' knowledge and abilities of SI, but also it is important to elaborate on corresponding knowledge (e.g., concepts of dependent and independent variables) and practice its application during SI. These approaches can be referred to as *explicit instruction*. In contrast, *implicit instructional approaches* are based on the assumption that engaging students in (structured) inquiry activities fosters their related knowledge and abilities automatically (e.g., Holliday, 2006). Studies investigating and comparing explicit

and implicit approaches show that generally explicit instruction is superior to implicit instruction (Klahr & Nigam, 2004; Lazonder & Egberink, 2014). However, under certain circumstances (e.g., duration of instruction) implicit instruction can be equally effective (e.g., Dean & Kuhn, 2007; Vorholzer, 2016).

In order to investigate differences between explicit and implicit instruction on SI, studies typically use a quasi-experimental design and assess students' knowledge and abilities of SI before and after the instruction with paper-pencil test instruments (e.g., Chen & Klahr, 1999; Lazonder & Egberink, 2014). Such an analysis of instruction and its effects provides a (valuable but) partial picture of what caused differences in students' learning in an explicit and implicit instructional approach, since the actual learning processes remain a black box in between the assessment. Analyzing students' verbal and nonverbal activities while working on the instruction can provide valuable insights into what may have caused differences in students' learning of SI and how students develop knowledge and abilities of SI in an explicit or implicit instructional setting. Main research questions about the SI learning processes are:

- 1) Within each instructional approach: *(How) do students with high increase of SI knowledge differ from those with low increase in (a) frequency and/or quality of SI-related activities and utterances, (b) frequency and/or quality of content-related activities and utterances (indicating a better understanding of the topic which may help to understand SI better), (c) other patterns such as situated experiences of their activities / engagement in activities?*
- 2) Between the instructional approaches: *(How) does students' development of SI-related abilities and knowledge differ between explicit and implicit instruction? (Analyses can use results from (1) as a foundation.)*

## RESEARCH DESIGN AND METHODS

Data were collected by Vorholzer (2016) in 2013 with a quasi-experimental design consisting of three phases: pretest, intervention, and posttest. The intervention comprised three units in the context of mechanics. The units addressed the three facets *formulating questions and hypotheses, planning investigations, and analyzing and interpreting scientific data* as these facets are considered relevant for SI (e.g., Rönnebeck, Bernholt, & Ropohl, 2016). Duration of the units added up to 225 minutes (45+90+90 min); the entire instruction was written down on cards trying to avoid teacher-interaction so that comparison is possible. The sample consisted of twelve parallel classes ( $N_{\text{Pre-Post}} = 204$  students), the students were about 16–17 years old. Six classes were assigned to the treatment group (TG) and received the explicit instruction. Six classes were assigned to the control group (CG); they received the implicit instruction. Within TG and CG, the students worked in teams of 2–3 each on the instruction. Pretest results were used to ensure that the TG classes and CG classes were as similar as possible regarding dispositional factors such as cognitive abilities and interest in physics.

A paper-pencil based pre- to posttest comparison was conducted by Vorholzer (2016). To investigate students' learning processes in the context of explicit and implicit instruction, the study reported in this paper combines data from this comparison with data from the video footage of the

students' activities recorded during the intervention. The study focuses on the analyses of the video recordings of  $N_{\text{video}} = 95$  students (56,8 % female, 2–3 students per team, 24 CG teams, 18 TG teams).

For the analyses of the videos, a coding scheme has been developed to investigate students' activities and their utterances for both SI and content. In order to gain a more coherent picture about the process, further variables have been added, for instance, students' situational affective utterances while working on the instruction (see Fig. 1). The coding scheme also assesses the unit and the task on which the students are working.

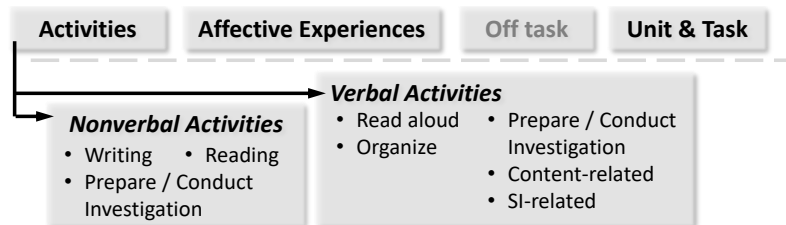


Figure 1. Main codes of the current coding scheme.

The development of the coding scheme has been taking into account preexisting coding schemes (e.g., Steckenmesser-Sander, 2015) as well as categories derived inductively during the analyses.

A key element of the coding scheme is the differentiation between content- and SI-related utterances ("verbal activities"). *Content-related* is coded when students' utterances refer to content knowledge (e.g., "The heavier an object is, the quicker it falls down"; "This release angle will make for a wider distance"). *SI-related* is assigned to students' utterances that seem to be based on their understanding of SI (e.g., "Well, you have to remember that one should always vary not more than one variable at the time"; "Here, the independent variable is the height"). Furthermore, the code *Prepare / Conduct Investigation* is used to differentiate SI-related utterances from comments on what a student (herself/himself or another group member) is doing or should do in the context of preparing or conducting an investigation (e.g., "Hold the ruler horizontal, please").

## PRELIMINARY FINDINGS AND OUTLOOK

So far, video recordings of four teams of the TG working on the second unit have been coded. This data have been analyzed using a graphical representation of all codes (Fig. 2). Preliminary findings indicate that activities regarding preparing and conducting investigations (both verbal and nonverbal) are roughly of the same quantity and duration for the four groups.

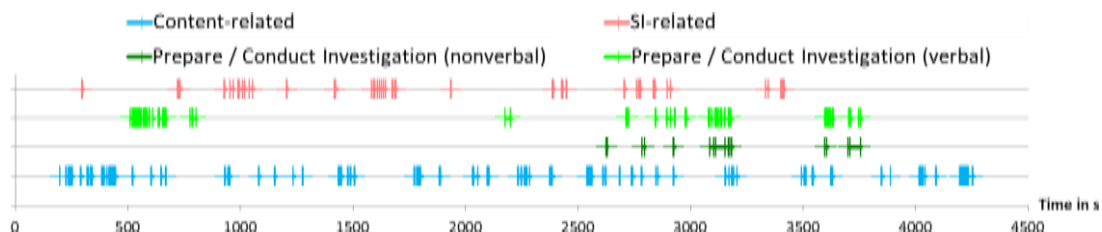


Figure 2. An example of the graphical representations of the codings for all members of one team working on unit 2.

Interestingly, most of the SI-related utterances appear in-between but not during experimentation phases (which are marked by many codes of verbal and nonverbal preparation and conducting). A comparison of the codes with the paper-pencil data indicates that students with a higher average pre–post increase in knowledge and abilities of SI show more SI-related utterances during the intervention (see research question 1).

Further analyses will focus on, e.g., the factors that trigger students to elaborate on SI-related aspects. To investigate this and other questions, a validation of the coding scheme and a verification of the findings presented above are needed first. Results of the validation and more detailed analyses of these and additional groups will be presented at the ESERA Summer School 2017. Furthermore, the codes and other approaches to the data shall be discussed critically—particularly with respect to students’ development of knowledge and abilities of SI (see research question 2).

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# THE ENERGY TRANSITION AS A CONTEXT FOR SECONDARY SCIENCE EDUCATION

Sybille Hübner

Leuphana University Lüneburg, Institute for Sustainable and Environmental Chemistry, Germany

## FOCUS OF THE STUDY

The energy transition is a core strategy to contain the human-induced climate crisis. In order to foster scientific literacy in terms of an active participation in societal communication and opinion making, it is important to actively address this topic in science education. In favour of this, students need an appropriate understanding of the scientific background of the energy transition because a lack of knowledge in this field can lead to an inappropriate choice of action (Cotton, Miller, Winter, Bailey, & Sterling, 2015).<sup>1</sup> The main goal of the PhD-project at hand is to provide an evidence-based background for the development of learning sequences that support an appropriate understanding of the energy transition from non-renewable to renewable energy resources<sup>2</sup> in the perspective of natural sciences. Therefore, the inquiry of the students' preconceptions and the clarification of the scientific background are essential.

## REVIEW OF RELEVANT LITERATURE

The German *Energiewende* (Eng. energy transition) means the transition from fossil and nuclear energy resources to renewable energy resources. From a natural scientist point of view the *Energiewende* is necessary to reduce the emission of greenhouse gases and to prevent nuclear waste (WBGU<sup>3</sup>, 2003, 2011). Concerning the term "renewable energy" there is a common agreement that energy resources derived from the sun (indirectly including wind, hydropower, biomass), geothermal heat and tidal action are considered to be renewable (e.g. WBGU, 2003, 2011; Spellman & Bieber, 2011). In contrast to this, other definitions of "renewable energy" based on scientific criteria seem to be difficult to formulate. One example for a vague definition is renewable energy resources being characterised as "*naturally replenished*" (e.g. Spellman and Bieber, 2011: 8). This is debatable because it could be claimed that fossil fuels are also naturally replenished, although this process takes billions of years. Furthermore, the sun is considered to be a renewable energy resource though its nuclear processes will come to an end sometime in the far future. Other publications avoid the definition problems by implicitly assuming a common shared understanding of "renewable energy resources" (WBGU, 2003, 2011).

Due to the vagueness of technical terms it is not surprising that there are studies that suggest that students are having problems with defining the phrase "renewable energy source" in a scientifically appropriate way and with correctly assigning energy resources like natural gas or geothermal heat to the groups "renewable" or "non-renewable" or (e.g., Bodzin, 2012; DeWaters & Powers, 2011). In his study, Menhe (2006) let students justify given examples announced to be renewable energy resources or fossil

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<sup>1</sup> I am aware that knowledge does not automatically lead to action.

<sup>2</sup> In the following, I avoid using the rather unspecific and misleading term "energy" and speak of energy resources.

<sup>3</sup> WBGU is the German acronym of the German Advisory Council on Global Change of the German government

fuels. He found three categories of conceptions<sup>4</sup> of fossil fuels (they cause pollution, are limited, vanish after usage) and two categories concerning renewable energy resources (are natural, are reusable). Since the terms “renewable” and “non-renewable” are used to classify energy resources it remains to be researched which conceptions lead students to assign different energy resources to one of these categories. The model of educational reconstruction (MER) stresses that considering both students’ and scientists’ conceptions<sup>5</sup> of a specific content are a crucial starting point for effective learning sequences (Duit, Gropengießer, Kattmann, Komorek, & Parchmann, 2012). In the case of the energy transition this is particularly relevant as potential obstacles for understanding the scientific reasons and circumstances of the switch from non-renewable to renewable energy resources lie in the students’ as well as in the scientists’ conceptions.

Using the MER Niebert and Gropengießer (2013) emphasise the impact of embodied cognitions on conceptions (both scientists’ and students’). Based on the theory of Lakoff and Johnson (1980) they stress that we use bodily experiences from a source domain to understand and explain phenomena of an abstract target domain.<sup>6</sup> In most cases this is not a process people are aware of. It helps them to understand abstract issues. Since the energy transition is a rather abstract content it is likely that students and scientists use embodied cognitions, which has not been researched in this context yet. In our language the underlying experiences are shown in the use of certain metaphors.<sup>7</sup> As Niebert and Gropengießer (2013) demonstrate, the analysis of conceptual metaphors within students’ and scientists’ conceptions are a fruitful starting point for the design of effective content-related learning experiences.

## RESEARCH QUESTIONS

The aim of the study is to provide an evidence-based background for teaching sequences that foster the scientifically appropriate understanding of the energy transition from non-renewable to renewable energy resources. Based on the theoretical background and the MER presented above the following research questions derive:

- 1) *How do secondary school students conceptualise renewable and non-renewable energy resources?*
- 2) *How do scientists conceptualise renewable and non-renewable energy resources?*
- 3) *Which differences and similarities derive from the comparison of the students’ and scientists’ conceptions of renewable and non-renewable energy resources?*
- 4) *What conclusions could be drawn for effective teaching elements concerning the topic of energy transition?*

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<sup>4</sup> Throughout this synopsis, I refer to a moderate constructivist point of view of learning and teaching. Therefore, by the term “conceptions” I mean a mental construct of a phenomenon.

<sup>5</sup> I speak of conceptions here, as even scientific knowledge published in papers or books in a constructivist point of view can be seen as a shared mental construct of a certain scientific community.

<sup>6</sup> For example, we speak of “having a long way to go” (source domain: bodily experience of walking on a path with a start and a goal), if we refer to a task (target domain) that has to be accomplished.

<sup>7</sup> In my study I follow the definition of (Lakoff & Johnson, 1980), whereas metaphors are understood as words or phrases that have more than the direct meaning for the speaker and have a source domain from which they are applied to a target domain.



## RESEARCH DESIGN AND METHODS

My research design is also based on the MER (Duit et al., 2012). I analyse the conceptions to design and evaluate a teaching sequence fostering the understanding of the energy transition. Due to the explorative character of this study qualitative methods are appropriate.

To investigate the learners' conceptions I conducted guideline-based, problem-centred interviews (Niebert & Gropengießer, 2014) with 27 8<sup>th</sup> grade students (20 pair interviews, seven single interviews) from different school-types in Northern Germany. The interview included a narrative impulse with cards that pictured nine different renewable and non-renewable energy resources (coal, oil, natural gas, biomass, uranium, wind, sun, water, geothermal heat). The students started with commenting on the cards. After that they should organize them according to their own criteria and explain their classification. If not done before, the students then should sort the cards into the categories renewable and non-renewable energy resources. The interviews were audiotaped, transcribed and anonymised.

To analyse the scientists' conceptions, I chose sections of two reports of the WBGU (2003: 47-102, 2011: 118-128), because they include a wide and substantial collection and evaluation of the relevant aspects of the energy transition.

Transcripts and report sections were analysed with qualitative content analysis (Mayring, 2002). First, I inductively identified categories that the students used to describe renewable and non-renewable resources. I analysed the transcripts of the interviews until I reached a theoretical saturation. In the next step, I deductively applied the categories I found to the report sections. Partially, further categories had to be added inductively.

To understand the underlying embodied cognitions that are used by the students and the scientists to explain renewable and non-renewable energy resources, I will analyse conceptual metaphors (Schmitt, 2017) in the transcripts of the students' interviews as well as in the scientific texts. The findings will be used to structure learning interventions to foster appropriate conceptions of the energy transition. So far, I plan to conduct the interventions with a group of learners and videotape it. Then the video will be analysed with qualitative content analysis (Mayring, 2002) including the analysis of metaphors (Schmitt, 2017) to evaluate if the intervention is able to support the construction of appropriate conceptions concerning the scientific background of the energy transition.

## PRELIMINARY FINDINGS

Via the qualitative content analysis of the students' interviews and the scientific reports I could identify six categories used to characterise renewable and non-renewable energy resources (availability, consequences of use, producibility, conservation, naturalness, costs). Comparing the students' and the scientists' conceptions I found that they share only two of these categories: availability and consequences of use. Only the students use the categories producibility, conservation and naturalness whereas the category cost is only found in the analysed scientific report.

The results of the content analysis were critically discussed in our working group to meet the quality criteria for qualitative research (Mayring, 2002). This part of my study is completed.

Until the ESERA summer school, I plan to have preliminary findings of the analysis of the metaphors. During the summer school, I would like to critically discuss the results and how to integrate them with my previous findings. It would also be helpful to reflect on the research design for the 4<sup>th</sup> research question.

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# THE UNDERSTANDING OF EVOLUTION AT PRIMARY SCHOOLS IN THE UK: CAN AN INTERVENTION IMPROVE CONCEPTUAL UNDERSTANDING?

Jennifer McGowan-Smyth

University of Oxford, United Kingdom

## FOCUS OF THE STUDY

The study aims to examine the impact of a teaching intervention on the understanding of evolution of 10-11 year olds at primary school in England. The study involves the development of an instrument to assess the understanding of children and the implementation of a teaching intervention. The study is timely as recent changes to the Primary National Curriculum in England saw the inclusion of evolution for the first time in the science statutory requirements for 10-11 year olds (National Curriculum in England, 2013).

Evolution is the unifying concept in biological science and yet it is widely misunderstood, attracting controversy and media attention especially when discussed within an educational context (Rosengren, Brem, Evans and Sinatra 2012). There is a void of empirical research with primary-aged children and this study will attempt to address the significant lack of literature in the UK, by examining the current levels of conceptual understanding and exploring teaching approaches that aim to improve understanding.

## REVIEW OF THE LITERATURE

Evolution is considered to be a widely misunderstood topic with a growing body of research to show that adults from a variety of educational backgrounds, including biology undergraduates, hold many incorrect conceptions of evolution (Shtulman 2006, Shtulman and Calabi 2013, Gregory and Ellis 2009, Evans, Spiegel, Gram, Frazier, Tare, Thompson and Diamond, 2010). Therefore, it seems unlikely that simply learning the facts will lead to a secure understanding of evolution by primary school children and it is more likely that a significant restructuring of thinking is required (Vosniadou, 2013). When a substantial revision of existing knowledge is required to acquire new conceptual knowledge the process of learning is called conceptual change (Duit and Treagust, 2003). For evolution there are two opposing conceptions termed *variational* and *transformational* by Mayr (2001). The process of conceptual change would take an individual from the incorrect transformational conception to the correct variational one.

The variational understanding is the accepted Darwinian viewpoint that variation exists randomly within a species and is not determined by purpose or intention. This variation is essential for the process of natural selection as some individuals will have traits that make them better or worse suited to their environment and the population will experience differential survival which in turn leads to differential reproduction. The subsequent generation will show a greater frequency of any beneficial trait and a reduction in any trait that has a detrimental effect on survival. The transformational understanding is the rejected Lamarckian approach which focuses on the inheritance of acquired characteristics that an

individual has obtained due to the benefit that characteristic provides during its lifetime. The offspring then inherit the beneficial acquired trait.

These two conceptions exist along with a transitional phase where individual's explanations may exhibit characteristics of both a variational and transformational understanding (Shtulman and Calabi, 2013). Shtulman (2006) identified six introductory level concepts that need to be addressed during science education if a secure variational understanding of evolution is to be achieved. The six concepts as well as their variational and transformational interpretations are summarised in table 1.

Table 1. Summary of variational and transformational interpretations adapted from Shtulman (2006).

Concept	Variational	Transformational
Variation	Individual differences drive selection.	Individual differences are non-adaptive.
Inheritance	The heritability of a characteristic is determined by genetics.	The heritability of a characteristic depends on how beneficial it is.
Adaptation	Adaptation depends on differential survival and reproductive ability.	Adaptation occurs regardless of differential survival.
Domestication	Species can be domesticated by humans by selective breeding.	Species can be domesticated by humans by changing individuals.
Speciation	All species share a common ancestor.	Only closely related species share a common ancestor.
Extinction	Extinction is more common than adaptation.	Adaptation is more common than extinction.

Currently, it is unknown which of the listed concepts primary-aged children can understand as there is an absence of empirical research with this age group. Likewise, there is very little research addressing which concepts are more difficult to understand than others and research is required to determine which concepts are necessary to learn at the introductory level (Smith, 2010). This study will contribute to knowledge about the conceptual understanding of primary school children as it aims to describe the understanding of different concepts.

## RESEARCH HYPOTHESES

The first hypothesis states that explicitly teaching the six evolutionary concepts will result in conceptual change from a transformational to a variational understanding. This effect is deemed to be specific to the concept taught and not to be apparent in another scientific concept, namely electricity.

The second hypothesis is that, due to the nature of the teaching programme, which is based on the use of cognitive conflict, discussion and reconstruction of the pupils' solutions to problems, there will also be a measurable effect on the pupil's cognitive development.

## RESEARCH DESIGN AND METHODS

### *Design*

The study implements a random assignment experimental design which utilises a pre-test, teaching sessions and then a post-test. Participants have been randomly allocated to one of three groups and the random assignment to groups maximises the chance that the groups will not differ in a

systematic way. One group will receive teaching about evolution. One group will be the active control and will be taught electricity, another topic in the curriculum. The final group is an unseen control group and do not receive any teaching. Randomisation was blocked by classroom, so that factors such as teacher and school are maintained constant across groups. The post-test will provide a measure of the dependent variable and the intervention sessions will act as the independent variable. Pre-test scores will provide a baseline standard to compare both groups to at post-test. The manipulation of the independent variable will allow differential exposure to the treatments for all groups, therefore increasing the probability that any post-test differences are due to the intervention. An experimental design engenders confidence in the causal explanations that link the intervention to the children's performance at post-test. The design is summarised in table 2.

Table 2 – summary of research design

Group	Pre-tests (December 2016)	Intervention (December 2016 - February 2017)	Post-tests (March 2017)
Evolution group (n = 35)	Evolution assessment,	Teaching of evolution	Evolution assessment, Science reasoning task.
Electricity group (n = 35)	Science reasoning task,	Teaching of electricity	
Unseen control group (n = 35)	WISC verbal reasoning.	No teaching	

### *Measures*

The evolution assessment was developed for the study using the six concepts of variation, inheritance, adaptation, domestication, speciation and extinction as a framework. Questions were written about unfamiliar organisms and piloted with 57 10-year old children. The data was analysed and the wording of questions was changed if necessary. The final assessment was a pen and paper test consisting of 18 multiple choice questions. The science reasoning task was used to assess cognitive development and was taken from the Piagetian reasoning tasks developed at King's College as part of the assessments for the Concepts in Secondary Maths and Science (CSMS) study (NFER, 1979). A verbal reasoning test was added to act as a covariate in the analysis. A subtest (similarities) from the Wechsler Intelligence Scale for Children was selected to assess the participant's verbal reasoning and their ability to conceptualise and categorise items.

### *Intervention*

The evolution intervention was designed to have six lessons, one for each of the six concepts previously discussed. Each lesson was piloted with 2 groups of 15 children to trial the activities and determine the timings of each lesson. Alterations were made and the final lessons were designed to be 45 minutes long. The active control group intervention was adapted from an existing programme about electricity.

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# ENHANCING INTERDISCIPLINARY APPROACH IN SCIENCE EDUCATION USING CONCEPT MAPPING

**Aet Möllits**

Tallin University, Estonia

## OUTLINE OF THE STUDY

With newest developments in the society, more and more people, including students, are uncritical or passive about the information they receive. The complex problems they will face in their studies need critical use of knowledge and skills to make right decisions. The endless information is forcing to learning for understanding the world. For example, in chemistry writing and balancing chemical equation or learning chemical laws is becoming less important than describing the world with chemistry concepts and abstracting these concepts from the world. Meaningful learning is the key for understanding and concept mapping helps to develop the ability to learn meaningfully.

The aim of the study is to find out how to enhance interdisciplinary approach in science education with concept mapping. The goals are:

- to find out ways to assess interdisciplinary knowledge with concept mapping;
- to develop methodology for analyzing interdisciplinary of concept maps.

## REVIEW OF RELEVANT LITERATURE

Joseph Novak and his research team developed concept mapping method in 1972. (Novak & Cañas, 2008). It was based on David Ausubel's cognitive learning theory, which states: (1) learning takes place only when new knowledge is associated with that already existing forming a logical system; (2) reorganization and integration of old knowledge with new information facilitates meaningful learning. (Ausubel, 1968).

Ausubel (1968) brings out differences between rote learning and meaningful learning. The learning process where new information is acquired by chance and is not associated with previous knowledge is called rote learning. During the meaningful learning process the meaning of new concept has to be learned first and then it can be associate with previous knowledge. As a result of meaningful learning a learner acquires a well-organized structure of relevant knowledge and the ability to integrate the new information with existing ones and gain a better understanding of the learning content. (Novak, 2004)

To organize a hierarchically well-structured map it is recommended to define a focus question. Concepts in concept map are connected together with a line and linking word(s) that indicate the relationship between them. One meaningful proposition in concept map contains two or more concepts that are connected with linking words. Putting all propositions together it gives a structured picture of the student's knowledge. (Novak & Cañas, 2008).

In using concept mapping as an assessment tool, two factors need to be considered: the type of concept mapping task and the type of concept mapping scoring method. Ruiz-Primo (2004) put forward

a directness of concept mapping tasks, where directness is related to the amount of information that is provided with the concept mapping task. This varies from high to low. High-directed tasks provide students with concept or linking words, but do not restrict how maps may be drawn. A low-directed mapping technique gives freedom to decide which concepts and linking words can be used and how many and in which way. It has been found that concept maps evaluate many of the same aspects as do traditional tests, but also aspects that traditional tests do not measure well (Ruiz-Primo, 2004). Farrokh and Krause (1996) found a correlation between concept maps scores and grades in a college biology course and Wilson (1993) showed concept maps as predictors of students' performance on national standardized tests.

There are several measures for analyzing concept maps. By using quantitative assessment method, a range of characteristics can be assessed (Croasdell et al., 2003) e.g. number of concepts; number of propositions; number of cross-links, which describe the size of concept maps. The structure of the map can be described by centrality of concepts, number of cross-links, density of concepts, inter and intra cluster proposition count and branch point count. The main problem with such a quantitative assessment method is that it might make an assumption that bigger is better. Actually, experts often produce smaller concept maps than do novices, because the focus is placed on the most important concepts, which are then connected by highly informative statements (Kinchin 2011). Thus the quality of a concept map is shown by which concepts, linking word and propositions are in the map. Typical quality indicators are correct proposition count, average rating of propositions and relevance of concepts. Regularly experts are used to assess the accuracy of propositions (Reiska, et al., 2008).

## RESEARCH QUESTIONS

To reach the goals of the study three research questions were defined:

- 1) *How students' interdisciplinary knowledge is developing during the high school studies?*
- 2) *How can students connect specific science concepts with everyday life concepts?*
- 3) *How are correlating higher order thinking skills with concept mapping measures?*

## RESEARCH DESIGN AND METHODS

To assess students' biology knowledge in high school, a large-scale study was carried out in 2012 and 2014 (Laius et al., 2016). First, the PISA-like tests and computer-based concept maps of over 2000 first year high school students were collected. In two and half years the same students' were tested again at the end of high school. In the study 374 concept maps and results of PISA-like tests of 187 students from 20 different Estonian high schools, were analyzed. These students made the same tests and concept maps at the beginning and at the end of high school. For the concept mapping task the focus question and 30 concepts were given. The focus question for this study was: "Milk - is it always healthy?" Experts divided concepts from collected concept maps into 4 subject categories: "biology", "chemistry", "physics" and "everyday life". The correlation between the measures of concept maps and PISA-like test results were calculated.



In the pilot study I have analyzed about 25% of collected data, for my entire PhD work I will analyze all concept maps (over 1000 concept maps) and results from PISA-like tests.

## PRELIMINARY FINDINGS

The results showed, that there is a significant correlation between PISA-like test results and characteristics of concept maps (Table 1.). The most correlations were statistically significant.

Table 2. Correlation coefficients of concept map characteristics with PISA-like test results

	2-rated propositions	1-rated propositions	0-rated propositions	Number of propositions	Avg. proposition per Concept	Branch point count	Taxonomy score
10th grade	0,52	0,04	0,04	0,29	0,39	0,39	0,03
12th grade	0,31	0,19	-0,17	0,21	0,20	0,18	0,17

It is interesting to see, that the highest correlation with PISA-like test results has the quality measure of concept maps – number of 2-rated propositions (high quality propositions). It is also important to notice, that there is very weak correlation of everyday knowledge (number of 1-rated propositions) with PISA-like test results.

The findings showed that concept maps composed in grade 12 were on a higher level than those from students in grade 10 in all three characteristics (size, structure and quality). The results showed a statistically significant increase in the number of propositions. The number of high quality propositions was especially high. The structure of the maps didn't change so much. Also the increase of density and the taxonomy level was significant, but not high. Positive result was that the quality measures increased (e.g number of high quality propositions), but negative side was the number of incorrect propositions that did not decrease. The change in the size of concept maps during high school is shown in the Figure 1.

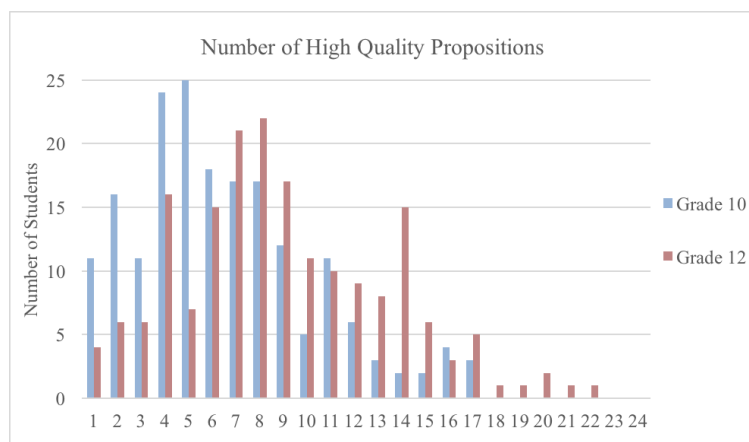


Figure 1. Number of proposition in grade 10 and grade 12.

Figure 1 describes that the concept maps of grade 12 contain more high quality propositions then the concept maps of grade 10.

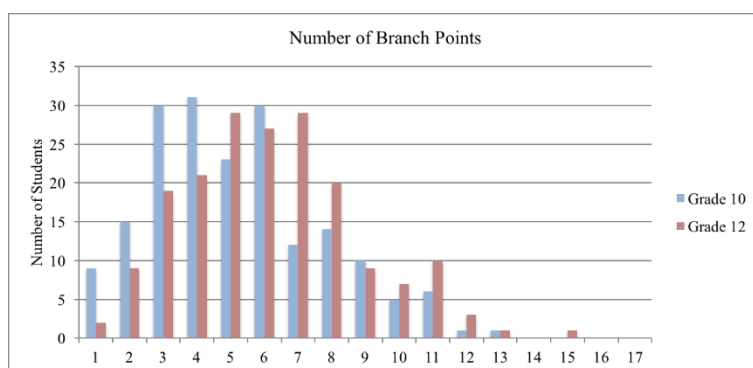


Figure 2. Number of branch points in grade 10 and grade 12.

Figure 2 shows, how many branch points had the students from grade 10 and 12 in their concept maps. Branch points are important to describe the depth and hierarchy levels of concept maps. Figure 2 shows the polynomial trend line with the maximum shifted to the right by class 12. According to that the concept maps of grade 12 contain more branch points than the concept maps of grade 10. From the higher number of branch points by class 12 can be also concluded the higher number of hierarchical levels by class 12.

## SUMMARY

The study revealed that there are also other relevant assessment methods, e.g. concept mapping, which correlates with traditional methods, e.g. PISA-like test. The results of the study demonstrate that concept mapping can be used to assess components of students' knowledge, such as understanding of the specific concepts and changes in their thinking process. On the one hand the concept mapping method helps to identify students' misconceptions at an early stage and on the other hand, it helps to make better links between specific subject concepts and everyday life. Based on the results of the study, it is recommended that teachers use more variable teaching and assessment methods, such as concept mapping.

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## **SESSION T: SCIENCE TEACHING**

# PROBLEM-ORIENTED LEARNING SITUATIONS IN PRIMARY SCIENCE EDUCATION

**Tereza Češková**

Masaryk University, Faculty of Education, Czech Republic

## THEORETICAL FRAMEWORK

During the last decade the Czech educational system has undergone a curricular reform and began to emphasise pupils' key competencies. Our research focuses on one of them – the problem-solving competence. There is a lot of research showing that Problem-Based Learning (further PBL) as an educational approach can effectively develop problem-solving competence (e.g. Gijbels et al., 2005). We believe that as primary Science lessons focus mostly on pupil's close surroundings, they are especially suitable for including problem-oriented tasks (further POT) and thus developing problem-solving competence. When considering the tasks, we take into account the broader context of the learning situation as a whole, i.e. consider also pupils' and teacher's previous knowledge, experience and skills and other observable characteristics of the classroom situation. A learning situation based on POT is called a problem learning situation (further PLS).

Even though PBL promotes pupils' autonomy, the learners should be taught some basic steps in solving problem-oriented tasks. Based on available studies (cp. Delisle, 1997; Edens, 2000; Segers, 1997; Schmidt, 1983; Torp & Sage, 2002; Zumbach, Kumpf, & Koch, 2004 etc.), we distinguish 8 phases of a PLS. These phases provide an analytical framework for a more detail investigation of PLSs and their use in a primary Science education.

- Phase 0 – Problem structuring – Teacher judges external and internal situational conditions and designs the problem.
- Phase 1 – Initiation – Teacher poses preparatory tasks connected to the issue developed in POT and motivates pupils.
- Phase 2 – Analysing the POT
- Phase 3 – Searching for information
- Phase 4 – Synthesizing findings
- Phase 5 – Summarizing the solution
- Phase 6 – Presenting the solution
- Phase 7 – Reflecting on the solving process

These phases provide an analytical frame for a detailed investigation of PLSs and their use in primary Science education.

The phases can be divided into two groups with different foci: (a) phases focused on solving POT as such (Phases 2, 3 and 4) – those instigate pupils' cognitive activation; and (b) phases that develop and support the process of solving a POT (Phases 1, 5, 6 and 7). We suppose that those lessons in which solving POT is given more prominence, develop the problem-solving competence better. However, the

effects are strongly influenced by the concrete realization of the phases, thus also by classroom interaction and communication.

Classroom interaction has its specific rules, e.g. a pupil cannot speak without the teacher's instruction (c.f. McHoul, 1978). The usual pattern of communication is IRF (initiation, response, follow-up; Sinclair & Coulthard, 1975). In Science instruction especially follow-up may be slightly different to what is usual in other subjects (c.f. Chin, 2006).

In our analysis we focus not only on the distribution of the PLS phases, but also on their actual realization.

## **RESEARCH AIMS AND QUESTIONS**

The presented project aims to: (1) briefly introduce how the PLSs in the research sample are organised; (2) describe what the actual realization of the solving phases (2, 3, and 4 – see above) in potentially qualitatively better PLSs looks like (from a conversation analysis point of view). The conversation analysis will focus on those PLSs that allocate more than half of their time to phases 2, 3, and 4 and are thus potentially more suitable for developing problem-solving competence (i.e. are potentially qualitatively better).

## **RESEARCH DESIGN AND METHODS**

The research sample consists of 10 videorecordings of primary Science lessons. The data were collected as a part of the IRSE Videostudy (Institute for Research in School Education, Masaryk University, Czech Republic) in 2010/2011. Five classes in the fifth grade of primary school were randomly selected and two lessons in each were videotaped. No special task was set so the lessons are taken to represent a typical Czech Science lesson. A structured nonparticipant observation of the videorecordings based on a categorical system was used for the analysis. The categorical system results from the descriptions of the phases of PLS. To report the overall results we use descriptive statistics, for a description of the distribution of the phases in the PLS we use absolute and relative frequencies. PLSs with potentially higher quality were defined in accordance with Klieme, Schümer, and Knoll (2001, p. 51, see aim 2) as those PLSs that devote more than half of their time to POT solving phases (i.e. phases 2, 3, and 4).

To better understand the process of solving a POT, we focus on their organisation using conversation analysis (ten Have, 2007). We look at the organisation of turn-taking, sequence and repair during the phase. Conversation analysis uses fragments of talk as a unit of analysis. In this project, the analysed fragments of talk are those sequences in classroom communication that correspond with the phases connected with solving of POTs as such.

## **PRELIMINARY FINDINGS**

The analysis is currently underway. So far we have overall results of the first research question: In our research sample we have identified 522 tasks in total, out of which 41 were problem oriented and were organised in 31 problem learning situations. The most frequent phases were Phase 2 (Analysing), Phase 1 (Initiation) and Phase 5 (Summarisation).

Although only 8 % of all tasks were POT (the ideal proportion is 25–30 % according to e.g. Mullis et al., 2009), in 6 out of 10 lessons the time allocated to PLS is more than a quarter of the lesson duration. 12 PLS were selected for further analysis. The conversation analysis is currently underway. Preliminary findings suggest that the process of solving POT is rather like a discussion, pupils are more often allowed to react to each other, the teacher gives pupils more time to solve the task independently, tries to guide them by follow-ups like What else? The prevalent structure is IRFRF rather than the usual IRF. The microanalysis of the selected part of the learning situations, i.e. POT solving phases, helps us understand how it is actually realized in instruction.

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# **IMPROVING PEDAGOGICAL PRACTICES OF IMPLEMENTING INQUIRY TEACHING IN THE PRIMARY SCIENCE CLASSROOM: AN ACTION RESEARCH STUDY**

**Mohd Syafiq Aiman Mat Noor**

University College London, United Kingdom

## **INTRODUCTION**

The idea of inquiry teaching has a decades long and persistent history in science education, with evidence showing that inquiry teaching produces positive results (Bybee, 2000). However, many questions surround inquiry (Anderson, 2002). What precisely do we mean when we assert that much of science should be taught as inquiry? Many of the debates about reform-based science education seem to include the word 'inquiry' but there is a lot of argument as to what inquiry teaching actually entails (Crawford, 2015). Different scholars define inquiry differently, or the researcher may choose to use a different term for an approach that others would apparently identify with inquiry. Moreover, lively discussion and debate among science educators about the place of inquiry in the teaching of science has continued into the 21st century (Crawford, 2015). Regardless of the confusion about what teaching science as inquiry means, it has been suggested that with regards to its implementation in the classroom, we espouse the idea but do not carry it out in practice (Bybee, 2000).

Traditionally, authentic scientific inquiry refers to the systematic approaches used by scientists, who conduct in everyday practice to answer their question of interest that leads to the development of scientific knowledge (van Rens et al., 2010). Scientific inquiry advocates that the questions guide the approach and the approaches vary within and across scientific disciplines and fields (Lederman, 2009). Schwartz et al., (2004:308) also conceptualised "scientific inquiry as the process by which scientific knowledge is developed and, by virtue of the conventions and assumptions of this process, the knowledge produced necessarily has certain unavoidable characteristics". Based on the concept of scientific inquiry above, using an inquiry approach to teaching may simply mean learning how to apply the procedures and protocols of a particular field of science (Deboer, 2006). Thus, the term 'inquiry teaching' refers to pedagogical approaches that model aspects of scientific inquiry. Inquiry teaching encompasses processes, such as using investigative skills, actively seeking answers to questions about specific science concepts and developing students' abilities to engage, explore, consolidate and assess information (e.g. Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002).

## **FOCUS OF THE STUDY**

This study tells the story of the development of my knowledge, understanding and educational practice as I have investigated how I might improve my pedagogy skills of inquiry teaching since it goes to the heart of science and therefore requires a prominent position into my practice. Therefore, given the nature of action research, it makes sense to improve instructional practice involves strategic action (McMahon, 1999). As point out by Kemmis (2006), quality in practitioner research is a matter of addressing important problems of action and thought in theory and practice, for the good of each



person, for the good of societies and for education. Therefore, I have decided to use action research as a method of developing scientific inquiry teaching and so improving my practice as a science teacher. It has been shown by Huziak-Clark, Van Hook, Nurnberger-Haag and Ballone-Duran (2007) that inquiry teaching implementation improves teachers' pedagogical skill (i.e. effectiveness of questioning techniques, greater confidence in planning and implementing inquiry lessons, and an increase of content knowledge and breadth of knowledge) and so impacts on student conceptual understanding. Besides, I had encountered action research during my previous study (see Mohd Salleh & Mat Noor, 2015) and I could see through my own eyes that action research provides an ideal vehicle to accomplish this goal. Therefore, as action research, my main research question for this study is "How to develop a scientific inquiry approach in science teaching to improve my practice as a science teacher through the development of my pedagogy skills?".

Inquiry teaching, as mentioned above, is an approach that needs to be a central strategy of science instruction and it will be a particular component of this study. For instance, there are lots of documents and reports that focus attention on the importance of inquiry teaching, yet very little research exists providing empirical evidence on how teachers implement inquiry in their science teaching (Lin et al., 2013). Although some previous studies in the literature have been designed to help science teachers incorporate inquiry into science teaching (i.e. Waight & Abd-El-Khalick, 2011), only modest gains have been made and few studies discussed the limitations of the instructions that were implemented. Importantly, most previous studies of the implementation of inquiry into science teaching have been done focusing on middle, secondary or high school level (e.g. Walker & Molnar, 2014) rather than primary or elementary level (e.g. Van Zee, Hammer, Bell, Roy, & Peter, 2005). Hofstein and Lunetta (2004) and Keys and Bryan (2001) recommend that studies of the implementation of inquiry into science teaching are still needed, particularly studies that not only model the instruction of inquiry but also develop inquiry-based curricula. Therefore, this study is also trying to determine the impact of inquiry on science teaching, particularly into the context of my practice – the primary school. Thus, a subsidiary, second research question is "What is the impact of implementing a scientific inquiry approach into science teaching at primary level?".

## **RESEARCH DESIGN**

The research design is based on the purposes of the study to develop an inquiry approach in science teaching to improve my practice as a science teacher through the development of my pedagogy skills. This study employs the basic method that is central to the action research approach, a self-reflective spiral of cycles of planning, acting, observing and reflecting (Carr & Kemmis, 1986). My research design is adapted from 'the action research spiral' of Kemmis and McTaggart (1988: 11) and is mainly structured by the cycles of action research, and within each cycle contains the four action research phases. Generally, my action research spiral contains several cycles and each cycle represents the themes of the science curriculum for primary schools in Malaysia (e.g. biological science, physical science, material science, etc.). Each cycle embodies a set of teaching modules within the selected science themes, which are ready to be implemented in the science classroom. Elliott (1983) suggests that

it is often necessary to undertake a cluster of steps every cycle. Therefore, my development of the action research spiral is a unique form of action research with main cycles and branching sub-cycles. This process will undertake to determine my pedagogical practice, consistently improving through reflective practice while I engage in a process of continuous learning.

In constructing my action research study, I use single research methods, all which are qualitative in nature. A qualitative approach seeks to provide an in-depth understanding and description of an individual's perspectives (Merriam, 1988). Multiple sources of data will be used to answer all research questions concurrently, partly for the purpose of triangulation and partly because the different methods taken together provide me with rich understanding of what is going on in the classroom. Thus, I have identified five different sources of data collection, namely; (a) video-based observation, (b) students' interviews, (c) my own reflective journal, (d) teaching artefacts, and (e) students' written work. Analysing qualitative data entails discovering and exploring ideas from the data, handling and using the evolving ideas to build up the study. Data analysis involves the idea of transformation; I have started collecting large amounts of qualitative data and then process these, through the analytic procedures, into a clear, understandable and reliable analysis. Narrative and thematic analyses are the main approach for analysing data in this study.

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# MODELING SCIENCE TEACHERS' PROFESSIONAL KNOWLEDGE IN ELEMENTARY PARTICLE PHYSICS

**Michaela Oettle**

Pädagogische Hochschule Freiburg, Germany

## OUTLINE OF THE FOCUS OF THE STUDY

The project aims at designing an instrument for the assessment of the professional knowledge of science teachers regarding elementary particle physics.

Particle Physics is an intriguing topic for school pupils due to the combination of a rapidly evolving research accompanied by the development of everyday applications, and an increasing media interest.

On the level of educational policies, the subject is in the progress of being included in scholar curricula. However, there is an enormous discrepancy in the lacking current effort in exploring the professional competences needed by teachers and educators in order to teach particle physics.

Due to the complexity and advanced structure of the subject, teaching particle physics can be challenging for teachers. This project aims to address this issue by ultimately developing a teacher training program whose contents and structure should build upon the teachers' existing knowledge and conceptions. For the example of the German setting, the program could be integrated either in the university course of preservice teachers or as advanced training program for in-service teachers, both concerning high school physics teachers.

In the first stage of the project, the present study focusses on the nature and level of high school physics teachers' existing content knowledge (CK) in modern particle physics. Hence, we try to construct a test instrument suitable to portray and describe the status quo of the teachers' competences in this knowledge domain. A question to be answered is: In which aspects of particle physics do teachers have particularly strong deficits or misconceptions?

To structure the broad field of knowledge about particle physics, we first intend to identify knowledge categories and later knowledge levels before constructing test items accordingly.

## LITERATURE REVIEW

From a theoretical point of view, the study draws upon the model of teachers' professional competences established by Baumert and Kunter (2006) that comprises general pedagogical knowledge (PK), subject matter content knowledge (CK), pedagogical content knowledge (PCK), organizational and counseling knowledge. Besides this approach, teachers' professional knowledge has been conceptualized in several different ways in the past, for example by Shulman (1986, 1987) who mentioned seven dimensions of professional knowledge or by Elbaz (1983) naming five dimensions. There have been various studies indicating that teachers' competences belonging to the components PK, CK and PCK have the largest impact on students' learning progress (Abell 2007, Blömeke, et al. 2009, Kunter, Klusmann, & Baumert 2009). Due to the prioritization on domain-specific aspects connected to particle physics in this project, the study scope is limited to CK.

Regarding the conceptualization of the CK domain, there are no (inter)national research findings available concerning elementary particle physics in particular, although for example Tepner et al. (2012) assessed the professional knowledge of science teachers and used a test in mechanics for the content knowledge domain in physics. Consequently, we intend to establish a new model for the conceptualization of teachers' knowledge in particle physics. Reviewing a variety of standard text books, including Griffiths (2008), Martin (2009), and Kolanoski & Wermes (2016) among others, and the latest available teaching resources of the German outreach project *Netzwerk Teilchenwelt*<sup>8</sup>, we divided the field of particle physics into three subject areas before asking the experts about the key ideas they have in each area (see below).

## RESEARCH DESIGN, METHODS AND PRELIMINARY RESULTS

As previously described, the content knowledge domain is conceptualized by first identifying well defined knowledge categories. For this purpose, we applied a research design based on the Delphi method. In two consecutive survey rounds, we asked a panel of  $N \approx 40$  experts from particle physics research, teaching and outreach to name their key ideas and central concepts belonging to the three subject areas *findings of modern particle physics*, *experimental research methods* and *research spin-offs*. Methodically, we used an online-survey with open and closed answers formats. We analyzed the results of the first survey round pursuing the guidelines of a qualitative orientated content analysis. Additionally, the grouped answers were matched to well established physical concepts using again the standard text books. In this way, we found a set of  $N \approx 10$  categories for each of the predefined subject areas. Furthermore, as regards content, each category is divided into several subcategories. The system of categories and subcategories forms our first model for the content knowledge domain in particle physics. In the second round of the survey, the same population of experts will be confronted with the analyzed results of the first round in form of the categorial model and they will be asked to validate it.

The validated model will provide the basis for the construction of performance test items corresponding to the different categories.

At the current stage of the project, the collection and analyzation of the data from the first survey round is completed and we are currently in the process of validating our model in the second round. Further discussion points at the summer school – amongst others – are possible procedures on how to translate the knowledge categories into performance test items with varying levels of difficulty.

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<sup>8</sup> Could be translated as *Network Particle World*. This outreach project under the leadership of Professor Michael Kobel (Technische Universität Dresden) consists of 24 scientific institutes in Germany and is affiliated to CERN, in Geneva, to give access to the current research being undertaken in the fields of particle and astroparticle physics to a broader audience, comprising teachers and students. (Webpage: [www.teilchenwelt.de](http://www.teilchenwelt.de))

## FURTHER RESEARCH QUESTIONS

Besides the answer to the question of how well the teachers perform in each knowledge category of particle physics, there are several other interesting questions this study addresses. Firstly, can we classify the overall and categorial level of teachers' content knowledge in terms of a gradual scale and if so, how are the increments defined?

Secondly, due to huge international differences in teacher education as well as in structure and contents of syllabi, the research initially focusses on the German-Speaking world. However, we plan to expand the experiment to an international setting. Thus, it would be interesting to draw comparisons between the results of our test in different countries and continents.

Finally, coming back to our starting point, how is it possible to incorporate our results about the teachers' existing knowledge into future teacher training programs in modern particle physics?

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# AN INVESTIGATION OF TEACHING FOR CONCEPTUAL UNDERSTANDING OF SCIENCE CONCEPTS IN A YEAR 5 UK PRIMARY CLASSROOM

Shone Surendran

UCL, Institute of Education, United Kingdom

## RESEARCH FOCUS AND AIM

Teaching science in the primary classroom involves engaging children in talking and making sense of the world around them. This study investigates how teachers can use *talk* in the classroom as a pedagogic tool to support and develop children's understanding of scientific concepts. The language of science vastly differs from our everyday language-use. This is confounded by the use of familiar words such as 'force', 'weight' and 'hard', which are employed with different meanings within a scientific context. In science lessons the primary teacher is tasked with explaining scientific concepts in a manner that allow children to make sense of what is being conveyed. This *communicative act* is referred to by Mortimer and Scott as 'meaning making' (2003) and sits at the heart of my research study. Following a social constructivist approach to research on classroom talk, Mortimer and Scott (2003) offer their *meaning making* framework, which serves to analyse classroom talk and to support teachers in planning for science lessons. In contrast to their account of meaning making, I draw inspiration from the recent philosophical work by Vygotsky scholar Jan Derry (2013b) who is an advocate of Inferentialism (Brandom, 2000, Derry, 2013a). Inferentialism is an emerging epistemological perspective in the education literature, which offers a theory of meaning advanced by the philosopher Robert Brandom (2000). Through my research investigation I argue that this inferentialist view not only serves to critique Mortimer and Scott's conception of 'meaning making', but simultaneously illuminate pedagogic challenges in teaching for conceptual understanding in science classrooms.

My empirical work is set in an inner-city primary school. I will work closely with the teacher within a Year 5 primary classroom consisting of 28-30 pupils (9-10 year olds) during science lessons. The investigation will focus specifically on 'Properties and changes of materials' unit addressed in Year 5 as specified by the *National curriculum in England: science programmes of study - key stages 1 and 2* (DfE, 2014). The central scientific concept will be 'matter' related to the topic of states of matter and state changes, and often by teachers' extension, include the particulate theory of matter. Having observed primary science teaching practices I draw on theoretical perspectives, which I detail below, to propose a pedagogic intervention that aims at developing pupils conceptual understanding of states of matter, state changes and the concept of 'matter'.

## LITERATURE REVIEW

Over the last 30 years there has been a shift in emphasis in educational research from individual cognition to the social context of learning and development. In science education, the focus turned on classroom discourse and the role of social interactions and language in influencing learning (Lemke, 1990; Mortimer and Scott, 2003). Mortimer and Scott's (2003) meaning making framework serves as a



tool for analysing and planning science by placing an emphasis on the form and use of language, which views science pedagogy as an induction into and rehearsal of the *social language of school science*. The framework aims to promote the 'meaningful understanding of scientific conceptual knowledge' (Scott, Mortimer and Aguilar 2006, p.606). *Inferentialism*, as a theory of meaning advanced by the philosopher Robert Brandom (2000), provides a more fine-grained analysis of language and meaning in discursive interactions (Derry, 2013b). Inferentialism's focus on *how* the connection between a word and its referent is established is a matter of great pedagogic importance (Derry, 2013a). The pedagogic implication of the inferentialist perspective is, in short, a critical shift in emphasis away from concepts as *given* through language and words towards privileging classroom activities and the discursive practices between teacher and pupils, which are viewed as a language game of '*giving and asking of reasons*' (Brandom, 2000; Derry, 2013b). This game conceives 'meaning' as the interconnection of ideas, shaped by the learner's experience. Meaning according to inferentialism is not rooted in the *use* of language itself but what one *does* in communicating with others i.e. interconnecting ideas and making inferences. For example, consider a science lesson on the classification of materials into solids, liquids and gases. The teacher introduces the term 'solid', then provides some examples of 'solids' highlighting typical properties such as 'hard' or 'breakable', which classifies them as 'solids'. According to inferentialism, to understand a concept does not involve induction into using or rehearsing scientific words. Rather, it involves the learner in connecting experiences and ideas that operate when a term is expressed. The pedagogical claim here is that, concepts should not be *given* through language-use but should rather be grasped by the learner through discursive practice. This dialogue between teacher and learner in *giving and asking for reasons* should allow the learner to connect a network of ideas that operate in expressing a term appropriate to the unspoken or normative 'rules' of a knowledge domain such as science. This teacher-pupil dialogue should support the learner to understand the conditions that allow a concept such as 'solid' to be picked out from a network of ideas. For example, Levinson (2000) presents problematic cases where certain materials may not clearly fit into any one particular 'state'. Dilatants are materials, such as custard, jam, or toothpaste, which display properties of solids and liquids under various conditions and pose difficulty in being classified (Levinson, 2000; Skamp, 2014). Levinson problematizes the concept of 'states of matter', as most materials to some degree possess all three state properties. Highlighting the complexity of scientific concepts afford teachers the opportunity to engage learners in thinking through problems and to *articulate* their *reasons* in order to encourage deeper discussion (Levinson, 2000; Skamp, 2014). This example highlights aspects of science teaching and classroom discourse that extend beyond the meaning making framework's focus on the various forms of discourse to promote science concept development. Derry's (2013b) inferentialist approach offers a distinctive critique of the meaning making framework, whilst providing a novel perspective from which to consider pedagogic issues related to the development of children's scientific concepts anew.

## RESEARCH QUESTIONS

This research study investigates classroom discourse and pedagogic practices in an attempt to address the follow question:

- *What pedagogic strategies can primary teachers employ with children in classroom talk about science that better support and develop a meaningful understanding of scientific concepts?*

In order to address this question there are some guiding research questions, which I undertake:

- *How do primary teachers talk about science with children to support meaningful understanding of scientific concepts?*
- *In what ways can inferentialism inform pedagogic practice in primary science classroom discourse?*
- *What pedagogic resources could inferentialism offer primary teachers to promote meaningful science discourse and children's conceptual understanding?*

## RESEARCH DESIGN AND METHODS

This research study adopts a 'flexible' design employing qualitative methods in investigating science discourse in the primary classroom (Robson, 2011). Classroom observations are the main method of collecting data on classroom talk. I have adopted a marginal participant approach to observation (Robson, 2011). Whole-class and table-group discussions have been captured using audio recordings and field notes. My field notes record critical events in communicating scientific concepts (Wragg et al., 1999). I follow up observations by conducting twenty-minute semi-structured interviews (Robson, 2011) with the teacher. Group interviews will be conducted with the table-groups I observed, to review children's conceptual understanding. I limit interviews to fifteen minutes in order to retain their attention (Cohen et al., 2011). The audio recordings of the classroom talk will be analysed using the meaning making framework (Mortimer and Scott, 2003). Taking utterances as its basic unit of analysis, it renders the *communicative approaches* and *discourse patterns* visible. I propose extending this framework drawing on an inferentialist analysis of classroom talk, which I refer to as *deontic analysis*. This modified analytic framework, in guiding my pedagogic intervention, aims to provide a resource to support primary teachers in planning and implementing teaching sequences on the 'Properties and changes of materials' unit.

## PRELIMINARY FINDINGS

Classroom observations I have conducted provide episodes of classroom dialogue and critical events, which could be illuminated by an inferentialist perspective. The data illustrates how both teachers and pupils struggle to make meaning of concepts such as 'states of matter' and 'state change'. Although the meaning making framework serves as a pedagogic tool, there is evidence that an inferentialist perspective could buttress its effectiveness. I propose a pedagogic intervention for use in the primary science classroom informed by Derry's inferentialist approach to meaning making and

pedagogy. The impact such a strategy exercises on classroom talk and pupils' conceptual understanding is something I look forward to reporting in my final PhD thesis.

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# SCIENCE TEACHERS' MOVES CONTRIBUTION TO ELEMENTARY SCHOOL STUDENTS' ARGUMENTATION SKILLS AND QUALITY ABOUT SOCIO-SCIENTIFIC ISSUES

Hilal Yanış

Middle East Technical University, Turkey

## AN OUTLINE OF THE STUDY

Turkey is one of the countries in which a middle school science curriculum has been changing due to increase in development of science and technology in all over the world. In 2005 curriculum emphasized the “constructivist learning approach” while in 2013 curriculum emphasized a learning-teaching strategy based on “research-inquiry” (Karatay, B. Timur, & S. Timur, 2013). With the change in curriculum there has been a growing interest in using the argument based inquiry (Erduran, Ardaç, & Yakmacı-Güzel, 2006; Kaya & Kılıç, 2008). Maloney and Simon (2006) state that argumentation is a necessary component of inquiry because it makes students aware of the variable nature of scientific knowledge. Moreover, the goal of science education ought to be not only learning specific scientific knowledge, but also developing skills of scientific thinking (Driver, Newton, & Osborne, 2000; Kuhn, 1993; Zohar & Nemet, 2002); and the skills of argumentation play important roles in high-level brain-storming, such as critical reasoning, creative thinking, and problem-solving (Coles & Robinson, 1989). Furthermore, the role of argumentation in science discourse has gained prominence in the last 20-30 years. Discourse among scientists is characterized by debate and argumentation based on evidence (Kuhn 1993). In their professional discourse, scientists share their evidence and findings and try to convince their peers through their explanations. Also, questioning, a central feature of their discourse, is used to clarify and challenge claims and evidence, gain deeper insights, and generate next steps and new directions for inquiry. Classroom discourse is a necessary for teachers to determine what the students understand and misunderstand, what they are thinking, and what they are learning (National Research Council, 2000). When students learn science, they construct meanings and develop understandings in a social context (Duit & Treagust, 1998). Much of this meaning-making occurs through classroom discourse as part of teacher talk and teacher–student interactions.

Argumentation and discourse have been the emphasis of a number of studies in the field of science education during the last decades, but regardless of the vast amount of studies in both research areas, there is need to research in science education. Also, there is a clear desire on the part of educators and policy makers to help students improve their argument skills (Common Core State Standards Initiative, 2010; Kuhn, 1991). In order to support the development of those skills, teachers' instructional, talk and scaffolding moves and questioning style should be examined. Although the importance of the skills of argumentation is known, how students become proficient in such skills has not been clear. Thus, in this study, how science teachers facilitate inquiry dialogue to contribute to the argumentation skills and quality of elementary school students will be examined during small group discussions in the context of socio-scientific issues (SSIs). SSIs were chosen for the present study such as nuclear power plant construction, hydroelectric power plant construction, organ transplantation. These issues were started

to be criticized and people in the society started to generate arguments on both the negative and positive sides. Hence, addressing an issue on which the society awareness increased is valuable.

## REVIEW OF RELEVANT LITERATURE

Different studies have highlighted, from various points of view, the importance of investigating classroom discourse in science education (see, e.g., Lemke, 1990; Mortimer & Scott, 2003). In studies on science classroom discourse, several perspectives dominate the literature. Some researchers use Toulmin's argument theory to frame their studies, while others find this format too limiting due to being more suitable for analyzing the structure of the arguments (Nussbaum, 2011). Other alternatives include characterizing the discourse through monologic and dialogic frameworks as well as describing discourse functions through authoritative and generative frameworks.

This study aims to understand how science teachers facilitate inquiry dialogue to contribute to the argumentation skills and quality of elementary school students in the context of SSIs. A great body of research in the field of argumentation in science education investigated the quality of students' argumentations by focusing on structure, content, and justifications of argumentations (Sampson & Clark, 2008). In these studies, emphasis is placed on the identification of the structural features of arguments (e.g., claims, data, warrants, backings, and qualifiers). On the other hand, argumentation skills of elementary school students in the science classroom discourse about SSIs which are included in research questions will be analyzed according to The Lakatos' framework (Lakatos, 1970) that comprises indicators of informal argumentation (hard-core, positive and negative heuristics, protective belt). Also, this framework is better suited for socio-scientific settings (Chang & Chiu, 2008; Nussbaum, 2011).

## RESEARCH QUESTIONS

Research questions that will be investigated are as follows:

- 1) *How do the elementary science teachers' instructional moves contribute to the argumentation skills and argumentation quality of elementary school students in the science classroom discourse about SSIs?*
- 2) *How do the elementary science teachers talk moves contribute to the argumentation skills and argumentation quality of elementary school students in the science classroom discourse about SSIs?*
- 3) *How do the elementary science teachers scaffolding moves contribute to the argumentation skills and argumentation quality of elementary school students in the science classroom discourse about SSIs?*
- 4) *How do questioning patterns of the elementary science teachers contribute to the argumentation skills and argumentation quality of elementary school students in the science classroom discourse about SSIs?*

## RESEARCH DESIGN AND METHODS

In this study, basic interpretive qualitative research approach will be adopted (Denzin & Lincoln, 2000). Multiple case studies as a qualitative research design will be used. Cases in this study will be the science classroom discourse of 4 elementary science teachers from different public school. Moreover, data will be collected through video recording and semi-structured interview with elementary science teachers. Transcriptions will be analyzed qualitatively. Participants in this study will be 4 elementary science teachers and their 80 seventh grade students from public school in Ankara, Turkey. They will be selected by typical case sampling as a purposeful sampling. In this study, teachers will be selected according to their experience in using argumentation as an instructional method. These 4 elementary science teachers will be the teachers participating in a larger study who attended a 5-days workshop on argumentation in physics, chemistry, and biology conducted by Türkiye Bilimler Akademisi. As well as argumentation activities elementary science teachers attended the scientific discourse, nature of science and inquiry based teaching sessions.

SSIs as Nuclear power plant construction, hydroelectric power plant construction, and organ transplantation which are appropriate topics for the seventh grade science curriculum (MEB, 2013) were chosen for the present study. Moreover, these issues are controversial in Turkey. Therefore, to explore students' argumentation skills and quality, these issues are appropriate to be utilized.

In order to examine the effect of intervention on students' argumentation skills and quality; to see the whether there are changes in classroom discourse pattern and teachers' moves or not, study timeline will be divided into 3 period: Baseline 1, intervention, and baseline 2.

Baseline 1: During the Baseline 1 period the teachers conducted their classes in their typical way. No attempt was made to influence their behavior. Elementary science teachers will be observed during 5 weeks in order to observe regular pattern of their classroom.

Intervention: Argumentation will be used as a teaching method during 3 weeks. SSIs will be the topic. Researcher will also guide teachers about argumentation.

Baseline 2: During the Baseline 2 period elementary science teachers will be observed during 5 weeks in order to observe whether the changes due to the experimentation occur or not. Moreover, video recordings and teachers' semi-structured interviews will be transcribed and used for the coding and data analysis. Descriptive analysis will be made for data analysis. Elementary science teachers' instructional moves will be analyzed according to Waggoner, Chinn, Yi, and Anderson's (1995) codes. Waggoner, Chinn, Yi, and Anderson (1995) identify seven instructional strategies or moves which are prompting, modeling, asking for clarification, challenging, encouraging, summing up, and fostering independence. Their talk moves which are revoicing, restating, reasoning, prompting, explicit reasoning, and wait time will be analyzed according to NRC (2007, p. 91). Teachers scaffolding moves promote children's argumentation skills. Teachers' scaffolding moves will be analyzed according to Jadallah, Anderson, Nguyen Jahiel, Miller, Kim, Kuo, Dong, and Wu's (2010) coding which are prompting children, asking children for clarification, challenging children, ratifying children, providing adequate wait time, summarizing children's arguments, and debriefing children and encouraging them to reflect on how well their discussion went. Teachers' questions are coded according to two categories of Molinari, Mameli,

and Gnisci (2013): function which includes new question, elaboration, and relaunch codes and form which includes authentic and focused codes. Finally, Erduran, Simon, and Osborne's (2004, p. 928) analytical framework which were coded as level 0 to level 5 will be used for assessing the quality of argumentation.

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## **SESSION S: SCIENCE TEACHER EDUCATION**



# STUDENTS' PERCEPTIONS OF A NEW LECTURE FORMAT IN ORGANIC CHEMISTRY

**Robert Marten Bittorf**

Leibniz Universität Hannover, Institute for Science Education, Germany

## OUTLINE

With high exam failure rates (60% and higher), “organic chemistry I”, an introductory module over the course of one semester, is considered as one of the great challenges for second year chemistry students. The students rely on a classic lecture format as well as structured tutorials to be introduced to the subjects of organic chemistry. However, there is evidence that these course offerings fall short when it comes to instructing students in organic chemistry.

To face this problem, new teaching-elements have been implemented in the organic chemistry I lecture in the winter semester of 2016/17. These elements include a flipped classroom format as well as the presentation of intended learning outcomes. In the present study, the students' perception of these teaching-elements analyzed.

## RELEVANT LITERATURE

### *Flipped Classroom*

Several suggestions have been made in order to enhance the quality of classical lecture formats. Examples are the methods of peer-instruction (Mazur, 2006, 2009) or just-in-time teaching (Novak, Gavrin, Christian, & Patterson, 1999). The flipped classroom is also reported as being an aspiring method in higher education in general (e.g. Lage, Platt, & Treglia, 2000; Warter-Perez & Dong, 2012) and chemistry in particular (e.g. Robert, Lewis, Oueini, & Mapugay, 2016; Ryan & Reid, 2016; Weaver & Sturtevant, 2015). A flipped classroom setting turns the traditional lecture upside down. Students are provided with relevant information beforehand, e.g. in a blended learning scenario: students can study documents, video recorded lectures and self-assessment tasks in a web-based learning environment. Facultative tutorials also support students to reach a minimum standard. This way, the face-to-face time in class can now be used with activities to deepen understanding (Jarvis, Halvorson, Sadeque, & Johnston, 2014). Possible examples are the discussion of complex concepts or the solving of sample problems. During these activities, it is possible for the lecturer to check students' progress as well as to address common misconceptions (Jarvis et al., 2014). Additionally, it allows for interaction with the students in a way that may help them getting over critical obstacles of conceptual understanding or to mediate expert strategies of learning. There is furthermore evidence, that a flipped classroom scenario can reduce students' cognitive-load during classes (Seery & Donnelly, 2012; Sirhan, Gray, Johnstone, & Reid, 1999).

As most of the above reported benefits focused on chemistry lectures in general, some studies specifically analyzed organic chemistry lectures (e.g. Flynn, 2014; Mooring, Mitchell, & Burrows, 2016). The published results are promising, as they report a reduction in student attrition and an increase in overall student grades (Flynn, 2014; Mooring et al., 2016). Although a direct linking of these findings with

the flipped classroom format could not be established, evidence suggests at least a correlation (Flynn, 2014). However, a more holistic view on the effects a flipped classroom setting exhibits on students' perception and conceptual understanding remains elusive.

### *Intended Learning Outcomes*

Intended learning outcomes (ILOs) state what the instructor or lecturer wants the students to know or do at the end of a given course (Stoyanovich, Gandhi, & Flynn, 2015). It has been shown that a clear statement of ILOs, as part of teacher clarity, has a beneficial effect on student learning (Fendrick, 1990). It is furthermore proposed, that ILOs reduce the cognitive-load of students during class (Herweg, 2008). Therefore, the generation of clear ILOs should support students during a lecture, giving them a clear view of what is expected from them at the end of class. Similar to the flipped classroom there are only a handful of studies existing in general and little is known about the impact on students' perception in academic fields like chemistry.

### RESEARCH QUESTIONS

The study is framed around the following research question:

- 1) *How do the teaching-elements flipped classroom and ILOs, implemented into an organic chemistry lecture, effect the students?*

This study will take a more holistic view on the development of students' perception over the course of the semester. As stated above the evidence is still vague in the case of a chemistry lecture. However, it is clear enough to formulate propositions regarding student reactions:

- *Students recognize and asses the value of the implementations.*
- *Students change their applied learning style in the course of the lecture.*
- *Students perception of organic chemistry changes in the course of the lecture.*

As we suppose a variance in students' initial conditions and therefore also in how the innovations affect students regarding the propositions, this study also focusses on identifying variables of influence explaining the variation.

### RESEARCH DESIGN AND METHODS

In order to answer our research questions, the usage of a control-group design would seem practical. But this bears an inconvenience in regard to our research setting. We would face the ethical question of implementing possible beneficial changes in a lecture for one group, while the other remains untreated. Students of both groups would still have to take the same exam at the end of the semester, leaving one group with a possible advantage or even disadvantage. This question may be circumvented, by comparing one semester of untreated students with a semester of treated students one year apart, therefore leaving all or no students of a particular group exposed to the changes. In this case, the problem of not only comparing student cohorts of two different years with each other but also two years of studying conditions, teaching conditions and various other factors would surface. Due to these

inconveniences, a control-group design was disregarded and a partial approach was chosen. The implementation of the flipped classroom and the ILOs would take place at the midpoint of the lecture in one semester. This leaves one cohort of students that experiences both settings, the classic as well as the changed lecture. These circumstances leave us with a research setting which is multi-variant while simultaneously allowing us to exert very little control over the given variables.

This study design is based on the “case study research” method by Yin (2003), a method able to cope with varying uncontrollable conditions. It establishes a framework that supports the generation of propositions rather than hypotheses (see research questions) and allows for the collection and analyzation of a broad variety of data. The rationale of the data collected are the propositions (what kind of data is needed to get a sufficient answer or explanation?) but this method is also open to new possible correlations not covered by previous research. The analyzed case is the entire organic chemistry I lecture. This includes the classic lecture, the newly implemented teaching-elements as well as the influence the lecture has on attending students over the course of the semester.

For broad data collection, a questionnaire is answered by every student during the fourth week of lecturing. The questionnaire covers several item scales (e.g. experiences with the current lecture, perception and assessment of teaching elements) to gain an initial insight of the student body. Towards the end of the lecture, a similar questionnaire will be answered covering analogous item scales but focusing on the flipped classroom and the ILOs. In addition, a cohort of 12 students (7 female and 5 male) was generated as a representative cross-section over all students attending the lecture in terms of their degree program. Each student agreed to be interviewed (video typed) six times over the course of the semester (winter semester 2016/17). The interview questions cover a holistic view of students’ attitudes and perceptions of the lecture in general. Furthermore, they will allow to gain insight into the propositions stated above.

After carrying out the interviews, the generated audio and video footage and other artifacts will be transcribed or encoded. The data will be analyzed by identifying meaningful fragments in relation to the generated propositions, thereby linking the propositions to the data. Afterwards, students’ responses will be compared over time and across the cohort in order to elucidate underlying patterns. These patterns will be used to describe the influence of the implemented teaching-elements on students and to evaluate, whether a productive learning-environment has been established. As the student cohort is heterogeneous, we also assume different progressions on different levels. In this case the forming of contrasting groups is a promising measure to indicate correlations or explain the variance.

This study is part of the project “Leibniz Prinzip” at the Leibniz Universität Hannover. The project aims to improve the quality of university education. Findings of the case study serve to further develop the teaching-elements and other supporting measures for the organic chemistry lecture and also other chemistry lectures that will be implemented and tested again in future semesters.

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# REPRESENTATIONS AS TOOL IN THE FORCE CONCEPT CONSTRUCTION IN PRE-SERVICE PRIMARY TEACHER TRAINING

Àngela Garcia-Lladó

Universitat de Barcelona, Spain

## FOCUS OF THE STUDY

One of the most difficult topics in the pre-service primary teachers learning is the one of the forces and its relationship with everyday situations. The context of this research is Teacher in Primary Education Degree and the semi-annual subject Didactics of the Matter, the Energy and the Interaction (DMEI).

The proposal of this study is to find out how internal and external representations of forces and their interrelation could offer a guide to develop new materials and practices to improve the learning of the concept of force and of how to teach it in pre-service primary science teachers training. Because of our specific context, with a small number of sessions into the DMEI subject, in this research we will only explore deeply one of the most fundamental but the less intuitive concepts as a case study: the force as an interaction between two objects or systems. The research is part of the research project EDU2013-47593-C2-2-P, IP: Mercè Garcia-Milà (UB) titled 'Impact of the external representations on the conceptual change' carried on by the Group ALFAGRAF integrated by Psychologists, Physicists and Mathematics.

Our proposal has three specific aims: (1) to characterize the scientific and educational knowledge about forces that Primary Education pre-service science teachers have when they begin the degree; (2) to use students' external representations as a window to access their internal representations of forces; (3) to analyze the development of the concept of force when the pre-service teachers work different external representations applied to everyday situations; and (4) to explore the main difficulties that these pre-service teachers have with the use of canonical representations applied to everyday situations.

## RELEVANT LITERATURE

To develop this research we use literature from two complementary fields: Science Education with the studies on teaching and learning force concept and studies from training science teachers, and Educational Psychology with studies on the role of internal and external representations on the knowledge construction.

Related to the first field, we will consider a wide range of literature on teaching and learning the force concept. We take into account the ideas and proposals of the classic ones (Black & Harlen, 1995; Mazzoli, Arcà, & Guidoni, 1987; Twigger et al., 1994) to explore the basic misconceptions on force concept and the first attempts to guide the learning process. And we complement that knowledge with the modern concept of learning progressions. Learning progressions are accepted to be an empirically grounded hypotheses about how students understanding of scientific concepts grow and become more

sophisticated with appropriate instruction (National Research Council, 2007). Project 2061 (AAAS, 2016) aims to develop several learning progression maps for specific key ideas related to forces and motion. We complement also this literature with some recent specific researches on how to work with alternative representations of forces (Heywood & Parker, 2010).

In Educational Psychology we work with the literature on the role of internal and external representations on the construction of the concept of force. This literature is based on three disciplines. The first one is cognitive science that explains us how an implicit knowledge (like an internal representation) could be progressively explained (Pozo & Gómez-Crespo, 1998) and how this change could guide a particular knowledge to a more scientific knowledge in any domain (Dienes & Perner, 1999). Related to these theories, we can learn how people construct his internal representations on forces and how are they (White, 2012). The second one is sociocultural theories that understand scientific learning as an introduction to scientific practices. For these theories the work with representations is one of those practices and we can't understand the construction of scientific concepts without them (Ford, 2008; Lemke, 2004). We review relevant literature focused on how students' representations could be a tool to explore his ideas and how they could help them to structure his construction of concepts and reasoning (Waldrip & Prain, 2012). We consider too, different authors that have studied how cognitive and communicative conditions contribute to the construction of scientific knowledge, who have concluded that the use and development a wide range o representations has a positive contribution to the student learning (Brizuela & Gravel, 2013; Gunstone, 1995). And the third is semiotics that understands science as a multimodal discourse. This means that learning is understood as an integration of meanings that emerge from different modes (DiSessa, 2004; Jewitt, 2009).

## RESEARCH QUESTIONS

Related to aim (1): *What are the Primary School pre-service teachers' ideas, concepts, external representations and ways of reasoning on forces at the beginning of their training?*

Related to aims (2 & 4): *Which characteristics of the canonical representation of force are the most difficult for pre-service teachers; and what are the difficulties that the canonical representation adds (if any) to their comprehension of the scientific concept of force? Which characteristics of the canonical representation of force help pre-service teachers to understand forces?*

Related to aim (3): *How might the students' concept of force change by using external representations to explain their internal representations of force applied to everyday situations?*

## RESEARCH DESIGN AND METHODS

### *Materials and method*

We divide the research in two different studies to better achieve our objectives. The first study will be an open questionnaire that students will answer individually. The answers will provide us information about the different spontaneously representations and conceptions that students have. The second study will be a Case Study with group and personal interviews based on microprocesses of progressive explicitation, emphasizing in the justification of students of the use of vectors and other types of representations. A sequence of problems, mainly qualitative and open, that students will solve

in small group will guide to the constructions of the concept of force as an interaction between objects. Metacognition will be the focus of the interviews.

For collecting exhaustive data of the Case Study we will collect the productions of the students during the work sessions. These sessions will be video-record to collect those aspects that may be overlooked and after each work-session I will write a journal to reflect all those interesting aspects that have not been recorded.

### **Participants**

For the first study we a sample of approximately 120 - 150 students of Teacher in Primary Education Degree in the DMEI course. For the case study we have a population of 5-8 students who have participated in the first study.

### **Data analysis**

The data of the first study will be analysed quantitatively comparing them with the description of the literature and performing some categories in relation to the external representations and its use. The data of the second study will describe in depth the external representations constructed by the students during the interview, their progress and their response to the metacognitive prompts

### **PRELIMINARY RESULTS**

Over the last academic course we made an exploratory study with two main objectives: to develop the questionnaire and to explore how the forces sessions of the DMEI course are effective for conceptual and didactic learning. The preliminary findings from this study have shown that students arrive to university with deeply rooted misconceptions and without knowing the meaning of scientific representations of forces. Students neither have ideas and concepts about how to teach forces, different from those acquired as students in secondary education. After the four sessions of DMEI about forces, the responses of the questionnaire had no significant changes. Because of this, we follow with a deep case study with a small number of students. Some preliminary results from this case study will be presented in the Summer School.

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# **A LONGITUDINAL STUDY OF SCIENCE TEACHERS' PERSONAL EPISTEMOLOGIES AND PERCEPTIONS OF EDUCATION STUDIES**

**Liam Guilfoyle**

University of Limerick, School of Education, Ireland

## **FOCUS OF THE STUDY**

The “theory-practice divide” has been a long-standing issue for the teaching profession (Korthagen, 2010; Korthagen & Kessels, 1999; Loughran, Brown, & Doecke, 2001). This is a result of teachers continual rejection of ‘Education Studies’ (also termed Foundation and Professional Studies, Educational Theory, among others terms), which are often critiqued as irrelevant or idealistic (Sjølie, 2017). Many researchers have problematized the issue and have sought to “bridge the divide”, using various methods to make theory and research seem more relevant or appealing to teachers. As this problem persists in teacher education, there is a need to move beyond addressing perceived relevance to explore deeper factors that contribute to this rejection (McGarr, O’Grady, & Guilfoyle, 2017). This study explores one such factor – the epistemic comparisons between teachers’ subject disciplines and Education Studies.

## **DEFINING THE PROBLEM IN KEY LITERATURE**

Student science teachers who are enrolled on concurrent initial teacher education programmes simultaneously study separate modules in their subject discipline, science, and in ‘Education Studies’. However, how student teachers might reconcile these two bodies of knowledge with respect to each other has not been subjected to investigation, with the exception of one study in mathematics (Löfström & Pursiainen, 2015). Given that research findings suggest many student teachers hold less sophisticated epistemic beliefs in science (Akerson, Morrison, & McDuffie, 2006; Lee & Tsai, 2011) and Education Studies (Joram, 2007), it is pertinent ask whether these epistemic beliefs and resulting comparisons of knowledge play a role in why student teachers might reject Education Studies.

This study focuses on how student science teachers compare these separate bodies of knowledge, weighing one against another, and examines the impact of these comparisons on the acceptance or rejection of Education Studies. In order to achieve this, the study specifically examines (1) student teachers epistemic beliefs in science and Education Studies, (2) how student teachers compare these areas of knowing, and (3) student teachers’ evaluation of Education Studies as useful or relevant to their practice. In doing so, the possible connections between a student teachers epistemic beliefs, and their ultimate acceptance or rejection of Education Studies as part of their professional knowledge base can be illuminated. If epistemic beliefs and comparisons are influential in student teachers rejection of Education Studies, it would support the argument for explicit epistemic development in initial teacher education (Brownlee, Schraw, & Berthelsen, 2013; Erduran, Bravo, & Naaman, 2007; Sandoval, 2005).

## KEY TERMS

The study draws on the understanding of personal epistemology as consisting of a set of epistemic beliefs on multiple, somewhat independent, dimensions (see Table 1.) (Hofer & Pintrich, 1997). This study adapts a framework from Hofer & Pintrich in order to evaluate epistemic beliefs.

Table 1. Dimensions of Personal Epistemology (Hofer & Pintrich 1997)

Dimension	Knowledge as...	
Certainty	Fixed, unchanging, certain, stable	Fluid, changing, tentative, evolving
Simplicity	Unrelated, discrete, concrete facts	Relative, contingent, contextual
Source	From outside the self, transmitted from authority	Constructed by the knower through interaction with others
Justification	Knowing justified on basis of authority and/or observation	Use of rules of inquiry and evaluation of expert views

‘Education Studies’ is not a universal term, even within the Republic of Ireland where a number of alternative terms are used by policy makers and teacher educators for similar components of teacher education. Alternative terms include Foundation Disciplines, Foundation and Professional Studies, Educational Theory. Furthermore, there is no universal agreement as to what should be included in these components. Broadly speaking, however, we can consider ‘Education Studies’ to be inclusive of curriculum studies, the history and policy of education, philosophy of education, psychology of education, and sociology of education (Teaching Council, 2011; Walsh, 2011).

## RESEARCH QUESTIONS

The following questions will be addressed:

- 1) *What are participants’ beliefs about the nature of knowledge and knowing in Education Studies and Science Disciplines?*
- 2) *What are the perceptions of science teachers towards Education Studies from their Initial Teacher Education (& Newly Qualified Teacher) experience?*
- 3) *In what way, if at all, are participants’ beliefs about the nature of knowledge and knowing connected to these perceptions of Education Studies?*
- 4) *What changes occur, if any, in these perceptions and beliefs about the nature of knowledge and knowing over time?*

## RESEARCH DESIGN AND METHODS

This mixed methods, longitudinal study will collect data at 3 time-points over 18 months. Participants come from a cohort of 75 final-year students in a 4-year concurrent science teacher education degree programme. A pilot was conducted to test and enhance the research instruments. Time-points are as follows:

- T.0 (Apr 2014): Pilot Study [20 questionnaires, 5 interviews – cohort of AY13/14]
- T.1 (Sept 2015): Semester 1 Final Year AY14/15 [53 questionnaires, 12 interviews]

- T.2 (May-Jun 2016): On completion of Final Year [38 questionnaires, 7 interviews]
- T.3 (May-Jun 2017): One year after programme [anticipated 7 interviews]

#### **Research Question 1:**

Epistemic beliefs will be explored (in science and Education Studies) using an instrument developed by Hofer (2000): the Discipline-Focused Epistemological Beliefs Questionnaire (DFEBQ). This instrument was piloted in April 2015 and a cognitive interview (Muis, Duffy, Trevors, Ranellucci, & Foy, 2014) was carried out to explore *item interpretation*, *coherent elaborations* and *coherent response choice*. It was distributed to the cohort of 75 potential participants in September 2015. The instrument was completed by 53 student teachers and served as a recruitment tool and primer for the interview, where participants volunteered to further take part in an interview (n=12). Likert scale responses to statements in the questionnaire were probed and discussed in the interview. This allows the researcher to more extensively explore participant's beliefs about the nature of knowledge and the nature of knowing in two domains, particularly the differences and similarities of responses between these domains. Responses (DFEBQ and interview) are analysed through comparison with Hofer's (2000) Model of Personal Epistemology in order to create a rich description of each participants' own epistemic beliefs. This was repeated with the same participants in May-June 2016 (DFEBQ n=38; Interview n=7), and will be repeated once more in May-June 2017.

#### **Research Question 2:**

Perceptions of Educational Studies will be explored through written responses to open-ended questions in the questionnaire and in-depth semi-structured interviews discussed above. The interview schedule was piloted in April 2015 and alterations to the schedule were made before its initial implementation in September 2015 (T.1). Data from each data point will be transcribed and initially analysed using a thematic analysis to get a sense of the overarching and crosscutting themes (Braun & Clarke, 2006). Individual participant profiles will be constructed and merged with individual epistemic belief profiles to provide an overall picture of the individual's beliefs and perceptions.

#### **Research Question 3:**

The word 'connected' in the research question is used tentatively and will be assessed in a qualitative rather than a quantitative manner. The profiles discussed above will facilitate a comparison of the beliefs and perceptions held by the individual. Analysis will include, for example, investigating whether participants draw on epistemic statements or beliefs in order to provide rationale for their use of Education Studies.

#### **Research Question 4:**

As discussed above, data were collected at a number of time points. This allows the researcher to explore differences and similarities in responses over time, and probe possible reasons for any changes that occur. Descriptions of each individual's changes over time will be added to their profile.

## PRELIMINARY FINDINGS

Participants' epistemic beliefs vary widely, but some statements can be made in summation. Science seems to be viewed as more certain and concrete than knowledge in other domains, particularly education studies. Knowledge in science is often experienced as a body of discrete, universally applicable and knowable facts. In comparison, Education Studies is viewed as highly contextual and particularistic. For most participants this reduces its credibility, applicability, and value. However, participants' understanding of the types of claims made within educational research, and how these claims are justified, appears to be limited. While participants state a value in experience and active participation in science learning, many also believe that there is ultimately one right answer which is known by an authority figure. As such, participants own justification for knowing in science is more often on the basis of authority rather than inquiry and evaluation of expert views. Conversely, in Education Studies, knowledge from experts is doubted and one's own experience is seen as a more reliable way of knowing.

Participants' perceptions of Education Studies as useful or beneficial varied. Participants who demonstrated more sophisticated epistemic beliefs also described Education Studies as vital for practice and could provide examples of such integration. Other participants with less sophisticated epistemic beliefs could be seen to either accept knowledge from Education Studies without much critical engagement, or reject it outright with similarly little engagement. It is becoming more evident that those who believe in science as a body of somewhat 'perfect knowledge' seem to either dismiss Education Studies on the basis of it never being able to achieve the same certainty, or blindly accept it because they believe it is the same as science. In the latter instances teachers lose faith in the knowledge when it fails to operate as they expected it would, leading to a scepticism or rejection.

Other connections and influences may become more apparent as changes over time are considered through analysis of further time-points. Further in-depth analysis will be required.

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# USING VIDEO-CASES TO SUPPORT PRE-SERVICE CHEMISTRY TEACHERS' PCK DEVELOPMENT AND RECONSTRUCTION ABOUT CHEMICAL EQUILIBRIUM

Julian Heeg

Leibniz Universität Hannover - Institute of Science Education, Germany

## FOCUS OF THE STUDY

Pedagogical content knowledge (PCK) is a fundamental element of teachers' knowledge base (Shulman, 1987). When entering the first step of their education, pre-service teachers do not possess a well-developed and integrated PCK (e. g. Loughran, Mulhall, & Berry, 2004). On the one hand, PCK cannot be gained on a theoretical level alone (Jong & van Driel, 2005). On the other hand, practical training phases can decrease pre-service teachers' teaching efficacy beliefs (Tschannen-Moran, Hoy, & Hoy, 1998). Cased-based learning, using video vignettes as cases (video-cases), reduced in their complexity through a research-based design, can be used to enhance and link theory- and practice-based knowledge (Zumbach, Haider, & Mandl, 2008).

## REVIEW OF RELEVANT LITERATURE

### *Chemical equilibrium*

According to van Driel and Gräber (2003), chemical equilibrium is a key concept in chemistry. However, it is also one of the most difficult topics for students and teachers to understand (Locaylocy, van den Berg, & Magno, 2005). Over the last decades researchers have shown that students (e. g. Hackling & Garnett, 1985), pre-service teachers (Özmen, 2008) and even in-service teachers (e. g. Banerjee, 1991) all express alternative conceptions in this domain.

### *PCK*

According to Schmelzing et al. (2013), three cognitive dimensions are central for PCK (components, types and topics). Whereas the other dimensions are broadly discussed in literature, the topic-specific nature of PCK in general or in its original form is widely accepted (e. g. Abell, 2008; Aydin, Friedrichsen, Boz, & Hanuscin, 2014). Based on the work of Schmelzing et al. (2013), Alonzo and Kim (2015) proposed that PCK can be divided into a declarative (knowing that) and a dynamic (knowing how) knowledge type. Concerning the components of PCK, most studies use the original Shulman (1987) components, namely knowledge of learner (KoL) and knowledge of instructional strategies (KoIS) (Park & Oliver, 2008). There are several factors that influence the development of PKC, e. g. content knowledge (CK) (Evens, Elen, & Depaepe, 2015). Collaboration (Kind, 2009), reflection (Park & Oliver, 2008) and teachers' conceptions about processes of teaching and learning can also have an effect on PCK or the integration of its components (Friedrichsen et al., 2009). Besides these domain-specific conceptions there are topic-specific ones that could have an influence as well.

Only few studies deals with PCK with respect to chemical equilibrium (e. g. Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008; van Driel, Verloop, & Vos, 1998). In most cases, in-service teachers

were studied. Therefore, this study focusses on the evaluation of pre-service teachers' PCK regarding the chemical equilibrium and the analysis of their PCK development.

### *Cased-based learning*

Learning through cases has a long tradition in professional fields like law or medicine, especially in situations without any schematically solutions (Merseeth, 1994). In teacher education, case-based learning can help bridging theoretical concepts and their practical application (Zumbach et al., 2008). Additionally, it can be used to promote pre-service teachers' conceptions about teaching and learning (Merseeth, 1991).

### RESEARCH QUESTIONS

- 1) *What knowledge and conceptions do pre-service teachers have of PCK in general and of its single components (KoL, KoIS) about chemical equilibrium?*
- 2) *To what extent can video-cases support the development of pre-service teachers' PCK and the reconstruction of their conceptions about PCK?*

### RESEARCH DESIGN AND METHODS

The design of the study is divided into three recursive levels (fig. 1). The first level describes the development and construction of the video-cases based on video recorded interviews with small groups of grade 12 students expressing their conceptions about chemical equilibrium. The second level involves the pre-service teachers' application of the generated video-cases. Here, they work in small groups, up to three persons, on four video-cases over the course of one semester. Their work is supported using exercises and additional materials. Each video-case has its own priorities which are orientated on the three single research tasks of the educational reconstruction (Duit, Gropengießer, Kattmann, Komorek, & Parchmann, 2012). In addition, pre-service teachers are requested to reflect on their own approach towards the video-cases at the end of each session. The third level involves the analysis of pre-service teachers' PCK development.

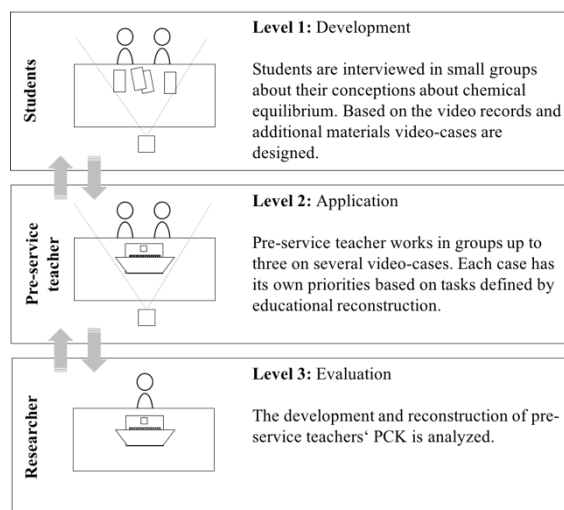


Figure 4: Design of the study

## DATA COLLECTION AND ANALYSES

At the second level a multimethod approach is used to investigate the possible impact on pre-service teachers' PCK (Evens et al., 2015). This includes, on the one hand, in-depth methods like video recorded semi-structured interviews in order to analyze the pre-service teacher conceptions about PCK (van Dijk, 2009). On the other hand, two-tier multiple-choice-tests are used to measure the pre-service teachers' CK and Content Representation worksheets (e. g. Loughran et al., 2004, 2008) to study the impact on the declarative type of PCK. In addition, the entire process of working with video-cases is video recorded to analyze the dynamic PCK-type with qualitative content analysis (Gropengießer, 2008; Krüger & Riemeier, 2014).

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# **SUPPORTING SCIENCE TEACHERS WHEN TEACHING OUTSIDE THEIR SUBJECT SPECIALISM**

**Doreen Mizzi**

University of Malta, Malta

## **OUTLINE OF THE STUDY**

Science in secondary schools is taught using different approaches ranging from integrated approaches to more specialised approaches (Eurydice, 2011). In Malta, Integrated Science is part of the core curriculum at early secondary level and includes topics from Physics, Chemistry and Biology. At upper secondary level students study one of the science subjects (generally Physics) as part of the compulsory curriculum but can opt to study the other two science subjects in combination with their compulsory science. Science teachers may be asked to teach their specialised science subject or else a combination of Integrated Science with their specialised science subject.

In Malta to date teachers can become science teachers through two different routes: (1) an undergraduate B.Ed. (Hons.) programme where they have a subject specialism in one of the sciences that is in Physics, Biology or Chemistry and the other two sciences are covered at a much broader level and (2) an undergraduate B.Sc. degree in a specific science subject(s) followed by a postgraduate certificate in Education. When teaching Integrated Science to students (age 11-13), teachers will be teaching within their area of expertise and outside their area of science specialism which for the purpose of this study means that one has not studied the subject at Degree or at Advanced level.

My research study explores the challenges faced by science teachers when teaching outside their area of specialism, particularly how science teachers who are non-Chemistry specialists approach the teaching of Chemistry-based science topics in the Integrated Science Maltese curriculum, how they deal with the challenges of teaching such topics and how they seek to improve their practices. A professional development (PD) programme was developed and implemented throughout a whole scholastic year. Eight teachers from different schools participated in the PD sessions on a voluntary basis. The PD programme was based on a number of interactive sessions and workshops that allowed the participant teachers to explore their fears and challenges and to work together to develop skills and resources that helped them improve their practice. As they became involved in the PD programme they formed a community of practice (CoP) that allowed them to share and reflect on their experiences, learn together and improve their practice through dialogue and collaboration.

## **LITERATURE REVIEW**

Learning to teach is a complex process because it involves learning how to think, know, feel and act like a teacher, thereby interlinking the content, process and context (Feiman-Nemser, 2008). When teachers develop their professional knowledge base and skills required to become science teachers, they develop professional knowledge from a cognitive perspective that is subject matter knowledge (SMK) of the subject they are to teach and also pedagogical content knowledge (PCK) which “represents the

blending of content and pedagogy into an understanding of how particular topics, problems or issues are organised, presented and adapted to the diverse interests and abilities of learners and presented for instruction” (Shulman, 1987, p.8). Affective aspects are also an important component of the teachers’ professional knowledge base since content specific beliefs affect the way teachers understand and teach a particular subject. More recently educational researchers have also started to recognise the importance of considering sociocultural influences on teacher learning (Lee & Shallert, 2016). Greeno (1997) argues that learning how to teach is not only a set of knowledge and skills but it is also a ‘situated perspective’ which means that learning is a means of social participation and developed within a particular context as result of social interaction. These perspectives (the cognitive, affective and learning in a sociocultural context) impact the development of a science teacher identity which is continuously evolving. Teacher identity is shaped by various factors such as personal background, social, cultural, historical context, emotions and relationships and interactions with others (Rodgers & Scott, 2008). Teachers develop an identity that is very strongly connected to the situated, cultural context of the subject that they teach. When asked to teach science topics within an integrated science curriculum with which they are unfamiliar, teachers can feel less confident and show apprehension. As a result teachers encounter various challenges when teaching outside subject specialism (Childs & McNicholl, 2007; Hashweh, 1987; Kind, 2009; Sanders, Borko & Lockard, 1993). They have difficulties in selecting appropriate tasks, in giving appropriate explanations, in balancing teachers’ talk with students’ talk, in answering students’ questions, in diagnosing students’ misconceptions and in setting up experiments. Teachers found different ways to deal with these challenges such as using knowledge from their area of specialism to explain concepts in their non-specialist area (Nixon & Luft, 2015), conduct research from books and other resources (Kind, 2009), be prescriptive and rely more on worksheets keeping students busy on their tasks (Lee, 1995) and seek help from colleagues who are specialist in the area (Childs & McNicholl, 2007). In developing strategies to overcome challenges when teaching outside expertise teachers will be thinking about their own personal and professional identity as a science teacher.

Professional development is a means of helping teachers develop their competences, knowledge base and skills throughout their career. Considering the sociocultural influences on teacher learning (Lee & Schallert, 2016) and its situated perspective, these learning theories have shaped the design of PD sessions by focussing less on individual learning and encouraging learning by participating within a CoP (Lave & Wenger, 1991). This leads to more effective PD as through dialogue and interaction teachers’ identities are co-constructed with others in the CoP. By reflecting on their own experiences and on the narratives of other teachers members are able to interrogate their past experiences and beliefs in a CoP. This supports them to make transitions in their identity and overcome the challenges faced when teaching outside specialism by developing their adaptive expertise (Hobbs, 2013).

## RESEARCH QUESTIONS (RQS)

The research study aims to (1) outline the challenges encountered when teaching outside subject specialism and ways of dealing with such challenges and (2) develop of a PD programme and find out how this PD programme supported teachers teaching outside subject specialism. The research questions are the following:

- 1) *What are the challenges faced by science teachers who do not have a background in Chemistry when teaching Chemistry topics in the Maltese Integrated Science curriculum?*
- 2) *How do non-specialist Chemistry teachers cope with the challenges that they face when teaching Chemistry topics in Integrated Science?*
- 3) *What kind of support and professional development do teachers who teach outside their area of science specialism need?*
- 4) *What were the views of the science teachers regarding the professional development programme?*
- 5) *What are the main characteristics of professional development that support science teachers when teaching outside their area of science specialism?*

## RESEARCH DESIGN AND METHODS

The research study follows a qualitative design more specifically a case study approach since it narrates the lived experiences of teachers when teaching outside their area of expertise and during the PD programme. Qualitative research tools were chosen since I wanted to gain an in depth perspective of how teachers were living their personal and professional story as science teachers. I was interested in understanding how teachers “interpret their experiences, how they construct their worlds, and what meanings they attribute to their experiences” (Merriam & Tisdell, 2016, p. 5). Following Denzin and Lincoln (2005, p. 21), I understood that “no one single research method could capture all the subtle variations in on-going human experience”. Therefore I decided to use a variety of research tools in order to try and provide a more holistic picture and a more entwined and interrelated narrative of the research process. These research tools were used to build the teachers’ profile, to gather experiences throughout the PD programme and to identify effective support structures for teachers when teaching outside their area of expertise. These included:

- A) A questionnaire given at the beginning of the research study to build the teachers’ profile. Follow up semi-structured interviews were carried out to provide an in-depth profile of the eight participant teachers.
- B) Discussions during PD sessions were recorded to capture the teachers’ feelings, reasoning, learning and development of ideas. These were supported by my reflections written in a journal after each workshop.
- C) Lesson observations were held to comprehend the teachers’ context and their teaching styles particularly how they taught a subject outside their area of expertise.

Interviews were held throughout the study to explore the challenges teachers experienced when teaching outside specialism and to capture the teachers' views, experiences and changes in teachers' confidence, beliefs, SMK and PCK throughout the PD programme.

## PRELIMINARY FINDINGS

Data has been gathered and transcribed verbatim. I have not started the process of data analysis yet. By recalling my experiences gathered in the research process Maltese teachers seem to experience similar challenges to those outlined in the literature review. They conduct research or ask help from the specialist teachers when facing difficulties. Their involvement in the CoP encouraged collaboration, sharing of experiences, helped them to engage in deeper reflection and feel less isolated. Discussion and interactions enhanced their SMK, PCK and confidence to teach a subject outside specialism, which impacted their teacher identity. Their active engagement in the CoP contributed to the development of knowledge as they experienced process of social and situated learning.

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# THE EFFECT OF THE OPEN EVENT WITHIN TRANSITION PROCESSES ON STUDENTS' ATTITUDES TOWARDS SCIENCE LESSONS ACROSS THE TRANSFER FROM PRIMARY TO SECONDARY SCHOOL

**Stuart Norris**

University of Lincoln, United Kingdom

## OUTLINE OF THE STUDY

Secondary schools place on transition events for students who are in the final year of their primary stage of learning. One such specific event, the year 6 open evening, is often a chance for the parents to peruse what is on offer in local schools that they are thinking of sending their child whilst giving a chance to the school to set out their stall and advertise what subjects they teach and what value for money they can offer. This is also the first time that students see more advanced subject learning in practical based subjects such as science.

The planning of these open events in relation to the subject of science and what this department chooses to put on show, and the effect this event could have on students' attitudes towards the subject of science, has yet to be assessed. As such this study uses a mixed methods design to assess if attending this open event impacts on students' attitudes towards the subject of science.

## REVIEW OF LITERATURE

The year 6 open evening as part of transitional processes has been a mainstay of British schooling since the 1970's (Oplatka, I and Hemsley-Brown, J. 2003). Its main purpose was to smooth the transfer process of students leaving their primary institutions of learning and moving school to receive a more advanced level of education: Attending secondary school. As this transfer process often resulted in anxiety for both students and parents the potential school opening its doors for one evening so that students' and parents could peruse the institution made sense. It also gives the school opportunity to differentiate themselves from their competitors by giving them the opportunity to show value for money and advertise what they can offer (Oplatka, I. 2007). A paper by Abrahams (2007) postulated that especially in the subject of science teachers are often their own worst enemies in that they want to impress and enthuse potential students about their subjects but that in turn could result in students developing unrealistic expectations of what that subject entails.

Research in transitions within education have shown a trend of students' attitudes towards school subjects declining after they transfer schools (Morgan, 1999). It could be argued that year 5 (9-10 year olds) is the start of this transitional process. It is at this age that studies have observed the start of the decline in attitude towards school and this is also the year that secondary schools use their links with their primary equivalents and bombard students with information regarding school placement choice. Explanations for this decline seem to centre around the Big Fish Little Pond syndrome in that primary school students have begun to outgrow their surroundings and that the drop in attitude is due to the perception that they are not children anymore and that they should be doing more grown up tasks

(Riglin, L. Fredrickson, N. Shelton, K. and Rice, F. 2013). Although the transition literature points to students perceive their leaving of school with optimistic apprehension no study to date have questioned the effect of year 6 open days as an effector in students' attitudinal state towards school.

## RESEARCH QUESTIONS

To summarise this therefore means that the aim of this thesis is to attempt to answer the following question:

- 1) *What impact does the year 6 open event have on students' attitudes towards science lessons?*

## RESEARCH DESIGN AND METHOD

The main research project chose a cross sectional design looking at changes in regards to the attitude of students towards science in lesson across different age groups during the transfer from primary to secondary school using a representative sample of typical feeder primary schools and associated secondary schools in England. As determined within the pre pilot study Open Events are generalizable and the selection of schools within this study, that covers 6 counties and are of mixed ability students, can be argued to be representative of the student population as a whole and as such be comparable; that is that a year 7 cohort in a typical secondary school will be generalizable with a year 7 cohort within another typical school.

To aid in what Litchman (2010) termed the 'credibility' of results, a mixed methods process was adhered to whereby focus groups and interviews were conducted after a likert scale questionnaire had been administered giving a triumvirate of methods of collecting data so that comparisons could be generated. The idea was that the questionnaire would be able to highlight key areas for discussion within the interviews and focus groups. As timing was of paramount importance as it could be a potential variable questionnaire samples from year 6 in term one before the transition event and after attending the transition event where no more than 25 days either side. This enabled the researcher to be able to gather rich data that could inform the results within the questionnaire giving a more detailed picture within this research area.

## PRELIMINARY FINDINGS

Currently preliminary findings support the literature that students' attitudes towards the subject of science declines after transfer from year 5 to year 8 (see table 1).

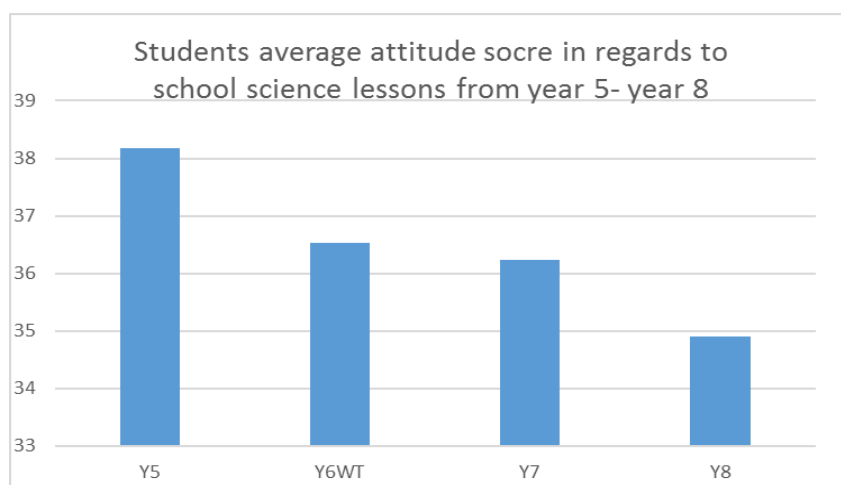


Table 1. Demonstrating average student attitude score by year.

What should be noted however is the effect the Open Event has on students held attitudes towards science just after the event. As shown by table 2 students' attitudes towards science have declined sharply when measured within 25 days after attending an open event but this effect seems to be short term in nature. When analysed the key variable that seemed to have been altered is the students held attitude towards current science lessons.

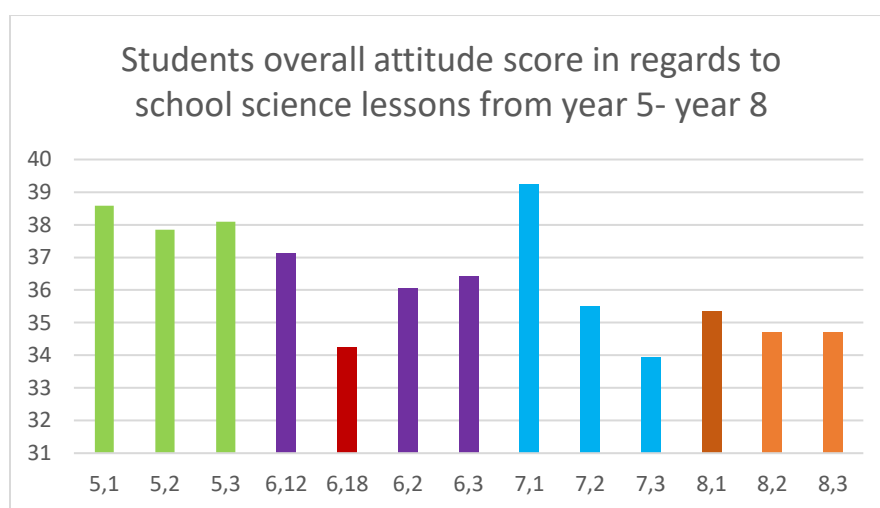


Table 2. Demonstrating average student attitude score by year and term. Open Event shown in red.

That is that year 6 students attitudes towards their primary school science lessons has declined rapidly after observing what occurs in science in secondary school. Focus groups and interviews of students in year 6 support the idea that a shift occurs in that students view science lessons in primary school more negatively in comparison to before the open event. As one student was recorded saying: 'We never do anything good in science like big school. I can't wait to leave and do proper science in Secondary'



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# **ANALYSING AND ENHANCING PRE-SERVICE PHYSICS TEACHERS' COMPETENCE OF REFLECTION DURING THE INTERNSHIP**

**Anna Nowak**

University of Potsdam, Germany

## **FOCUS OF THE STUDY**

Reflection is an element of both national and international standards of teacher training (KMK, 2004; InTASC, 2011). Among others purposes of reflection are professional development and adjustment to practical requirements (Larrivee, 2008). Helmke (2015) described the competence to reflect as a core requirement for the improvement of one's own teaching and therefore a central attribute of the teacher. Nonetheless reflection does not just happen but is a process that has to be required and nurtured (Wildman, Magliaro, Niles, & McLaughlin, 1990). Exactly this requirement and nurturing of the active process is part of the internship that has a special concept at the University of Potsdam. The pre-service teachers are in a school four days per week for a period of 14 weeks to have a realistic experience regarding the teaching profession. They spend the fifth day at university having classes in their two subjects and in educational studies. In school the pre-service teachers sit in on 66 lessons that are taught by their school-mentors and teach at least 25 lessons in each of their two subjects themselves. This diversified concept provides perfect ground to implement the (theoretical) topic of reflection at university and analyse the application of it in school. Due to the length of the internship and the number of hours each pre-service teacher teaches a long-term development of the pre-service teacher's competence to reflect can be surveyed. The survey will be conducted over four consecutive semesters and altogether 40 pre-service teachers are expected to participate. Various ascertained reflections will be analysed qualitatively with a categorical system to assess how pre-service teachers reflect, how their competence evolves throughout the semester and which topics they address.

## **SHORT REVIEW OF THE RELEVANT LITERATURE**

Reflection is a special form of reasoning (Dewey, 2002). Schön (1983) coined the terms reflection-in-action (reflection during an activity) and reflection-on-action (reflection after the activity) whereby the internship in physics is about promoting the ladder. A reflection always includes looking backwards and forwards (Valli, 1997) and is successful if an alternative for an action is created (Dewey, 2002). It requires an open attitude and volition and can be learned (ibid.). Korthagen & Kessels (1999) depict in their model of reflection ALACT how learning through experience happens in teacher training: An action (A) is looked back at (L). Thereby the person reflecting becomes aware of essential aspects (A) and creates alternative methods of action (C). The trial to realise this alternative constitutes a new action (T) which is once more looked back at and so on. This circulatory model fits Potsdam's situation as well. Davis (2006) recommends encouraging pre-service teachers constantly to reflect on a higher level and about certain contents, i.e. in a portfolio. Results of previous studies using qualitative content analysis show that reflections of pre-service teachers are mostly descriptive and evaluative rather than explaining

or naming alternatives (i.e. Hatton & Smith, 1995). Windt & Lenske (2015) use the concept of completeness to evaluate a reflection: A complete reflection contains the elements' description, rating, explanation, alternatives and consequences and the number of elements enables one to assess the quality of a reflection. Plöger & Scholl (2014) created a six step model with division into steps that refer to the sight structure or deep structure of a lesson.

## RESEARCH QUESTIONS

So far previous research is mostly based on self-evaluation of the pre-service teachers. We therefore want to directly assess the students' competence to reflect by analysing self-reflections qualitatively and derived the following research questions:

- 1) *How does the pre-service teachers' competence to reflect develop over the course of the internship?*
- 2) *Which topics are addressed in the pre-service teachers' reflections and are they domain-specific for physics, educational or neither?*
- 3) *How feasible in future teaching are the alternatives pre-service teachers name in their reflections?*

## RESEARCH DESIGN AND METHODS

The pre-service teachers are traced during the whole internship in a longitudinal study. Data is collected in school (6 to 15 test times). Altogether N=40 pre-service teachers are going to participate in the study, which proceeds over four semesters beginning in the winter semester 2016/17.

In the accompanying university seminars of the internship the pre-service teachers work together in small consistent group (a maximum of 5 members per group). Each pre-service teacher is responsible for bringing along and presenting a filmed lesson sequence that shows the application of a teaching method once. The pre-service teachers reflect on their own video (written self-reflection) as well as on the videos of the other pre-service teachers (oral external reflection) from a physics-specific, physics-didactic and educational perspective. The seminars are filmed and transcribed. In school the pre-service teachers teach at least 25 physics lessons. After 6 to 15 of them they reflect upon the application of one teaching method by their own choice guided by leading questions (written self-reflection). Those reflections are collected weekly online. Thereby the pre-service teachers gradually develop a reflection-diary. Each pre-service teacher gets at least two theory-driven feedbacks about the quality of his or her reflections.

The method used to analyse the reflections is Mayring's (2010) qualitative content analysis whereby a text is categorized into a category system. The reflection is divided into units of meaning and each unit is categorized. For that purpose the subject-specific model in figure 1 was developed based on the models of Windt & Lenske (2015) and Plöger & Scholl (2014).

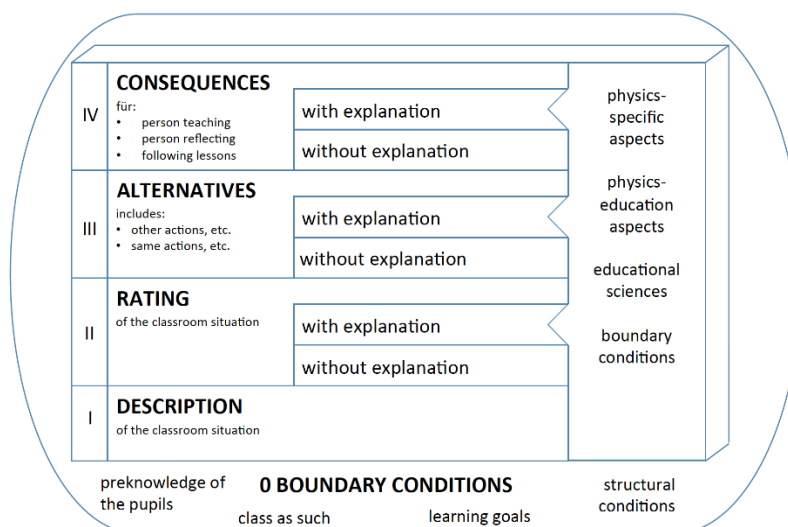


Figure 1: Model to evaluate reflection

The whole reflection is based on and made in the light of the information given in the category “Boundary Conditions”, i.e. the rating of a situation happens through comparing what happened during the lesson with what one planned to achieve the learning goal. The classification into the five different categories is used in order to examine completeness of the reflections (by counting the categories per section) and to figure out how well structured the pre-service teachers reflect.

Additionally to examining the completeness of the reflections it is also a goal to analyse the contents that are given in a reflection to see if they are domain-specific for the subject, educational or miscellaneous (content analysis). Another analysis will be to having a closer look at the named alternatives: are they feasible in future teaching, not feasible or can they not be assessed? A concrete categorical system for this analysis still has to be developed.

## PRELIMINARY FINDINGS

The first out of four planned iterations started in September 2016 and will be finished in February 2017. The analysis of the reflections of 14 participating pre-service teachers will be completed in March 2017. First reflections have been analysed and results are conform to previous studies: the reflections at the beginning of the internship are mostly descriptive and evaluative and not complete. About 30% are very well structured. Physics-specific as well as educational contents are being addressed. Physics-specific topics that are often addressed are i.e. simplification of subject material, suitable realisation and comparison of experiments and dealing with students’ conceptions.

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# **SUPPORTING THE ACQUISITION OF STRUCTURED AND CONNECTED ACADEMIC AND SCHOOL RELATED CONTENT KNOWLEDGE OF PRE-SERVICE CHEMISTRY TEACHERS BY THE MEANS OF AN ADDITIONAL TRAINING**

**Jenny Stäcker**

IPN – Leibniz-Institute for Science and Mathematics Education at Kiel, Germany

## **FOCUS OF THE STUDY**

As pre-service teachers for secondary schools are usually taught academic content knowledge, they often experience a mismatch between the content knowledge as provided at university and the school related content knowledge they have to teach. Hence, academic content knowledge is often considered too far away from their future profession as a teacher and therefore, pre-service teachers show a lack of interest and motivation in learning those contents.

The present study aims to evaluate the effect of specific learning opportunities that support the connection between academic content knowledge and school related content knowledge of pre-service secondary chemistry teachers. It focuses on the analysis of the impact that these learning opportunities have on the perceived professional relevance of the content taught at university. Those learning opportunities take place integrated in the obligatory courses in the three major disciplines inorganic chemistry, organic chemistry and physical chemistry. The effect on student teachers' perceived professional relevance and structure of their content knowledge will be analysed in an intervention study based on pre-, post and follow up-tests in a control group design.

## **REVIEW OF RELEVANT LITERATURE**

There is a substantial agreement about the subdivision of teachers' professional knowledge in content knowledge (CK), pedagogical content knowledge (PCK) and pedagogical knowledge (PK) (e.g. Shulman, 1985; Baumert & Kunter, 2006; Kleickmann et al., 2014). This study focuses on the content knowledge of secondary chemistry teachers which divides into academic CK and school related CK. Science subjects in particular show discrepancies between the concepts taught at school and the concepts of the scientific discipline itself (e.g. Deng, 2007; Bromme, 1994). Consequently, pre-service teachers have to transfer their content knowledge from the academic context to the school context and the other way round. If one considers i.e., the first law of thermodynamics in an academic context that states the change in the internal energy in a closed system is constant. By transferring this into a school context the focus moves from mathematical descriptions of energy to statements about conserving of energy and corresponding phenomena. Hence, pre-service teachers also need structured content knowledge next to sheer academic content knowledge and the knowledge about the school subject (Riese & Reinhold, 2008, 2010; Sumfleth, 2004). Structured content knowledge is understood as a form of metaknowledge about the structure and relations of both academic and school related content knowledge. This encompasses knowledge about the main ideas and concepts of the academic discipline and the school subject (curricular knowledge), on the one hand and on the other hand about the

interrelations between the academic and the school related content knowledge. It serves as a structuring element of content knowledge. Therefore, prospective teachers should be capable of mastering their subject matter in both ways, the academic content as well as the school related more didactical content knowledge (Helmke, 2003; Hascher, 2011). The described metaknowledge is also a precondition for sustainable learning, but the metaknowledge needs to be constructed by the students themselves i.e., specific learning opportunities are required (e.g. Schneider & Stern, 2012; Steiner, 2006).

The bachelor's programme at Kiel University comprises mainly courses that only address the academic content knowledge, which leads to student teachers dealing barely with structured knowledge related to their school subjects. Therefore, students do not perceive the academic content knowledge as something relevant to their future profession as a teacher (Blömeke, 2006; Kolbe, 2004). This could lead to negative affective and cognitive effects on learning motivation and on the results of learning (Schneider & Stern, 2010).

## RESEARCH QUESTIONS

Based on the background mentioned above the following research questions are posed:

- 1) *What is the present professional relevance of academic contents perceived by pre-service secondary chemistry teachers?*
- 2) *Which effects have additional learning opportunities on student teachers' perceived professional relevance of academic contents?*
- 3) *Is there a correlation between the individual level of student teachers' content knowledge and their perceived professional relevance of academic contents?*
- 4) *Is there a correlation between the level of structured content knowledge and the professional relevance of academic contents perceived by pre-service secondary chemistry teachers?*

It is assumed that the initially low level of perceived professional relevance of academic contents by pre-service secondary chemistry teachers increases by attending additional learning opportunities and positively correlates with the level of content knowledge and the level of structured and connected content knowledge.

## RESEARCH DESIGN AND METHODS

The effects of the additional learning opportunities will be analysed in an intervention study based on pre-, post and follow up-test design shown in table 1. According to this design, the independent variable is the additional training (learning opportunity vs. no learning opportunity). This design will be carried out for each discipline, inorganic, organic and physical chemistry.

Table 1: The test design and the sample size concerning the first intervention in physical chemistry

group	1st measurement	intervention	2nd measurement	intervention
intervention group [n = 20]	X	X	X	-
control group [n = 20]	X	-	X	X

The dependent variables comply with the research question are (1) the perceived professional relevance of content knowledge taught at university and (2) the level of structured content knowledge. Additionally, the level of content knowledge and certain background characteristics such as the subject combination (for teachers in Germany at least two subjects are required to study), the number of finished semester, the names of previously attended courses, and the corresponding marks will be assessed. This test design and evaluation will take place individually for each of the three major disciplines inorganic chemistry, organic chemistry and physical chemistry. The sample will consist of pre-service secondary chemistry teachers in the bachelor's programme at Kiel University and each group (intervention and control group) is comprised of n = 25 students.

Based on standards of the academic and school curriculum conceptual strand maps were developed which show how main ideas in chemistry are connected within and between the levels: university, upper secondary level and lower secondary level.

As the first training will deal with physical chemistry the following section illustrates possible methodical approaches. The training consists of three major parts which aim to promote the metaknowledge about the content knowledge taught at university and the content knowledge related to the school subject as well as to increase the perceived professional relevance of these contents. First, there are exercises for structuring and representing the academic knowledge. Second, after collecting and arranging the main ideas and important terms for academic content knowledge, the students have to analyse specific teaching situations in order to train their ability to make appropriate decisions concerning teaching choices of subject matter and the planning of lessons with the help of their content knowledge. Using the issue of physical chemistry as an example, the students have to decide whether they rather use the technical term (1) *boiling temperature* or (2) *boiling point* (which can be reasoned with (1) reducing the complexity or with (2) emphasising the fact, that the boiling point depends on the two state variables temperature and pressure). And third, exemplary exercises in checking academic content knowledge considering the usage in school lessons are carried out. For that a chemistry topic is picked which is not part of the school curriculum and its potentials and demands are analysed in order to become a school content.

The present doctorate study started in September 2016 and will be finished by the end of 2019. In a first step, the academic and school related content knowledge in the field of physical chemistry was analysed and displayed as a conceptual strand map. Based on these maps, detailed lesson plans and required tests instruments are just being developed or adapted. The following steps are the realization of the intervention for physical chemistry in summer 2017 and the development of the interventions in the fields of inorganic and organic chemistry that will be conducted in winter 2017. In 2018 and 2019 the



interventions will take place a second time in order to increase the sample size. At the time the ESERA Summer School will take place preliminary findings and specific training concepts can be presented.

This project will provide a systematic concept for specific learning opportunities for pre-service teachers to support their assembling of structured content knowledge, which aims to serve as a profound preparation for being a teacher. Although this training is initially designed and evaluated for chemistry teachers' education at Kiel University it can be implemented at other university locations.

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# VIDEO AS A TOOL FOR INCREASING MOTIVATION AND DEVELOPMENT STUDENT'S SKILLS IN DIDACTICS OF BIOLOGY

**Anna Vitásková**

Charles University in Prague, Faculty of Education, Czech Republic

## THE FOCUS OF THE STUDY

The main focus the PhD. research is lesson observation videos (LOV) and the use of these videos in the education of future biology teachers. It is based on previous master thesis *Video as a Tool for Increasing Motivation and Developing Student's Skills in Didactics of Biology*. This education style is common in mathematics and foreign language science. In the Czech Republic you can find many lesson observation videos from subjects English, P.E., Geography and Physics (thanks to the project *CPV videostudie from Faculty of Education, Masaryk University in Brno*) (Janík, Míková, 2006). But until now, there were no lesson observation videos from Biology. We created 8 videos as a crucial part of the master thesis (mentioned above) (Řeháková, 2016). Pilot watching LOV in subject Didactics of Biology showed that this way of education is highly motivating for students (motivation for studying education of biology and also for professional carrier as a teacher). We want to continue to work with LOV in this and future years in subjects *Didactics of Biology* and *Video club* in Department of Biology, Environmental and Geology of Faculty of Education, Charles University in Prague.

## A SHORT REVIEW OF THE RELEVANT LITERATURE

The first LOV were filmed in 60's of 20 century. Now it is common to film lessons, for example, mathematics and foreign language (Janík, 2009). Major propagators of this methods are Miriam G. Sherin, prof. PhDr. Jiří Mareš, CSc., prof. PhDr. Jozef Maňák, CSc., doc. PaedDr. Jan Slavík, CSc. a doc. PhDr. Tomáš Janík Ph.D.

LOV have two main functions – diagnostic and research – and there are two types of LOV – “other person lesson observation videos” (OPLOV) and “self-observation lesson videos” (SOLV) (Janík, 2009). “Self-observation lesson videos” have primary reflexion function “, “other person lesson observation videos” develop knowledge about pedagogic and didactic methods (Slavík, 2013; Janík, Seidel, 2009; Seidel 2011).

LOV are very important for teacher's profession, because a teacher's profession is based on feedback (Janík, 2011). Effective feedback isn't just watching, we must analyse and interpret. Analysis and interpretation aren't simple, therefore, students or teacher–novices need help of teacher-experts or from a professional didactics guides (Píšová, 2010). This method encourages teacher-novice to professionalization, which is heavily discussed in teacher profession today (Papáček, 2015; Marsh, Mitchell, 2014).

Lesson observation videos have many positives and they are useful tool for education (Minaříková, Pišková, Janík, 2015). They are time-saving, permanent and available. LOV allow students

to watch didactics and pedagogic methods. Often it is the only opportunity to get to know new didactics and pedagogic methods (Papáček, 2015).

In fact, LOV of biology have one main negative – availability and low quantity. We filmed eight videos and put them to password protected web page because of this problem.

## RESEARCH QUESTIONS, RESEARCH DESIGN AND METHODS

Our main hypothesis is that watching, analysing and interpreting of these videos improves students' professional skills. We presume that this improvement is positive (Sherin, Van Es, 2005; Janík, Seidel, 2009; Rich, Hannafin, 2009; Minaříková et al. 2015). All students will use the following methods for analysing videos, for example, 3A methodology, reflection essay, student discussion, observation report, portfolio from student's practise, etc. Students will evaluate their professional competences at the end of the seminar.

In thesis *Video as a Tool for Increasing Motivation and Developing Student's Skills in Didactics of Biology* (Řeháková, 2016) students consider this method (working with the videos) as beneficial. The most favourite analysis and interpretation is student discussion. There is a question – Is it just popular and motivational or is there a benefit for future improvement?

### Hypothesis

We would like to answer these research questions.

- 1) *Are the benefits for student's competences better for the experimental group or the control group of students? (For example, the ability to comprehend didactic elements?)*
- 2) *Is the benefit for student's competences better for the group working with "self-observation lesson videos" or for the group working with "other person LOV"? (for example, the ability to apprehend didactics elements)*
- 3) *Are the benefits for student's competences better for the group of students who study together at seminars or for the group of students who study separately at home?*

### Material

Now we have 10 videos OPLOV and 4 SOLV. We started *Video club* subjects in the winter semester 2016 and SOLV, which was made as one of results. There will be more SOLV according to number of students. These videos are placed on website [www.didaktikabiologievidea.cz](http://www.didaktikabiologievidea.cz). This website works just with password.

### Participants of research

Participants of this research are students of the first year of master's programme (academic years 2016/2017, 2017/2018 and 2018/2019) that study biology and subjects such as, *Didactics of Biology* and *Video clubs*. We count about 60 students.

## Methods

We are working with 5 groups of students. The first is a control group. The other groups are experimental groups. Students are divided into groups casually. Differences between groups are in working with different types of videos (OPLOV or SOLV) and place of work (home or school). Methods of working with videos are the same in all of groups.

Two of these groups will be working with OPLOV, one of them separately at home and the other in the group together during seminars. The first and the last video will be the same (pre-test and post-test).

The last two groups will be working with SOLV, one at home and one during seminars. All of the students will make SOLVs. The videos will have the same topic and the lessons will be prepared for pupils of the same age during.

A research team will work with the data provided by the students after the seminars. We will follow the methodology published by Sherin van Es (2005), Roth (2011), Sonmez and Hakverdi-Can (2012), etc. or we will make our own coding manuals. We are going to code sequences of student's written work and code it. Because of objectivity and portability of results we will code each of the works twice – by researcher and by supervisor. At the end of the subject we are going to give questionnaires to the students. These questionnaires will find out the progress of student's opinion.

Our preliminary findings are: the motivation and skills for studying Biology education are higher. Also, the motivation and skills for following a professional career is more advanced. Also, selected teacher's competences reach a higher level.

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# HOW SCIENTIFIC INQUIRY IS ACTUALLY IMPLEMENTED BY ITALIAN SECONDARY SCHOOL SCIENCE TEACHERS?

Alessandro Zappia

University of Camerino, International School of Advanced Studies, Italy

## INTRODUCTION

Scientific Inquiry (SI) has been since long time acknowledged as a teaching methodology that can promote a meaningful understanding of science concepts through active investigation of phenomena and processes, measurement, classification, experimentation, data analysis and drawing of reasonable conclusions (NRC 1996; NGSS 2013). However, at secondary school level, the implementation of inquiry practices is limited and their effectiveness still debated (Minner, Levy & Century, 2010). Such evidence may be justified by several factors, including teachers' limited knowledge of SI (Capps, Shemwell & Young, 2016) and the lack of appropriate training (Blanchard et al. 2009). However, while professional development (PD) courses may improve teachers' attitudes towards and beliefs in inquiry (Carleton et al. 2007), in some cases such improvement does not reflect in teachers' practice (Marshall and Smart, 2013). A useful construct to justify such results is that of "teacher's transformations" (Giberti et al., 2001). The term "transformation" refers to which extent teaching approaches are accepted, modified and reorganized by the teachers who adopt and implement them in their practice (Pintò et al., 2003). While some transforming trends may lead to fruitful modifications of didactical innovation, others may impact in a negative way, leading, in some cases, to what Brown and Campione (1996) call a *lethal mutation* in the enactment of curriculum materials, namely an adaptation of the approach that deviates substantially from the designers' aims. In this respect, not much is known about what are the specific aspects of inquiry that are more likely to be transformed by teachers.

For such a reason, this Ph.D. research study focuses on the analysis of how Italian secondary school teachers' transform inquiry aspects in their practice. The research question that will guide the study is: *to which extent teachers transform aspects of inquiry in their school practice?*

## THEORETICAL FRAMEWORK

To answer our research question, we adopted a modified ARI (Adaption and Re-Invention) Model (Rogers, 1983), useful to describe how a teaching-learning sequence (TLS, Méheut & Psillos, 2004), developed for a given educational context, is implemented in a different one. The framework works as follows: first, "core" and "non-core" elements of a given TLS are identified. "Core" elements are TLS essential features (didactical approach, objectives, assessment, type of activities), which should not be changed while implementing a TLS, since they characterize it in a unique way. "Non-core" elements are complementary features that mainly concern classroom management (Harris and Rooks, 2010), and can be changed to better fit the TLS in school practice. Then, after classroom implementations, the TLS, as enacted in teacher's practice, is compared with the original one to identify aspects that have been

adopted/ transformed. In this study, core and non-core elements are related to inquiry principles (see Table 1).

## RESEARCH DESIGN

The research project has been structured in three iterative phases: (i) involvement of participating teachers in a PD course (about 30 hrs); (ii) implementation on behalf of each teacher of an inquiry-based TLS in classroom (about 5 hours); (iii) feedback on classroom activities using video-based analysis of the activities. The aim of the PD course was to improve teachers' pedagogical content knowledge about scientific inquiry, through discussion of research papers and the implementation of existing TLSs<sup>9</sup>, already validated in different educational settings and adapted to the Italian one. Small group interaction was allowed to favour peer learning. In the second phase, teachers implemented in their classroom one or two TLSs among those proposed during the PD course. In this phase, enough freedom was given to teachers in order to adapt the proposed TLSs to their needs and specific school contexts. Audios, videos and field notes were the data collected to observe significant students' reactions to teacher's specific triggers. In the third phase, data analysis has been carried out to evaluate which inquiry aspects are mostly transformed by teachers.

Overall, thirty teachers participated to the PD course. For this study, we analyzed data from 13 teachers (students involved of about 14-16 years old).

Table 1 Core and non-core elements of inquiry<sup>a</sup>

Core elements	Non-core elements
Using a meaningful context/problem to introduce the activities	Supporting students in using the materials about the addressed science content;
Generating research questions and hypothesis;	Setting up a fruitful and collaborative classroom environment;
Collecting and analyzing data;	Managing time and school constraints;
Discussing and communicating results using collected evidence;	Designing suitable homework.
Creating a community of practice.	

<sup>a</sup> NRC (1996), NGSS (2013)

## METHODS

To analyze collected audio/video data, a coding system was inductively developed using the constant comparative method (Glaser 1965). Unit of analysis consisted in a period of ten minutes to observe significant teachers' actions and students' reactions to triggers. About thirty frames (300 minutes, 5 hours) for each teacher were analyzed. The emerging categories exemplify typical actions that teacher and students carried out during the activities and correspond to specific inquiry aspects. After two rounds of refinement, nineteen categories were adopted (defined, selected or identified).

<sup>9</sup> Sheffield Hallam University *Earth and Universe Project Research Briefs*. On-Line, retrieved 11-08-2014, [www.chreact.eu](http://www.chreact.eu)

Then, using the ARI model, the categories were assigned to inquiry core and non-core elements and scored using a three-level classification (*low – medium – high*). The aim was to evaluate to which extent a specific inquiry aspect, as instantiated by the emerging category, was accepted or transformed with respect to TLS designers' intentions. Then, a numerical score was assigned to each level (*low=1, medium=2, high=3*) and a final score for each aspect was calculated by averaging scores on all time frames, where the representative category emerged. Examples of how teachers' actions in the time frames were coded and scored will be reported during the summer school. Finally, to investigate whether a specific aspect was transformed across the sample, we introduced a numerical parameter,  $D$ , to indicate the difference between the number of teachers who did not transform that aspect (score = 3) and teachers who partially or fully transformed it (score  $\leq 2$ ). Depending on the calculated value, each category was labelled as: *heavily transformed* if  $-9 \leq D \leq -3$ ; *somewhat transformed*, if  $-1 \leq \Delta \leq +1$ ; *adopted*, if  $+3 \leq \Delta \leq +9$ . Finally, for each teacher, an overall score for core and non-core aspects was obtained by averaging the scores of each corresponding category. We introduced a three-level variable, to evaluate the degree of transformation enacted by each teacher: *heavy transformations*, Score  $< 2$ , *some transformations*,  $2 \leq \text{Score} \leq 2,5$ , *almost no transformations*, Score  $> 2,5$ .

## PRELIMINARY FINDINGS

Preliminary findings suggest that teachers were overall more resonant in non-core than in core aspects of the implemented TLSs. The most striking result is that the majority of the core aspects have been only partially adopted and in some cases completely transformed by the sample, leading teachers to do *heavy transformations* in these aspects. Plausible reasons for the obtained evidence will be investigated and discussed in more details during the Ph.D. course, comparing the results obtained with those we are going to collect in the next years of research. At the summer school, we will discuss time graphs of the video analysis and differences in the scores obtained by the teachers.

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## **ACKNOWLEDGEMENT**

This booklet was prepared with financial support of the University of South Bohemia in Ceske Budejovice.

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## USED WEBPAGES

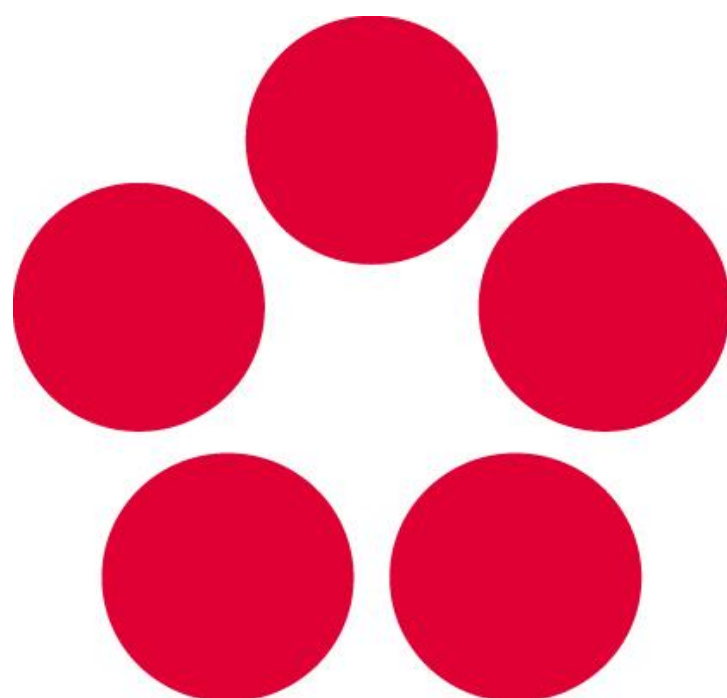
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## ATTACHMENT: MAIL ADDRESSES

Axelithioti Panagiota	p.axelithioti@gmail.com
Bhulana Lubabalo Albert	bhulanal@yahoo.com
Bittorf Robert Marten	bittorf@idn.uni-hannover.de
Buber Ayse	buberayse@gmail.com
Celik Kübra Nur	kuebra.celik@uni-due.de
Coppard Elizabeth	elizabeth.coppard-2016@brookes.ac.uk
Češková Tereza	tereza.ceskova@gmail.com
Dönmez Ismail	ismaildonmezfen@gmail.com
Gandolfi Haira	haira.gan@gmail.com
Garcia-Lladó Angela	angela.garcia@ub.edu
Gierl Katharina	gierl@uni-landau.de
Gigl Florian	gigl@uni-landau.de
Glomm Theresa	glomm@idn.uni-hannover.de
Gorges Anne	anna.gorges@uni.lu
Guilfoyle Liam	liam.guilfoyle@ul.ie
Hägele Jörn	joern.j.haegle@didaktik.physik.uni-giessen.de
Heeg Julian	heeg@idn.uni-hannover.de
Hüfner Sybille	sybille.huefner@leuphana.de
Ivanauskas Audrius	audrius.ivanauskas@leu.lt
Jackowski Andreas	andreas.jackowski@uni-due.de
Lämsä Joni	joni.lamsa@jyu.fi
Massolt Joost	massolt@uni-potsdam.de
McGowan-Smyth Jennifer	jennifer.mcgowan-smyth@education.ox.ac.uk
Mizzi Doreen	mizzidoreen@gmail.com
Möllits Aet	aetm@tlu.ee
Noor Mohd Syafiq Aiman Mat	m.noor.14@ucl.ac.uk
Norris Stuart	snorris@lincoln.ac.uk
Nowak Anna	anna.nowak@uni-potsdam.de
Oettle Michaela	michaela.oettle@ph-freiburg.de
Olsson Daniel	daniel.olsson@kau.se
Pols Freek	c.f.j.pols@tudelft.nl
Saadi Zakaria	zakaria.saadi@outlook.com
Sahin Emine	eminesahin59@gmail.com
Schad Vanessa	schad@uni-landau.de
Sinakou Eleni	Eleni.Sinakou@student.uantwerpen.be
Smerdel Snježana	ssmerdel@gmail.com
Stäcker Jenny	staecker@ipn.uni-kiel.de
Stern Florian	florian.stern@unige.ch
Surendran Shone	s.surendran.14@ucl.ac.uk
Takei Sandra	Sandra.Takei@kcl.ac.uk
Tamm Marja	marja.tamm@helsinki.fi
Taskin Nazli Ruya	nazli.ruya@gmail.com
Timonen Laura	laura.timonen@oulu.fi
Vitásková Anna	annarehakova12@gmail.com
Warren Clare	c.warren4@herts.ac.uk
Yanis Hilal	hilalyanis@yahoo.com
Zappia Alessandro	alessandro.zappia@unicam.it



ISBN 978-80-7394-653-1

