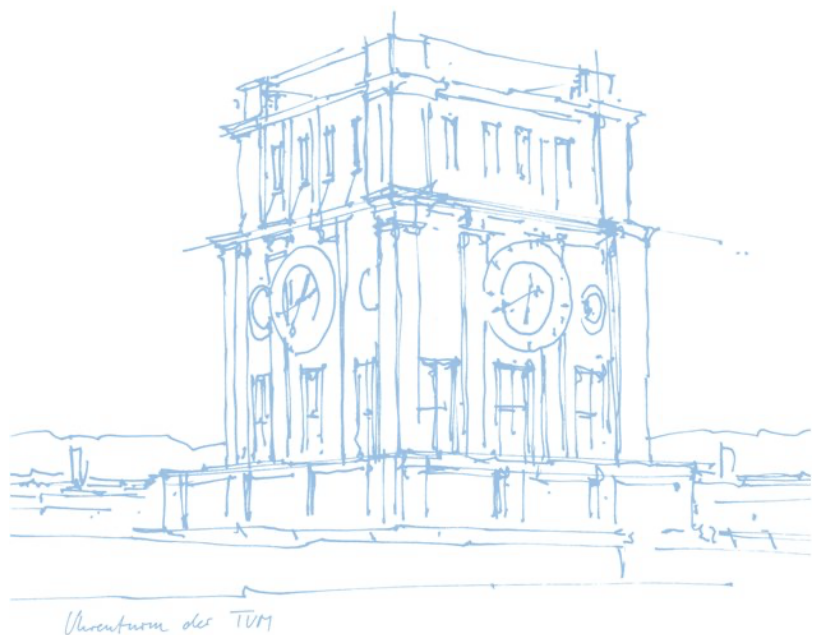


# Conceptual Change in the Era of Digital Transformation

13<sup>th</sup> International Conference on Conceptual Change

Program & Abstracts

Munich – August 27–30





# Welcome to Munich

## The City of Munich

Munich, the vibrant capital of Bavaria, is one of Germany's most significant metropolises, renowned for its rich history, lively culture, and modern economic power. The city captivates with a harmonious blend of historical landmarks, such as the Marienplatz and the magnificent Nymphenburg Palace, as well as contemporary architecture and innovation centers. Munich is not only home to world-renowned events like Oktoberfest but also a major hub for business and science, hosting numerous international companies and prestigious educational institutions. The high quality of life, excellent infrastructure, and diverse cultural offerings make Munich an ideal location for conferences and international encounters.

## Experience Culture at the Heart of Munich: The Conference Venue in the Kunstareal

The conference venue at the TUM main campus is located in the *Kunstareal Munich*. The Kunstareal is a significant cultural district in the heart of Munich. It boasts an impressive collection of museums, galleries, and cultural institutions, including the *Alte Pinakothek*, *Neue Pinakothek*, *Pinakothek der Moderne*, and the *Lenbachhaus*. With over 16 collections and around 40 institutions, the Kunstareal offers unique access to art and culture from various epochs and styles. Visitors can explore works ranging from antiquity to the present and discover a wealth of cultural treasures in the historic buildings and modern architectures. The Kunstareal is one of the central locations for art enthusiasts and a major hub of cultural life in Munich.

## Tap Water Quality

The tap water in Munich is known for its exceptionally high quality. It primarily comes from the protected mountain springs of the Mangfall Mountains and undergoes minimal treatment to preserve its purity and natural taste. Regular inspections confirm that Munich's drinking water meets the strict German drinking water regulations and can be consumed without concern.

## Electricity

A German power outlet operates at a voltage of 230 V, and the maximum current is typically 16 A. These values are in line with the common European standards for household outlets.

## Internet Access

The Technical University of Munich offers its guests comfortable and reliable internet connectivity through the international network *eduroam*. Eduroam allows students, researchers, and academic guests to securely access the internet using their home university's credentials.

## Smoking Policy

There is a general smoking ban, including the use of e-cigarettes, vapes and similar devices, in all buildings of the Technical University of Munich.

# Conceptual Change in the Era of Digital Transformation

Research has well established that learning is not always a smooth process but can require quite radical conceptual change. Despite its long research tradition, important questions about how to describe and effectively support individual learners' conceptual change processes are still a matter of current research. Modern technology offers novel ways of studying and supporting learners' conceptual change. For example, digital learning environments enable researchers to collect rich data (e.g., log data, mouse tracking, eye movements, heart rate) and to assess learning processes (including affective states) in real-time. Accordingly, digital technologies have the potential to model conceptual learning on a micro-level and to support individual learning adaptively.

However, using such technology comes with new challenges. Interpreting rich data in a meaningful way is not straightforward and using them to provide adaptive support for learners is even less. More fundamentally, the constant availability of digital tools and the speed at which digital media affect our everyday lives require researchers and instructors to re-conceptualize their ideas of learning. In other words, the digital transformation may require conceptual change in how we think about teaching and learning.

At this conference, we want to discuss especially the potential and the challenges of conceptual change theory in the era of digital transformation.

# Greeting From the Coordinators

Dear Colleagues,

On behalf of the organizing committee, welcome to the 13<sup>th</sup> International Conference of the Special Interest Group on Conceptual Change. We are delighted to have you join us at the Technical University of Munich for this bi-annual event, co-hosted by the European Association for Research on Learning and Instruction (EARLI).

Our conference theme "Conceptual Change in the Era of Digital Transformation" reflects the dynamic interaction of conceptual change research and digital innovation. As digital tools and media permeate our everyday lives, researchers and educators are challenged to rethink and reconceptualize traditional notions of learning. Our goal is to explore these evolving paradigms, highlighting both the opportunities and the challenges presented by digital transformation.

Throughout the conference, we will discuss the ways technology can enhance our understanding and support of learners' conceptual changes. However, the use of technology comes with significant challenges. As such, the digital transformation necessitates a fundamental shift in how we think about teaching and learning.

Our conference will feature an array of stimulating sessions including three keynote sessions, symposia, paper and poster presentations, panel discussion and roundtables. Additionally, we are excited to continue offering a Summer School preceding the main conference. Activities include presentations from PhD students with ample time for feedback and workshops by experienced researchers on topics such as conceptual change, statistics, writing and publishing. We especially thank Christian Thurn, our JURE coordinator, for organizing the Summer School and bringing together new researchers. We especially welcome those who are taking part at this conference for the first time to take part at the Summer School. This year, we are also introducing the SIG 03 JURE Outstanding Publication Award, to honor significant contributions to the field from early-career researchers. The award ceremony, held on the first day of the conference, will showcase the awardee's innovative work and present an award of 500€ sponsored by Springer.

We would like to express our gratitude to the local organizing committee, led by Andreas Obersteiner, for their dedication and hard work in bringing this conference to fruition. We also thank all conference participants—keynote speakers, organizers of the symposia and round tables, reviewers, and session chairs—for their valuable contributions. Lastly, we would like to thank many former SIG 03 coordinators who formed the evaluation committee of the SIG 03 JURE Outstanding Publication Award.

We encourage you to engage actively in the sessions, share your insights, and take advantage of the numerous networking opportunities also available through our social program. Let's make this conference a memorable experience filled with inspiration, collaboration and groundbreaking discussions.

Welcome to the conference, and we look forward to an enriching and productive meeting with wonderful events that will make a change!

SIG Coordinators,

Jake McMullen, Natassa Kyriakopoulou, Christian Thurn

# Greeting From the Local Organizers

Dear Colleagues,

Welcome to Munich! We are delighted to host the 13th International Conference on Conceptual Change here at the Technical University of Munich (TUM). It's a pleasure to have you join us for what promises to be an enriching and inspiring event.

The response to our call for papers has been overwhelming, and we are thrilled to welcome almost 100 participants from 19 different countries. This truly international gathering highlights the diverse perspectives that will enrich our discussions. To ensure a welcoming and inclusive environment for everyone, we have implemented a code of conduct, in line with EARLI's recommendations (see p. 7-8). Our Safe Conference Care Team will be available throughout the event, should any issues arise.

The theme of this year's conference, "Conceptual Change in the Era of Digital Transformation", resonates deeply with the mission of TUM and, in particular, the Department of Educational Sciences in the TUM School of Social Sciences and Technology. Our work focuses on the challenges and opportunities presented by digital transformation, integrating educational, societal, environmental, and technological perspectives.

We hope your time in Munich will be inspiring not just scientifically, but also socially and culturally. In addition to an exciting scientific program, we have planned several social events to help you strengthen your networks through informal exchanges. To give you a taste of Munich, we are offering excursions to exciting places in Munich or, either guided tours or informal walks (see p. 20).

In our commitment to sustainability, this conference booklet is available in digital format, with printed copies provided only to those who requested them during registration. Additionally, water fountains will be available throughout the conference, so please bring your own bottle to stay hydrated.

We look forward to sharing these exciting days with you!

The Local Organizing Team

Andreas Obersteiner  
Marian Anguela González  
Michael D'Erchie  
Alina Kadluba  
Ilka Nagy  
Judy Tzyy-Yuh Maa  
Michael Nickl  
Christian Schons  
Sabrina Schwarzmeier

# Code of Conduct

The organizing team of the 13<sup>th</sup> SIG 03 Meeting in Conceptual Change and the SIG 03 Summer School (SIG 03 Conference) is committed to respecting and promoting diversity, equality, inclusion, and freedom of expression. We strive to create a productive, safe, and harassment-free environment for all participants. By participating in the conference (whether as a speaker, guest, or member of the organizing team), you agree to the following Code of Conduct.

All forms of disrespectful behavior, including specifically all forms of discrimination, vilification, abuse, and harassment are not welcome. To determine whether disrespectful behavior is present in a specific situation, it can be helpful to consider the concept of structural discrimination, as disrespectful actions often manifest as forms of structural discrimination (cf. [www.humanrightswatch.ch](http://www.humanrightswatch.ch)). Structural discrimination manifests at individual, cultural, and institutional levels and pertains, among other things, to the diversity categories listed below.

Specifically, the following behaviors (physical or virtual) are considered undesirable:

- Harassment or intimidation based on (attributed) diversity categories such as age; biological, psychological, or social gender; geographical, cultural, or ethno-linguistic characteristics; political views; physical appearance; mental or physical disabilities; religion or secularity; sexual orientation; socio-economic status; or the intersection of several of these characteristics.
- Derogatory verbal or written expressions relating to the aforementioned categories that create a hostile environment (e.g., sexist or racist jokes).
- Sexual harassment or intimidation, including unwanted sexual attention and unwanted physical contact.
- Patterns of inappropriate or intrusive social contact, such as demanding or accepting inappropriate intimacy or continuing personal conversations after being asked to stop.
- Unwanted photography, audio or video recording, stalking, or pursuit.
- Threatening or inciting violence against a person, including encouraging self-harm.
- Public disclosure of aspects of a person's identity or (attributed) group affiliation against their will (e.g., outing of sexual orientation) or the use of names or designations for a person that they reject (e.g., deadnaming, misgendering).
- Persistent disruption of speakers or events (verbal or physical).
- Unwanted comments on a person's lifestyle and practices, including those related to nutrition, health, education, and employment.
- Retaliation against a person who has reported harassment or other unacceptable behavior or has participated in an investigation of such an accusation.
- Advocating or encouraging any of the aforementioned behaviors.

We are aware that cultural or any other differences may cause misunderstandings, but we do expect all SIG 03 conference participants to be both polite and proactive, and to ensure a pleasant conference experience for everyone.

This Code of Conduct aims to ensure conditions for open and respectful scientific exchange and communication. Critical examination, discussion, and strong disagreements regarding beliefs and viewpoints relevant to the topic of discussion, presented in a respectful manner, do not in themselves constitute harassment. We expect all individuals involved in the SIG 03 Conference to adhere to this Code of Conduct in all matters related to the conference.

## Consequences

All individuals involved in the conference are encouraged to look out for each other. When asked to cease harassing behavior, a person is expected to comply immediately. The organizing team reserves the right to take various measures to ensure compliance with the Code of Conduct. These measures may include addressing the individuals involved, expulsion from the conference without refund, requesting exclusion from future SIG 03 events, requesting cancellation of SIG 03 membership, and filing a police report. The national law of the conference location will be followed, as necessary.

## Reporting and Assistance in Incidents

If you or someone in your vicinity experiences or suspects disrespectful or intrusive behavior at the conference, please report it to one of the following members of the Safe Conference Care Team, who represent different levels of academic and institutional affiliation.

- Sabrina Schwarzmeier, Local Organizing Team, TUM (sabrina.schwarzmeier@tum.de)
- Michael Nickl, Local Organizing Team, TUM (michael.nickl@tum.de)
- Christian Thurn, ETH Zurich, SIG 03 JURE Coordinator (christian.thurn@ifv.gess.ethz.ch)
- TUM Compliance Office (compliance@tum.de)
- EARLI Conference Care Team (careteam@earli.org)

You can make a report in person or send it by email. All reports will be considered by the Safe Conference Care Team, which will then decide on appropriate measures.

We respect requests for confidential handling of a report if it serves the protection of an abuse victim. If there are security concerns, we reserve the right to publicly identify a person accused of harassment or privately warn individuals about them. We do not disclose the names of harassment victims without their explicit consent.

If you believe you have been falsely accused of violating this code of conduct, please notify the Safe Conference Care Team with a brief description of your perspective. Appeals against these measures will be decided by the board.

Members of the Safe Conference Care Team and any other individuals responsible for implementing or monitoring these measures will recuse themselves if they have a conflict of interest, such as being a specific target of harassment or a suspected harasser, or having a close personal or professional relationship with an affected or accused person.

## Feedback

We look forward to working together to create a safe, pleasant, and respectful atmosphere for professional and critical scientific exchange. We welcome feedback on this code of conduct or any other aspects of addressing diversity and discrimination at the conference via [sig03-2024.ma@sot.tum.de](mailto:sig03-2024.ma@sot.tum.de).

# Contents

Conference Venue	11
Program Overview	15
Keynotes	16
Excursions	20
Lunch	22
Tuesday, August 27	25
Wednesday, August 28	31
Thursday, August 29	56
Friday, August 30	75
Important Phone Numbers and Addresses	81
Acknowledgements	82

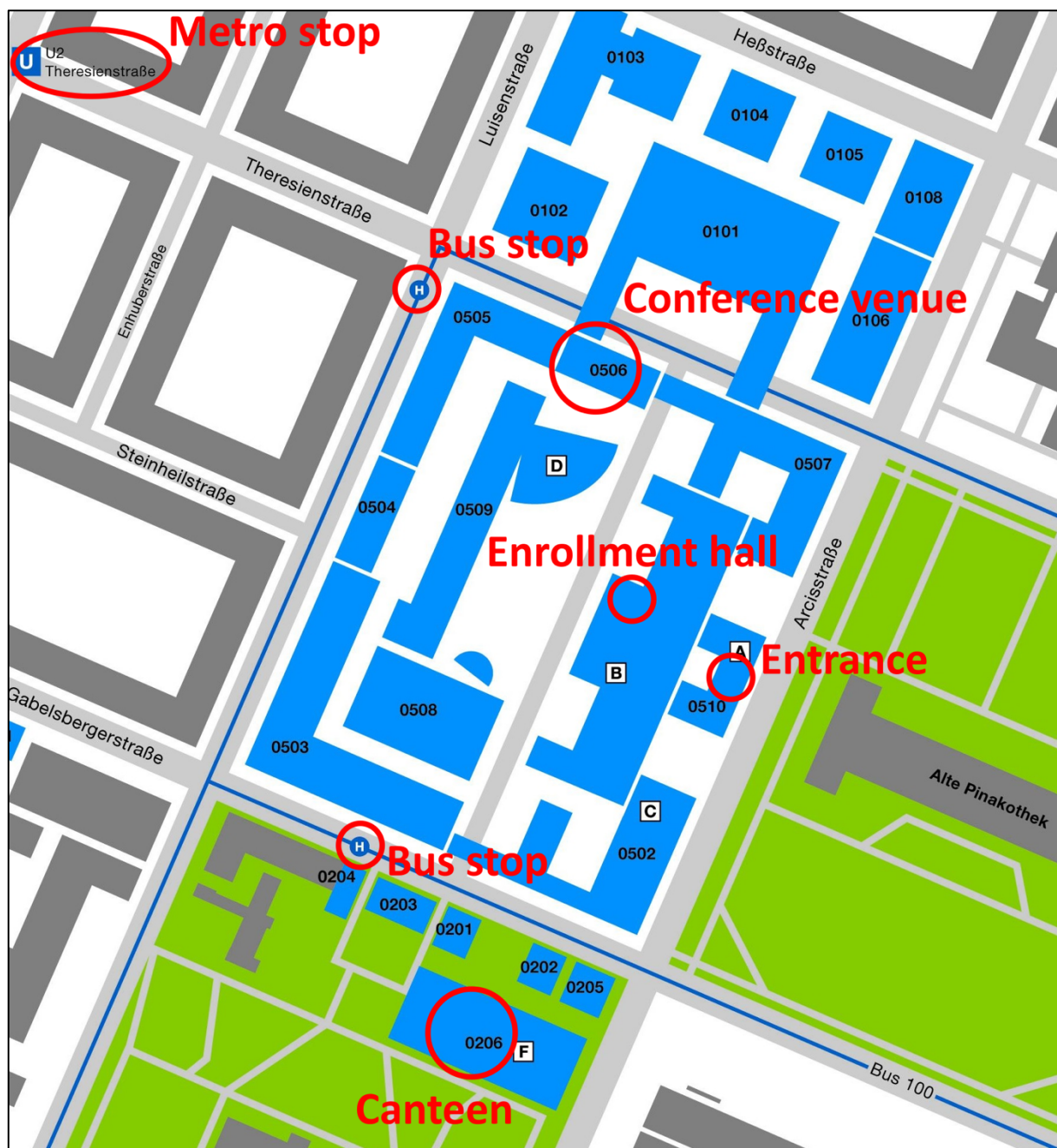


# Conference Venue

The **Main Conference** will take place in building 0506 (Theresianum), located at the main building of the Technical University of Munich (Arcisstraße 21, 80333 Munich).

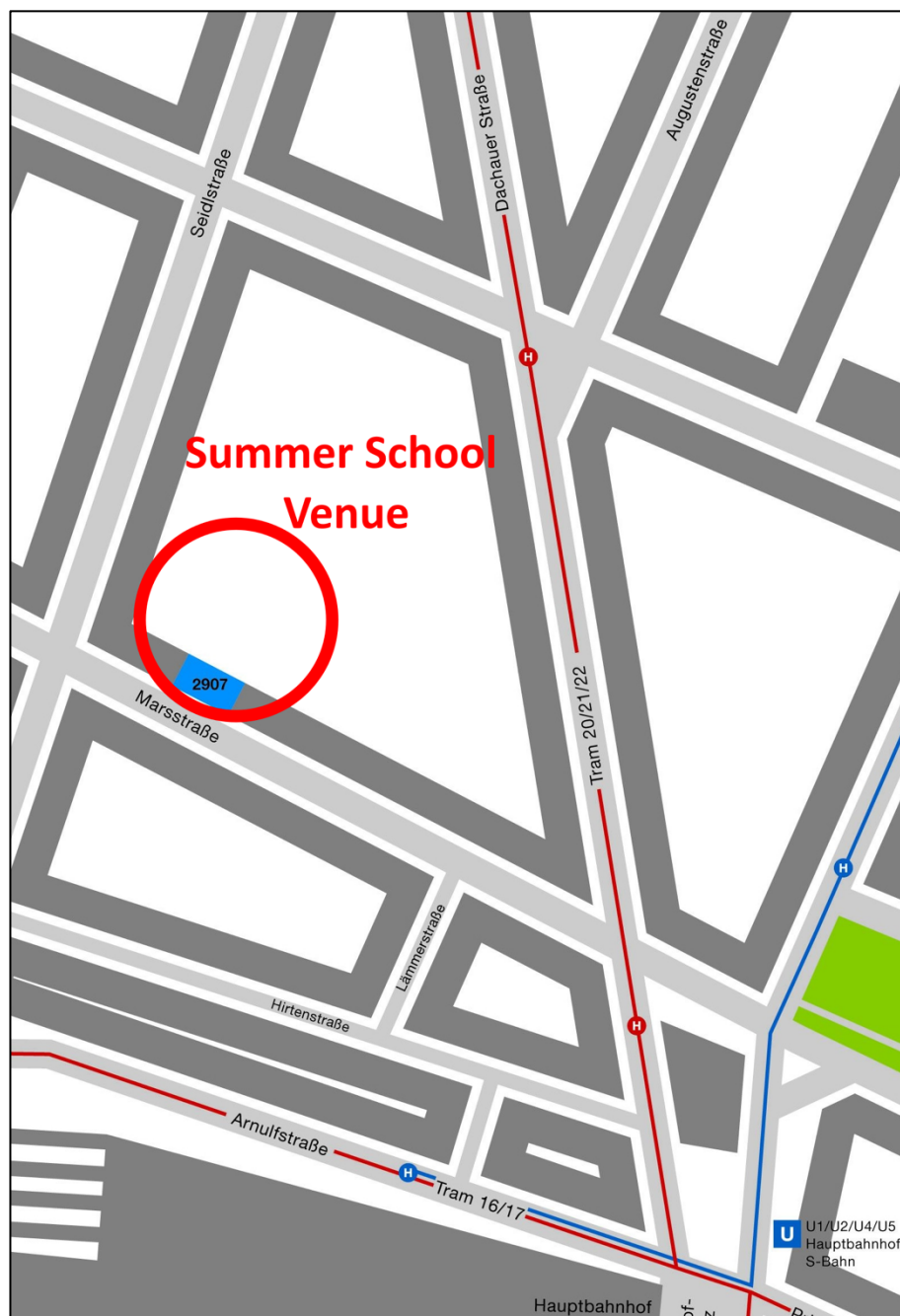
The canteen, where lunch will take place, is located just south of the main campus in building 0206. The welcome reception on Tuesday will take place in the enrollment hall. On Friday, the panel discussion and the farewell session will take place in building 0503 (Thierschbau).

We offer a quiet room (2607) from Wednesday (from 10:30 a.m.) up to and including Thursday, where participants can concentrate and work quietly or take a short break.



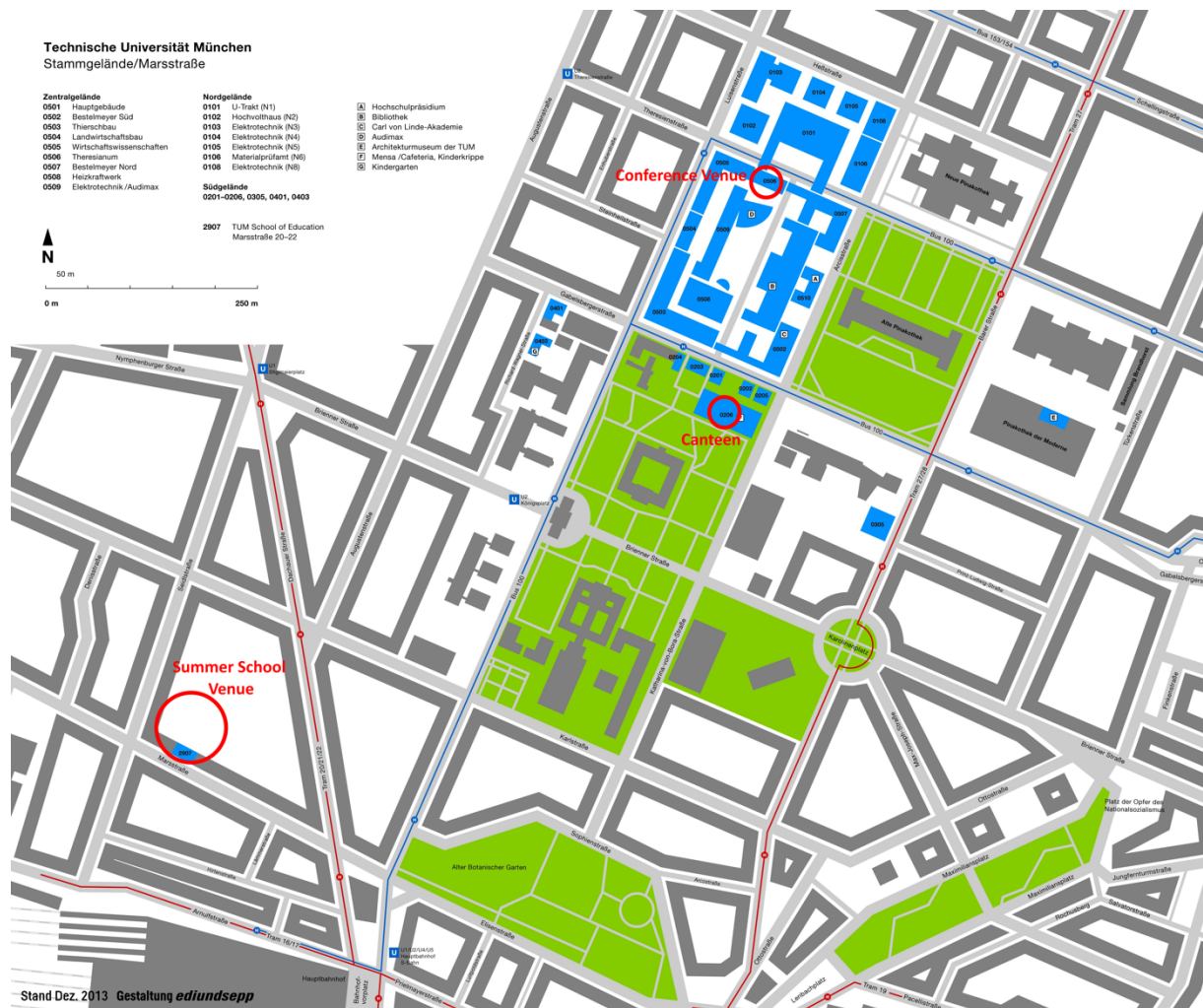
# Conference Venue

The **Summer School** on August 26-27 will take place in building 2907 (TUM School of Social Sciences and Technology), located at Marsstraße 21, 80333 Munich.



## Conference Venue

This map gives an overview of the venues of the Summer School, the Main Conference, and the Canteen.





# Program Overview

**13th International Conference on Conceptual Change 2024**  
**August 27–30**  
**Program**

Time		Tue, 27		Wed, 28		Thur, 29			Fri, 30				
09:00–09:30					Paper Session 2	Roundtable 1		Paper Session 3	Paper Session 4	Symposium 5	Symposium 6		
09:30–10:00					Coffee	Roundtable 1	Keynote 2: Depaepe	Lunch	Coffee	Panel Discussion			
10:00–10:30													
10:30–11:00													
11:00–11:30	Pre-Conference Session		Keynote 2: Depaepe		Lunch		Keynote 3: Brod		Farewell				
11:30–12:00	Pre-Conference Workshop												
12:00–12:30	Registration		Lunch		Symposium 2		Paper Session 5				Paper Session 6		
12:30–13:00													
13:00–13:30	Opening Ceremony		Symposium 3		Poster session and coffee		Coffee				Excursions		
13:30–14:00													
14:00–14:30	Keynote 1: Lehtinen		Symposium 4		SIG Business Meeting		Conference Dinner						
14:30–15:00													
15:00–15:30													
15:30–16:00													
16:00–16:30	Coffee		Symposium 1		Young Researcher Award		Reception						
16:30–17:00													
17:00–17:30	Paper Session 1		Reception										
17:30–18:00													
18:00–18:30	Young Researcher Award		Reception										
18:30–19:00													
19:00–19:30	Young Researcher Award		Reception										
19:30–20:00													

# Keynotes



Erno Lehtinen

## Can Educational Games Enhance Conceptual Change?

Regular teaching often fails to help students overcome misconceptions. Many intervention programs have been shown to be more effective at supporting conceptual change than conventional teaching, but many students still possess long-standing misconceptions about science and mathematics. The traditional theories of conceptual change, which assume the fast replacement of misconceptions with correct scientific knowledge, are not sufficient for supporting conceptual change in complex scientific and mathematical concepts. To achieve deep learning in these challenging topics, students must have insightful experiences and opportunities for long-lasting deliberate practice, which are difficult to arrange in traditional classroom settings. Educational simulations and games developed to support conceptual change provide promising prospects for novel teaching methods. The use of games can assist students in gaining a better understanding of why their preconceived ideas differ from the consequences of correct scientific concepts and provide opportunities for guided deliberate practice necessary for knowledge restructuring.

Erno Lehtinen is a professor (emeritus) of education at the University of Turku and visiting professor at the Vytautas Magnus University, Lithuania. He has worked as a teacher and researcher in several universities in Finland, other European countries and the United States, and has published more than 300 scientific publications. His research has focused on the development of mathematical thinking, educational technology and new forms of expertise in rapidly changing working life.

# Keynotes



Fien Depaepe

## Affordances of Educational Technology to Develop Students' Conceptual Learning

The talk will focus on the affordances of educational technology to develop students' conceptual learning. One of these affordances is to adapt learning environments to diverse learners' needs. I will present research in which the content and the feedback in the learning environment are adapted to students' learning needs. Effectiveness in terms of cognitive, non-cognitive, and efficiency outcomes will be described. Finally, I will focus on how a synergy between teachers and technology might be most promising in view of enhancing students' learning and the competences teachers need for an appropriate integration of technology in their classroom practices.

Fien Depaepe is a professor at the Center for Instructional Psychology and Technology (CIP&T) and itec, imec research group at KU Leuven. Her research deals with the effectiveness of technology-enhanced learning environments in different educational contexts (elementary education, secondary education, and higher education) and in diverse disciplines. This research focuses on the design, development, implementation, and evaluation of these technology-enhanced learning environments.

# Keynotes



Garvin Brod

## Understanding and Promoting Conceptual Change Using Bayesian Computational Modelling

Understanding when and how learners change their concepts in response to conflicting evidence is a key goal of our field. In my talk, I will first present attempts to model conceptual change at an individual level using mathematical modeling. Bayesian computational modeling makes it possible to capture learners' prior beliefs in great detail. It also allows us to compare how learners revise their beliefs in response to conflicting evidence with what a rational actor should optimally do based on probability theory. Second, I will present studies in which we have tested whether generating explicit predictions facilitates learners' belief revision and, ultimately, conceptual change in the domain of physics. Here, Bayesian computational modeling is used to evaluate success of the intervention. Finally, I will discuss future applications and limitations of this approach.

Garvin Brod is a professor of psychology at the German Institute for International Educational Research (DIPF) and the Goethe University in Frankfurt am Main. His research focuses on individualized and technology-supported interventions and on the development of learning and memory. Garvin Brod is the head of the Individualized Interventions Lab that develops psychological interventions to improve children's educational prospects.



# Excursions



## Guided City-Tour

You will visit the most beautiful places in Munich's old town (e.g., Marienplatz, Alter Peter, Hofbräuhaus, Viktualienmarkt, Residenz) and learn exciting stories about the city. As the guides know the old town inside out, they can organize the tour according to the interests of the guests. Please note that the tour takes place in all weathers. Please bring an umbrella if necessary.



## Guided Nymphenburg Palace Tour

With its unique combination of architecture and garden design, the palace and park complex of Nymphenburg is one of the best examples in Europe of a synthesis of the arts. On this tour you will have the chance to visit this beautiful place. A guide will tell you all the important facts and interesting stories about the palace and the park. Please note that the tour takes place in all weathers. Please bring an umbrella if necessary.



## Non-Guided City-Tour

Depending on their interests, we accompany smaller groups of participants, for example, to the English Garden, the Olympic Park, or the Munich city center.



# Lunch

- Lunch during the main conference will take place at the canteen. The canteen is located south of the main campus area (see p. 11).
- The daily menu of the canteen can be found on the next page. Please note that the menu may change.
- If you wish to dine at the canteen, please pick up a guest card from the welcome desk (Foyer). The card is preloaded with 30€ credit for the canteen (enough for two days). The card is free of charge, but you will need to confirm and sign a document that you received a card. Please return the card to the conference office after your visit to the canteen.

Failure to return the card will result in a 30€ fee!

- You can serve yourself at the counters. When paying, place each plate/bowl sequentially on the scanner, select your meal on the display, and then place your guest card on the card reader. Canteen staff or conference team members are available to assist if you have any questions.
- After eating, please place your used dish and cutlery, along with your tray, on the designed conveyor belts.
- We hope you enjoy your meals!

## Wednesday, August 28

Pasta	Spinach spaetzle pan with mountain cheese and sautéed onions
Pizza	-
Grill	Grilled zucchini with tomato-pepper ragout (vegan)
Wok	Coconut curry with soy and vegetables, topped with roasted peanuts (vegan)
Student Pot	Quinoa pan with vegetables and chilly (vegan, spicy) Daily soup
Meat	Schnitzel Caprese (1 piece from straw-fed pork)
Side dishes	Croquettes, boiled potatoes, broccoli, chia pudding with raspberry-coconut (vegan), ayran

## Thursday, August 29

Pasta	Pasta with white cheese, zucchini, and bell pepper
Pizza	-
Grill	-
Wok	Eggplant curry with chickpeas (vegan)
Student Meal	Colorful rice and vegetable pan (vegan) Potato soup
Meat	Viennese fried chicken breast with remoulade
Vegetarian/Meatless	Bernese potato gratin with herb dip
Side dishes	Potato-cucumber salad (vegan), roasted potatoes (vegan), natural peas (vegan), Stracciatella cream, ayran

If you prefer not to dine at the cafeteria, here are some nearby options for lunch (self-paid), conveniently located close to the conference venue. These locations offer a variety of cuisines and dining experiences, from traditional German to international flavors, as well as options for a quick takeaway. Enjoy exploring the local culinary scene!

#### Steinheil 16

- Address: Steinheilstraße 16, 80333 München
- Type: Restaurant
- Cuisine: German/Bavarian

#### Lubu Uni

- Address: Luisenstraße 41, 80333 München
- Type: Restaurant
- Cuisine: Asia

#### Brasserie Treszniewski

- Address: Theresienstraße 72, 80333 München
- Type: Restaurant
- Cuisine: International

#### Sam's Falafel

- Address: Augustenstraße 62, 80333 München
- Type: Takeaway with limited seating
- Cuisine: Middle Eastern

#### Burger House

- Address: Theresienstraße 60, 80333 München
- Type: Restaurant
- Cuisine: Burgers

#### Stehcafe an der TU

- Address: Luisenstraße 43, 80333 München
- Type: Bakery/Café with limited seating
- Cuisine: Various

# Tuesday, August 27

11:00 – 12:00	<a href="#">Pre-Conference Session:</a> Recent Advances in AI and Its Applications (607 at Marsstraße 20, Summer School Venue)
12:00 – 13:00	<a href="#">Pre-Conference Workshop:</a> Cutting-Edge XR Technologies: A Hands-On Experience (117 at Marsstraße 20, Summer School Venue)
13:00 – 14:00	Registration (Foyer)
14:00 – 14:45	Opening Ceremony (0602)
14:45 – 16:15	Keynote 1: Erno Lehtinen (0602)
16:15 – 16:30	Coffee (Foyer)
16:30 – 18:30	<p>Paper Session 1: Theoretical Issues and Implications for Teaching for Conceptual Change (0601)</p> <ul style="list-style-type: none"><li>▪ Metaphors in Chemistry: Didactic Tool and Constituent of Knowledge</li><li>▪ The Role of Conceptual Learning in Science Education for Sustainability</li><li>▪ Conceptual Change in the Social and Cultural Sciences</li><li>▪ A Model for Teaching for Conceptual Change? Six Challenges Regarding the ICAP Framework</li></ul> <p>Symposium 1: Second Symposium on Representational Plurality and Conceptual Change (0602)</p> <ul style="list-style-type: none"><li>▪ Turning the Plurality of Chemistry into a Resource for Learning: A Core Competency of Teachers</li><li>▪ Can We Help Students Navigate Multiple Representations? Evidence From a Warning Intervention Study</li><li>▪ Using Certainty Scales to Test the Effects of Refutation Texts in a Pluralist Perspective</li><li>▪ Managing Wide Plurality Through Meta Representations</li></ul>
18:30 – 19:00	Young Researcher Award (0602)
19:00	Reception (Enrollment Hall)

## Paper Session 1: Theoretical Issues and Implications for Teaching for Conceptual Change

Chair: Annika Sophie Krüger

16:30 – 18:30, Room 0601

### 1. Metaphors in Chemistry: Didactic Tool and Constituent of Knowledge

Charlotte Müller<sup>1</sup> & Martina Rau<sup>1</sup>

<sup>1</sup>ETH Zürich, Switzerland

Metaphors and analogies in chemistry education serve two main purposes. First, teachers may design analogies specifically as a didactic tool to illustrate a certain concept. Second, the metaphor may be heuristic, that is inherent to the domain-specific terminology. In this review, we assess the current state of literature in chemistry education on metaphors and analogies. Specifically, we are interested in the type of metaphor that are investigated, that is didactic or heuristic, student-, teacher-generated, or metaphors found in textbooks. We find that most research focuses on analogies designed for a specific (cultural) context with the aim of facilitating learning. Only one article focuses on metaphors in the spoken language of chemists during problem-solving.

### 2. The Role of Conceptual Learning in Science Education for Sustainability

Ilona Södervik<sup>1</sup> & Antti Laherto<sup>1</sup>

<sup>1</sup>University of Helsinki, Finland

Responding to global sustainability challenges demands people to learn to think and act in a fundamentally new way. The teaching of natural sciences plays an essential role in transformative sustainability education. The aim of this position paper is to examine the role of conceptual change in the emerging vision III -type science education aiming for sustainability transformations. We claim that the role of conceptual learning in science education is still highly relevant, but above all as a means of acting and influencing society. In this presentation, we focus particularly on certain essential concepts that pose a challenge of conceptual change in sustainability education to show the relevance of conceptual change tradition for sustainability education. The crisis of ecological sustainability shows the generally shared and established meanings of some concepts to be incomplete or even misleading. We propose that strengthening education for sustainability requires numerous experiences of conceptual change at the individual level and in societies.

### 3. Conceptual Change in the Social and Cultural Sciences

Christian Thurn<sup>1</sup>, Christian Mathis<sup>2</sup>, Sophie Faulstich<sup>3</sup>, Stefan Schröder<sup>4</sup>

<sup>1</sup>ETH Zürich, Switzerland

<sup>2</sup>PH Zürich, Switzerland

<sup>3</sup>Universität Bayreuth, Germany

<sup>4</sup>Universität Bayreuth, Germany

Whereas the framework of conceptual change is broadly applied in STEM subjects, it is much less applied in the social and cultural sciences. We present an edited volume that establishes conceptual change for subjects such as religion education, history education, and human geography education. The book emerged within a project that aimed at designing empirically based constructivist didactics of religion from a non-confessional perspective. In the process of discussing the book, we discovered the framework of Educational Reconstruction as fruitful to implement constructivist ideas in the social and cultural sciences. Educational Reconstruction is a didactical framework that stresses the need for teachers to build on students' (everyday) prior knowledge, as they are not able to replace intuitive conceptions but only to enrich them. We present challenges that teachers are confronted with when implementing conceptual change or Educational Reconstruction in social and cultural subjects. We also present ideas how teachers and researchers addressed these challenges in their respective subjects and discuss implications for conceptual change research.

### 4. A Model for Teaching for Conceptual Change? Six Challenges Regarding the ICAP Framework

Christian Thurn<sup>1</sup>, Peter Edelsbrunner<sup>1</sup>, Michal Berkowitz, Lennart Schalk<sup>2</sup>, Anne Deiglmayr<sup>3</sup>

<sup>1</sup>ETH Zürich, Switzerland

<sup>2</sup>PH Schwyz, Switzerland

<sup>3</sup>University of Leipzig, Faculty of Education, Germany

The ICAP (Interactive, Constructive, Active, Passive) framework is based on constructive ideas of student learning and widely used by practitioners and researchers. The ICAP framework links students' overt behaviors to covert cognitive processes and learning outcomes and proposes that "higher" modes of engagement (I > C > A > P) are likely to increase learning. We theoretically discuss these assumptions of the ICAP framework in light of its potential applicability to learning situations aimed at supporting conceptual change. We arrive at six challenges that question the framework's applicability to conceptual change-focused instruction and further educational environments: 1) the equation of overt student behavior with covert cognitive processes, 2) the favoritism of constructive and interactive modes, 3) the potential pitfall of having activities in the classroom that do not equate cognitive activation, 4) the weak and overstated empirical evidence in favor of the ICAP hierarchy, 5) the unclear guidance about when to attend to students' products, and 6) the complex directive for practitioners who would like to implement the ICAP framework. We aim to stimulate discourse on the multifaceted nature of learning processes and restate the importance of formative assessment to unveil students' learning at the covert cognitive level.

# Symposium 1:

## Second Symposium on Representational Plurality and Conceptual Change

Organizer and Chair: Michel Belang r  
Discussant: Patrice Potvin

16:30 – 18:30, Room 0602

Research on conceptual change learning and teaching can be described as focusing on the process of moving from students' initial conceptions to more scientific ones. It is increasingly recognized that, although we speak of conceptual change, this learning process, even if successful, often does not necessarily result in students having only one (scientific) conception in their mind. On the contrary, researchers are more and more aware that students, for various reasons, generally end up with several partly or completely incompatible representations of a single phenomenon. One reason is the possible persistence of students' initial conceptions and their possibly important cognitive role at the end of the learning process. This coexistence has received more empirical and theoretical attention in the past decade. Another reason concerns the target of this process (i.e. scientific representations themselves). Recent studies of scientists' actual practices and theoretical outputs have shown that these are better characterized as consisting in a plurality of often partially or completely incompatible models or theories about a single phenomenon. By acknowledging beforehand that plurality is a normal feature of students' and scientists' cognition and practices, the symposium aims to create a space for a deeper exploration of factors and processes that shape how the phenomenon of representational plurality takes place in cognition and learning. It is a follow-up of a symposium held at the 12th Conference on Conceptual Change that took place in Zwolle.

### 1. Turning the Plurality of Chemistry into a Resource for Learning: A Core Competency of Teachers

Andreas Nehring<sup>1</sup> & Sascha Schanze<sup>1</sup>

<sup>1</sup> Gottfried Wilhelm Leibniz University Hannover, Germany

Chemistry is a science that not only examines substances at different levels of abstraction and involves a multitude of cognitive and experimental operations, but also used and uses a variety of concepts and representations referring to the same term. At the same time, many studies on the professional competencies of teachers underline the importance of content knowledge as a prerequisite for pedagogical content knowledge and instructional quality for example. While these studies use a quantitative logic of more or less chemistry knowledge, this talk argues that teachers do not only have to understand chemical concepts but also have to be able to manage conceptual plurality. This involves explaining the same phenomena based on different concepts, comparing their explanatory power and their limitations, and reflecting upon their sometimes different ontological and epistemological status. This talk proposes conceptual clarifications for acid-base chemistry (in this extended abstract), redox chemistry, and atomic and bonding models (in the talk) to indicate how plurality manifests itself in chemistry in the first place. On this basis, we derive five mechanisms showing how managing conceptual plurality in chemistry helps to support learning chemistry: Teachers are more likely to make adequate curricular decisions (1), using concepts and representations consistently (2),

to support transitions between concepts meaningful (3) and taking pluralist perspectives on students' conceptions (4), or to foster epistemic cognition (5) as a part of learning chemistry. We discuss these mechanisms as explanations for findings in the field of teachers' professional competencies.

## 2. Can We Help Students Navigate Multiple Representations? Evidence From a Warning Intervention Study

Reuven Babai<sup>1</sup> & Genevieve Allaire-Duquette<sup>2</sup>

<sup>1</sup> Tel Aviv University, Israel

<sup>2</sup> Université de Sherbrooke, Canada

Representational pluralism puts forward that learners may hold several incompatible representations of a given phenomenon. One example of incompatible representations lies in the intuitive interference framework where intuitive and formal reasoning coexist for a given task. An illustration would be the widespread difficulty to compare perimeters of geometrical shapes where it is often intuited that geometrical shapes with larger areas have larger perimeters. Such intuitive responses may interfere with formal reasoning about the perimeters of the shapes. To help students overcome the intuitive interference, one approach focuses on a warning intervention consisting of an explicit notice about the possible interference of intuitive reasoning in this task. A warning intervention aims at activating executive control mechanisms, hence increasing the ability to overcome the tendency to respond in line with intuition. In this talk we examine the impact of a warning intervention aimed at helping learners in a comparison of perimeters task. Our data suggests that an explicit warning can help learners to opt for formal reasoning over intuitive reasoning. However, a key factor in a successful warning intervention seems to be securing the engagement of the learners possibly to increase the cognitive utility of the effortful formal reasoning. These results encourage reflection on the development of design principles for instruction in the context of representational pluralism such as exploring how engagement with the content affects the likelihood of opt for more formal reasoning.

## 3. Using Certainty Scales to Test the Effects of Refutation Texts in a Pluralist Perspective

Patrice Potvin<sup>1</sup>, Emmanuel Ahr<sup>1</sup>, Karène Brindle<sup>1</sup>, Maude Théoret<sup>1</sup>, Michel Bélanger<sup>2</sup>, Vincent Richard<sup>3</sup>, Oktay Cem Adigüzel<sup>4</sup>, Patricia Privé<sup>1</sup>, Lorie-Marlène Brault Froisy<sup>1</sup>

<sup>1</sup> Université du Québec à Montréal, Canada

<sup>2</sup> Université du Québec à Rimouski, Canada

<sup>3</sup> Université Laval, Canada

<sup>4</sup> Anadolu Üniversitesi, Türkiye

This study reports the results of two pre/post experiments conducted with secondary school students who read refutation and explanatory texts. The originality of the study lies in the use of certainty scales, which tested the feeling-of-certainty that participants reported about each and every possible choice of the multiple-choice questions (MCQ) presented. These special two-tailed scales were designed to track relative variations in

feelings of certainty regarding a plurality of representations and, ultimately, shifts in prevalence within it. While the first experiment only examined pre-post differences, the second experiment examined differences between refutation and non-refutation texts. Results show that conceptual shifts can be observed using this certainty-sensitive method but did not record differences between refutation and explanatory texts when the post-test was delayed.

## 4. Managing Wide Plurality Through Meta Representations

Michael Bélanger<sup>1</sup> & Vincent Richard<sup>2</sup>

<sup>1</sup> Université du Québec à Rimouski, Canada

<sup>2</sup> Université Laval, Canada

Various research on conceptual change in science education has concluded that successful science learning sometimes consists in having two or more incompatible representations regarding a phenomenon coexisting in the mind. Our working hypothesis in this paper is that in order for such plurality to be indeed functional, it must be adequately integrated into a cognitive structure responsible for its management. Following Cosmides and Tooby (2000), we use the concept of meta representation for this purpose. A meta representation is a structure that includes both a representation and various information about this representation (hereafter referred to as “tags”). We focus on two kinds of tags: 1) scope tags, which are cognitive elements responsible for specifying the circumstances in which a representation can profitably be used; and 2) qualificative tags, which are judgments about the properties and value of a representation (e.g.: simplicity, understandability, usefulness, etc.). We argue the concepts of meta representation and tags, or their equivalent, are required to better understand the nature of expertise in a situation of representational plurality. In our view, humans have large minds: they can acquire a repertoire of incompatible representations and use it efficiently in various situations. Expertise, then, does not lie solely in the mastering of one scientific representation, but in the capacity to operate efficiently the repertoire of representations one possesses.

# Wednesday, August 28

09:00 – 10:30	<p>Paper Session 2: Conceptual Change in Elementary and Middle School Students (0601)</p> <ul style="list-style-type: none"><li>▪ “The Water Disappeared” – Conceptual Change in the Model of the Water Cycle</li><li>▪ Spatial Reasoning Training and Evaluation of Lunar Phases Misconceptions in Late-Elementary Students</li><li>▪ The Opportunities to Enhance Conceptual Change in Out of School Learning Environment</li></ul> <p>Roundtable 1: Research on the Effects of Prior Knowledge on Learning: Where to Go Next? (2607)</p>
10:30 – 11:00	Coffee (Foyer)
11:00 – 12:30	Keynote 2: Fien Depaepe (0602)
12:30 – 13:30	Lunch
13:30 – 15:00	<p>JURE Symposium (0601): The Role of Executive Functions in Conceptual Change</p> <ul style="list-style-type: none"><li>▪ Examining the Roles of Executive Functions and Motivation in Supporting Conceptual Change in Physics Learning</li><li>▪ The Relationship Between Inhibitory Control Measures and the Conceptual Interference Effect in Mathematics</li><li>▪ Exploring the Links Between Executive Functions, General Cognitive Ability and Explanatory Coexistence in Adults From the United Kingdom, China and Greece</li></ul> <p>Symposium 2: Conceptual Change in Economics – Researching Students’ Conceptions in Times of Societal Challenges (0602)</p> <ul style="list-style-type: none"><li>▪ Lay Conceptions of the German Pension System</li><li>▪ Students’ Conceptions Regarding Ethical Issues in Economics</li><li>▪ Climate Change Challenge – Developing Students’ Conceptual Understanding of Policies</li></ul>
15:00 – 16:00	Poster Session and Coffee (Foyer)

16:00 – 18:00

Symposium 3:  
Cognitive, Affective, and Behavioral Perspectives on the Natural Number Bias (0602)

- Not Realizing Natural-Number Based Errors: A Conceptual Replication of Halme et al. (2023)
- The Role of Cognitive Processes and Individual Differences in Solving a Fraction Comparison Task
- Cross-Notational Knowledge of Rational Numbers in High School Students
- Reducing the Natural Number Bias Through Magnitude-Based Reasoning: Results of an Intervention Study

Symposium 4:  
Perspectives and Positionings in Teaching for Conceptual Understanding (0601)

- Perspectives, Positions, and Identity in Conceptual Change Research
- Challenges for Integrating Perspective Into Classroom Teaching. Lessons From a Failed Study
- Changing Conceptualization of Pre-Service Students on Teaching English Through Attentive Teaching
- Vary One Thing at a Time: The Control of Variable Strategy in Physics Learning

18:00 – 20:00

SIG Business Meeting (0602)

## Paper Session 2: Conceptual Change in Elementary and Middle School Students

Chair: Alexandre Hagan

09:00 – 10:30, Room 0601

### 1. “The Water Disappeared” – Conceptual Change in the Model of the Water Cycle

Annika Sophie Krüger<sup>1</sup>, Marc Rodemer<sup>1</sup>, Stefan Rumann<sup>1</sup>

<sup>1</sup> University of Duisburg-Essen, Germany

Especially in primary school, the development of concepts as a starting point for sustainable learning is important. One of these concepts is understanding the water cycle with the help of models. Learners' pre-concepts should be taken up and transformed into linkable knowledge. However, a cold conceptual change is rarely achieved through single instruction. Oser et al.'s "theory of negative knowledge" states that knowing how something does not work compared to how something works leads to greater learning gains and enables longer-term learning (2012). In order to investigate a possible connection between the two theories in more detail, we assessed whether negative knowledge might contribute to a conceptual change. We conducted a pre-, post-, follow-up design on the water cycle with N = 326 learners from 3rd grade in an out-of-school-laboratory with two groups. After activating prior knowledge, model experiments were carried out on the processes of the water cycle. The extent to which learners transfer their knowledge to a model of the water cycle (fill-in-the-blank-group) and whether they can recognize and correct common misconceptions in the model (error-search-group) was examined. After the project day, a significant increase in learning was observed in the pre-post comparison. Surprisingly, in the follow-up test, the learners in the error-search-group achieved lower scores than the fill-in-the-blank-group. Further results related to conceptual change theory will be presented.

### 2. Spatial Reasoning Training and Evolution of Lunar Phases Misconceptions in Late-Elementary Students

Pierre Chastenay<sup>1</sup>, Patricia Marchand<sup>2</sup>, Nathalie Sinclair<sup>3</sup>, Mylène Forest<sup>1</sup>

<sup>1</sup> Université du Québec à Montréal (UQAM), Canada

<sup>2</sup> Université de Sherbrooke, Canada

<sup>3</sup> Simon Fraser University, Canada

Understanding basic concepts in astronomy requires an ability to change perspective on astronomical systems. We report on a research project exploring the effect that training late-elementary students aged 10-12 years old in perspective-taking and mental rotation (spatial skills) has on the evolution of their misconceptions about the phases of the Moon. In this research, students embarked on a month-long observing programme of lunar phases while participating in spatial skills activities. We used a Moon Phases Concept Inventory and a Spatial Reasoning Instrument to collect pre and post data with experimental and control groups (intact classrooms). We discuss the results of this

research and draw tentative conclusions on the link between the development of spatial skills and learning in astronomy.

### 3. The Opportunities to Enhance Conceptual Change in Out of School Learning Environment

Vesta Vančugovienė<sup>1</sup>, Erno Lehtinen<sup>2</sup>, Ilona Södervik<sup>3</sup>

<sup>1</sup> Vytautas Magnus University, Lithuania

<sup>2</sup> University of Turku, Finland

<sup>3</sup> University of Helsinki, Finland

According to many past studies, inquiry-based learning contributes significantly to a student's conceptual understanding. Research on the long-term effects of inquiry-based learning on conceptual understanding among students is limited, however. We conducted this study to determine whether an inquiry-based learning environment in botanical gardens improves students' conceptual understanding of biological concepts over long time. There were 79 students in 9th grade who participated in inquiry-based learning biology lessons in a botanical garden, and 72 students in 9th grade who participated in traditional biology lessons in the classroom. In contrast to traditional classroom teaching, inquiry-based learning in a botanical garden was found to positively influence the development of correct scientific knowledge. Students can also overcome resistant misconceptions about photosynthesis and respiration through the learning activities in a botanical garden. Despite a slight decrease in correct scientific answers between the post-test and delayed post-test, the students in the experimental group outperformed those in the traditional classroom after three months. Eventually, specially designed interventions may allow for the implementation of conceptual change, leading to the alteration of previously held misconceptions into scientifically accurate concepts.

# Roundtable 1: Research on the Effects of Prior Knowledge on Learning: Where to Go Next?

09:00 – 10:30, Room 2607

Peter Edelsbrunner<sup>1</sup>, Simona Daguati<sup>1</sup>, Sarah Bichler<sup>2</sup>, Garvin Brod<sup>3</sup>, Christian Thurn<sup>1</sup>

<sup>1</sup> ETH Zürich, Switzerland

<sup>2</sup> Ludwig-Maximilians-Universität (LMU), Germany

<sup>3</sup> DIPF Frankfurt, Germany

Research on the effects of prior knowledge of learning is at a point of newfound interest, but surprising and inconsistent results, as well as missing theoretical models, pose a great challenge for further progress at this stage. In this roundtable, we will discuss three points with the overall aim to develop ideas for new research ideas in this area:

1. What are crucial topics or issues related to the influence of prior knowledge on learning for which we are lacking theoretical models?
2. How can novel methodologies such as formal models help us tackle current uncertainties in this area?
3. What empirical studies might provide the most informative next steps to further our understanding in this area?

In the setting of a structured group puzzle, we will conduct think-pair-share phases on these issues to end with three specific ideas for promising next steps. Conceptual change theory will be considered as a perspective that can serve as one puzzle piece in solving recent mysteries regarding this topic

## JURE Symposium: The Role of Executive Functions in Conceptual Change

Discussant: Christian Thurn

13:30 – 15:00, Room 0601

As learners need to deal with multiple conceptions that may be contradicting each other, the question arises, which mental abilities support learners in efficiently processing their conceptions. In the past decade, conceptual change research focused on the role of executive functions. Executive functions are a non-unitary trait, comprising three key processes: the inhibition of intuitive incorrect responses in favor of more appropriate ones, the updating and monitoring of mental representations in working memory, and the shifting of mental sets.

This JURE symposium sheds light on the presumed role of executive functions on conceptual change. While giving junior researchers the possibility to present their compelling and impressive work, it also encourages a constructive discussion of the role of conceptual change in different fields, age groups, and countries.

Tamer Said presents a study on secondary school students from Egypt in physics learning targeting misconceptions about density. Whereas shifting ability was related to prior knowledge, no associations were given between executive functions and learning gains.

Michaela Meier presents a study with undergraduate students on math learning. She examined the conceptual interference effect between congruent and incongruent statements and focused on the inhibition processes, assessing three subdomains. Across three studies and samples, the results did not indicate an association between individual differences in inhibitory control mechanisms and inhibiting naïve concepts.

Rui Wang presents a study on adults from three countries and physics as well as biology learning. Assessing inhibition, switching, working memory, and general cognitive ability, her findings reveal inconsistent associations with conceptual understanding.

This JURE symposium will discuss, what the current state of research on executive functions means for conceptual change and how we sail on from here.

## 1. Examining the Roles of Executive Functions and Motivation in Supporting Conceptual Change in Physics Learning

Tamer Said<sup>1</sup> & Michelle R. Ellefson<sup>2</sup>

<sup>1</sup> Anglia Ruskin University

<sup>2</sup> University of Cambridge

The alteration of students' ideas in favor of more scientific ones is known as conceptual change. Evidence shows that such process is likely facilitated by executive functions and motivation. The current study examines the role of executive functions (inhibition, working memory, and shifting) and motivation (self-efficacy, mastery and performance orientation) on conceptual change in physics understanding. We examined 256 Egyptian secondary school students ( $M_{\text{age}} = 13.5$  years)—an underrepresented population in the literature. The participants completed a short tutorial targeting misconceptions about density. Findings from a structural equation model indicated that shifting predicted baseline density understanding ( $\beta = .18, p < .05$ ), but not conceptual gains, whereas motivational elements, particularly, self-efficacy positively predicted conceptual gains ( $\beta = .15, p < .05$ ), but the relation with baseline density understanding was not statistically significant. However, performance goal orientation negatively predicted conceptual gains ( $\beta = -.18, p < .05$ ). We discuss whether executive functions are needed for the expression of students' understanding or whether it could be involved in the knowledge construction process.

## 2. The Relationship Between Inhibitory Control Measures and the Conceptual Interference Effect in Mathematics

Michaela A. Meier<sup>1</sup>, Stephan E. Vogel<sup>1</sup>, Roland H. Grabner<sup>1</sup>

<sup>1</sup> Talent and Learning Research, Department of Psychology, University of Graz, Austria

A common obstacle to learning mathematics is conceptual interference. From a very early age, individuals construct pre-instructional naïve theories that are not necessarily scientifically true. During formal education, these concepts change and evolve through the learning of correct, scientific concepts, a process called conceptual change. However, there is increasing evidence that the scientific theories do not replace the learner's naïve theories, but instead coexist in memory. This has been demonstrated using speeded-reasoning tasks, in which participants performed worse when evaluating scientific statements whose truth value differed between naïve and scientific theories (incongruent) than when evaluating statements with the same truth value (congruent). This conceptual interference effect (CIE) has been attributed to a cognitive conflict in incongruent statements that requires active inhibition of the naïve theory. However, the relationship between individual differences in the CIE and measures of inhibitory control is unclear. Therefore, in three studies with undergraduate students from an Austrian university ( $N = 85, N = 80, N = 60$ ), we examined how different measures of inhibitory control (prepotent response inhibition, resistance to distractor interference, resistance to proactive interference) are related to individual differences in a speeded reasoning task in mathematics that included 200 statements

from five subdomains (fractions, algebra, geometry and units, probability, and basic concepts). Surprisingly, we did not observe significant correlations between individual

differences in CIE and interference effects in inhibition tasks, even though these tasks were both domain-specific and process-related. This adds further evidence to the open question of the actual nature of the inhibitory (or other executive) processes required to overcome naïve theories.

### 3. Exploring the Links Between Executive Functions, General Cognitive Ability and Explanatory Coexistence in Adults From the United Kingdom, China and Greece

Rui Wang<sup>1</sup>, Hale Ögel-Balaban<sup>1</sup>, Konstantinos Tsigaridis<sup>1</sup>, Lei Huang<sup>1</sup>, Aidan Feeney<sup>2</sup>, Michelle R. Ellefson<sup>1</sup>

<sup>1</sup> University of Cambridge

<sup>2</sup> Queen's University Belfast

Naïve scientific thinking seems to coexist with scientific knowledge rather than simply being replaced or changed by it. Reasoning about coexisting explanations seems to rely on complex cognitive processes. However, previous studies are overly reliant on English-speaking participants, raising questions about the generalizability of current understanding of underlying cognitive mechanisms to individuals in different countries. To address this research gap, the present study examined the complex links between executive functions (inhibition, switching, working memory), general cognitive ability, and physics and biology explanatory coexistence in adult participants from the United Kingdom (n = 262), China (n = 234), and Greece (n = 404). Using efficiency scores derived from the same battery of computerized executive function tasks in different language versions, path analysis indicated varying contributions of executive functions and general cognitive ability to explanatory coexistence across the three sites.<sup>t</sup> Specifically, among participants from both the United Kingdom and China, switching predicted all explanatory coexistence tasks, inhibition predicted animism and buoyancy reasoning, and general cognitive ability contributed only to scientific statement reasoning. However, among participants from Greece, inhibition and switching predicted all explanatory coexistence measures, whereas general cognitive ability contributed to buoyancy reasoning only, and working memory contributed to scientific statement reasoning only. These results indicate that individuals from different countries might adopt different reasoning strategies when faced with coexisting explanations.

## Symposium 2: Conceptual Change in Economics – Researching Students' Conceptions in Times of Societal Challenges

Organizer and Chair: Cecilia Lundholm  
Discussant: Nicole Ackermann

13:30 – 15:00, Room 0602

In this symposium we present research that focuses on conceptual change in economics, an area that is growing and generating interest both among researchers and teachers. The papers report empirical findings of lay people and students' conceptions of concepts and topics that are important from a citizen perspective and part of current debate. The first paper aimed at exploring citizens' lay conceptions of the German pension system through interview studies, and in particular citizens' misunderstandings regarding the German statutory pension insurance. Results indicate various models of misunderstanding regarding the functioning of the German statutory pension insurance. The second paper focuses on upper secondary students' conceptions of ethical issues in economics and investigated the level of business ethics (individual consumer, company, government). Findings show that students emphasize personal consumption decisions while political activities receive less attention. Misconceptions regarding the roles of the state and companies in economic processes were also identified. The third paper presents findings from a project with students in year 9 aimed at developing their understanding of how policies, such as tax and subsidies, decrease climate gases. Citizens understanding of policies being effective has been identified as crucial for policy support. Using comparing interventions as design, results show a significant increase of students' understanding of tax in the main intervention. Finally, all papers discuss implications for instruction in the context of economics education.

### 1. Lay Conceptions of the German Pension System

Ronja Baginski<sup>1</sup>, Carmela Aprea<sup>1</sup>

<sup>1</sup> University of Mannheim, Germany

Various developments, in particular demographic change and a retraction of the states from social security systems, lead to a rise in self-responsibility regarding citizen's old-age provision in many Western countries. How well citizens provide for their retirement may also depend on how they conceive the respective pension system. In addition, pension systems are a concern of constant social policy reforms, which citizens judge as they vote. Their lay conceptions of the respective pension system are thus of vital concern not only for their retirement planning but also for their political preferences and voting behavior. In this paper, we present the results of three interview studies with different samples that aimed at exploring citizens' lay conceptions of the German pension system, in particular their misunderstandings regarding the German statutory pension insurance. After content analysis, the results indicate various models of misunderstanding regarding the functioning of the German statutory pension insurance. Further, these point towards information needs and further research. In sum, the study contributes to the slowly growing area of research on conceptions and conceptual change in economics (theoretical significance). In addition, it provides indications for learning needs, which are imperative to design respective learning arrangements as well as communication activities (practical significance).

## 2. Students' Conceptions Regarding Ethical Issues in Economics

Victoria Vochatzer<sup>1</sup>, Taiga Brahm<sup>1</sup>, Malte Ring<sup>1</sup>

<sup>1</sup>Eberhard Karls University Tübingen, Germany

This study addresses a significant gap in economic education research by exploring eighth-grade students' conceptions towards business ethics. Previous literature has predominantly focused on purely economic topics, neglecting issues of business ethics. To address this gap, 33 semi-structured interviews were conducted with students from secondary schools in Southwest Germany. Our study aimed to examine students' conceptions regarding ethical issues in economics. In this regard, we also investigated the level of business ethics the students' addressed (individual consumer, company, government) and the elaboration of their reasoning. Preliminary findings reveal that students primarily emphasize personal consumption decisions, with a strong emphasis on Fairtrade and product origins, while political activities receive less attention. Moreover, students perceive power and responsibility as contingent upon factors such as number of individuals, company size, position within the company, social environment, and age. Misconceptions regarding the roles of the state and companies in economic processes were also identified. This research provides an initial starting point with valuable insights into learners' ethical worldviews, essential for informing effective teaching practices in economics education.

## 3. Climate Change Challenge – Developing Students' Conceptual Understanding of Policies

Cecilia Lundholm<sup>1</sup>, Caroline Ignell<sup>1</sup>, Anna Bendz<sup>2</sup>

<sup>1</sup>Stockholm University, Sweden

<sup>2</sup>University of Gothenburg, Sweden

Climate change is a large-scale collective action dilemma in the context of democratic societies. As large-scale collective action-problems are unlikely to be solved by voluntary cooperation, coordination by external authorities ('third actor') is necessary. Such coordination can be governmental policies that affect markets, consumption and production. This requires, and highlights, the importance to increase citizens' knowledge of and support for measures such as taxes. In an on-going project we develop instruction that supports learning of the effectiveness of policies, using a design-based approach with cycles of comparative interventions in year 9. We designed interventions with teachers in social science and the main intervention draws on conceptual change theory of understanding phenomena as systems. This is central for understanding pricing and effects of tax and subsidies, and activities on concept maps were designed. Results from cycle 1 show a significant increase in students' understanding of tax and subsidies from T1 to T3 in the main intervention but no significant change from T1 to T2. In the alternative intervention there is a significant decrease from T1 to T2 concerning understanding of tax and a significant increase on subsidies. Both interventions show a significant increase of understanding tax from T2 to T3 but students in alternative intervention do not score as high as they did in T1/pre-test. The results are important in the light of lack of studies on instruction that supports students' knowledge of economic aspects in climate change education and subsequent cycles of comparative interventions will allow for further recommendations.

## Poster Session and Coffee

15:00 – 16:00, Foyer

### 1. Relationship Between Writing Support, Stress, and Motivation Among Female Doctoral Students

Wai Mar Phyo<sup>1</sup>

<sup>1</sup> University of Szeged, Hungary

This study investigated how female doctoral students' ability to handle stress and anxiety and maintain motivation correlates with the English academic writing support they received from their doctoral schools. A survey was conducted following the guidelines of Creswell and Creswell (2018) during the 2021-2022 academic year in Hungary. The survey items were presented on a 1-6 Likert scale. A total of 125 female doctoral students participated in the study: first-year PhD (35%), second-year PhD (25%), third-year PhD (19%), and fourth-year PhD (19%). Analysis results revealed that participants were satisfied with English academic writing ( $M=4.10$ ,  $SD=1.46$ ). They expressed confidence in their ability to handle stress and anxiety ( $M=4.06$ ,  $SD=1.45$ ), but the lowest mean score was observed among fourth-year PhD students ( $M=3.62$ ,  $SD=1.66$ ). Similarly, participants were confident about maintaining motivation to complete doctoral work ( $M=4.42$ ,  $SD=1.46$ ), though the lowest mean score was found in fourth-year PhD students ( $M=3.62$ ,  $SD=1.73$ ). According to Pearson correlation analysis, the doctoral school's academic writing support had a statistically significant positive relationship with participants' self-perceived ability to handle stress and anxiety.

### 2. Teachers Doing Research on Conceptions and Conceptual Change: Adopting a Teacher-Researcher Posture

Patrice Potvin<sup>1</sup>, Eric Durocher<sup>1</sup>, Bénédicte Boissard<sup>1</sup>, Abdelkrim Hasni<sup>2</sup>, Martin Riopel<sup>1</sup>

<sup>1</sup> Université du Québec à Montréal, Canada

<sup>2</sup> Université de Sherbrooke, Canada

This study investigates the challenge of altering science teachers' conceptions and beliefs regarding scientific activity and pedagogy. Despite traditional efforts relying on informational training, teachers often resist change. In response, a seven-year project in Québec, Canada, fosters professional learning communities among secondary science teachers. Participants engage in research projects within their classrooms, supported by professional development leaders (PD leaders) and researchers. The study aims to evaluate the project's impact on participants' beliefs using a semantic differential questionnaire and interviews. Preliminary analyses of the first available results on the pretest have been conducted, confirming the presence of somewhat surprisingly sophisticated epistemological beliefs, as further results and discussions will be presented at the conference. This initiative reflects a shift towards socio-constructivist, active-learning and authentic approaches, suggesting a pathway to enhance teachers' professional development and hopefully will contribute to reshape educational practices in science classrooms.

### 3. Testing a Digital Training Intervention on How to Address Misconceptions in Philosophy Classes

Marcus Bohlmann<sup>1</sup> & Markus H. Hefter<sup>2</sup>

<sup>1</sup> University of Muenster, Germany

<sup>2</sup> Bielefeld University, Germany

Future teachers face the challenge of how to tackle their students' misconceptions and induce conceptual change. Previous research has yielded promising approaches on instructional strategies to support teachers, albeit mainly in the domain of science education. Open questions remain whether such approaches are effective when applied to philosophy education, in particular in a digital format. We are therefore developing a short-term (~60 min.) digital training intervention for future philosophy teachers to foster instructional knowledge about how to address students' misconceptions. The intervention's core components are cognitive models of three instructional strategies (i.e., ignoring, refuting, and integrating) and self-explanation prompts. We plan to conduct an experimental study with 60 German teacher students in a between-subjects design to test our intervention against a control group. We will assess learning outcomes (i.e., instructional knowledge about how to address students' misconceptions) and learning processes (i.e., self-explanation quality). The expected positive effects on learning outcomes would demonstrate the potential of a short-term digital intervention for training future philosophy teachers about how to address their students' misconceptions. Analyzing the potential mediating effect of self-explanation quality on learning outcomes would underscore the practical relevance of generating self-explanations when learning from complex cognitive models. This research could be a promising initial step to develop more long-term digital and blended-learning interventions for philosophy education.

### 4. Exploring Learning Trajectories After Conceptual Change Intervention

Vesta Vancugoviene<sup>1</sup>, Ilona Södervik<sup>2</sup>, Erno Lehtinen<sup>3</sup>

<sup>1</sup> Vytautas Magnus University, Lithuania

<sup>2</sup> University of Helsinki, Finland

<sup>3</sup> University of Turku, Finland

Through conceptual change interventions, students can restructure their conceptual knowledge so that they can avoid prior misconceptions and give answers that are scientifically based. Seventy-nine 9<sup>th</sup> graders participated in conceptual change experiment, where the experimental group outperformed the control group in immediate post-test and delayed post-test. However, the experiment did not successfully support conceptual change in all experimental group students as their achievement in the delayed conceptual understanding test was lower than their immediate post-test. Systemic model of conceptual change processes identifies two critical aspects of learning that prevent students from maintaining and establishing conceptual change: over-confidence and under-confidence. The aim of this study was to explore different learning trajectories and possible explanations for successful and less successful long-term conceptual change. The results showed that the experimental group of students had very different learning trajectories. A relatively small group of students demonstrated the same high level conceptual understanding immediate after the intervention and three months later. There was a large group of students who demonstrated low conceptual understanding in all three measurement points. The largest group of students

had quite high achievement in the post-test but substantially lower achievement three months later. Comparison of students with different confidence levels showed that realistic confidence predicted high and sustainable conceptual understanding. Students who were over-confident developed less during the experiment. The under-confidence group developed strongly during the experiment in terms of correct answers in the post-test, but they were not able to answer the questions three months later.

## 5. Students' Conceptions of the General Validity of Mathematical Statements and Proofs

Sarah Lundt<sup>1</sup>, Milena Damrau<sup>1</sup>, Stefan Ufer<sup>1</sup>

<sup>1</sup> Ludwig-Maximilians-Universität (LMU), Germany

Universal statements that allow no exceptions are one central characteristic of mathematics. Mathematical proofs are used to justify such statements' general validity. Students often bring alternative conceptions about general validity and proof to the classroom, which result from everyday experiences. Since everyday rules allow exceptions, those conceptions may differ considerably from the scientific concepts. Closing this gap requires two conceptual changes: First, changing from an everyday conception of general validity to a scientific one that does not allow exceptions and, second, from an empirical conception of the verification of universal mathematical statements to a proof-based one. Since students' conceptions about the general validity of mathematical statements and proofs have rarely been researched so far, we conducted a qualitative exploration study with seven eighth-grade students. Our results indicate that some, but not all students show everyday-related conceptions of general validity. None of the students used the role of the proof as an argument to verify the statement. Some students showed inconsistent conceptions of the relation between the validity of a mathematical statement and its proof. No student relied on the role of variables when arguing about the general validity of the proof.

## 6. Signaling Conceptions and Refuting Misconceptions

Irene Anna Diakidoy<sup>1</sup> & Angela Symeonidou<sup>1</sup>

<sup>1</sup> University of Cyprus, Cyprus

The study compared the effectiveness of refutation and signaled texts in promoting learning about environmental phenomena and reducing misconceptions associated with them. An initial sample of 69 undergraduate students were pretested on their knowledge and six potential misconceptions about the greenhouse effect, ozone layer depletion, and acid rain before being randomly assigned to read either a standard expository text, or a refutation text or a signaled text on environmental phenomena related to climate change. The refutation text directly addressed and refuted the selected misconceptions, whereas the signaled text highlighted the corresponding valid conceptions in text. Reading was followed by an immediate and a delayed posttest - the same as the pretest. Preliminary findings indicated no overall significant effects of text type on learning or misconceptions. However, the contribution of both the signaled and the refutation texts to overall learning and misconceptions was higher than that of the standard expository text. The findings indicate that considerate texts that facilitate the organized encoding and retention of new information in memory can contribute to reducing the negative influence of invalid prior knowledge.

## 7. Can Oral Expression Promote Conceptual Change in Science? A Quasi-Experimental Study

Bénédicte Boissard<sup>1</sup>, Nancy Granger<sup>2</sup>, Patrice Potvin<sup>1</sup>

<sup>1</sup> Université du Québec à Montréal, Canada

<sup>2</sup> Université de Sherbrooke, Canada

Creating spaces for discussion and negotiation in the science classroom appears as a promising intervention strategy for fostering conceptual change (Herrenkohl et al., 1999). Analysis of classroom discourse has indeed shown that different forms of dialogue, such as justifying or challenging a peer's idea, can enhance student achievement (Howe et al., 2019). However, studies that examined the effect of such forms of dialogue on science learning and conceptual understanding have not led to univocal results. This study aims to verify if student's oral justification and reformulation can promote conceptual change as well as achievement in middle school science. A quasi-experimental design was used, in which students are in turn part of the controlled condition (customary teaching) and of the experimental condition (innovative treatment) (Taber, 2019). By means of multiple-choice items, student's prior knowledge regarding mass and volume and photosynthesis were assessed, as well as other potential confounding variables such as student self-concept and individual interest toward sciences. N=400 students (6 teachers, 5 schools) participated during the 2023-2024 school year. Preliminary results (with N = 40) show that when comparing average gains between pre- and posttests, our innovative treatment generated higher gains both for regular assessment items and mis-conceptual items. These rather encouraging results should however be considered with caution since only a subset of data was available for preliminary analysis. A complete analysis of the entire dataset will however be available at the conference.

## 8. Development of a Cognitive Task to Probe Conceptual Prevalence in Thermodynamics for Undergraduates

Vincent Natalis<sup>1</sup>, Patrice Potvin<sup>2</sup>, Loïc Quinton<sup>1</sup>, Bernard Leyh<sup>1</sup>

<sup>1</sup> University of Liège, Belgium

<sup>2</sup> Université du Québec à Montréal, Canada

Entropy and the second law of thermodynamics are challenging concepts for first-year undergraduates as they sometimes are subjected to misconceptions. We developed a consistent-inconsistent true-false task to evaluate the prevalence and possible coexistence of some known alternative conceptions by measuring accuracies, response times (RTs) and feelings of confidence. N=115 first-year undergraduates in a Belgian university undertook two tasks in a pre-test/post-test design in the context of a general thermodynamics course: our home-made task, and another, adapted from Shtulman and Valcarcel (2013). Results from the latter show good accordance with the authors' own results, while results from the entropy task show lower accuracies, lower confidence and higher RT for inconsistent statements compared to consistent statements. Pre-post comparison reveals rather disparate changes in measurements, which might be indicative of inconsistent prevalence, and the limited teaching impact of the usual thermodynamics course on prevalence shifts.

## 9. Resting-State EEG Asymmetry as Predictor of Theory of Mind in Children Aged Three to Four Years

Shuting Li<sup>1</sup>, Beate Sodin<sup>1</sup>, Barbara Müller<sup>2</sup>, Jörg Meinhardt<sup>1</sup>

<sup>1</sup> Ludwig-Maximilians-University (LMU), Germany

<sup>2</sup> Radboud University Nijmegen, Netherlands

Theory of mind (ToM), the ability to attribute mental states to others, is crucial for human cognition. A significant milestone in the development of ToM is typically reached between the ages of 3 and 4, which is marked by children's false belief understanding (FBU). Surprisingly, despite potential associations between resting brain activity and ToM, this crucial developmental phase remains poorly understood. Therefore, the current study delves into the underexplored relationship between resting-state EEG asymmetry and FBU in children aged 3 and 4, a critical period for FBU emergence. Employing a longitudinal design, we analyzed resting-state EEG alpha asymmetry across frontal and parietal electrode sites at 3 years, alongside explicit FBU at 4 years and implicit FBU at both time points. We conducted correlation and regression between resting-state alpha asymmetry and FBU at both time points. Results indicate that a better explicit false belief sum score at 4 years old was associated with greater right than left frontal activity at 3 years old. For implicit FBU, a better implicit FB task score from 3 to 4 years old was associated with greater relative right than left parietal-related activity at 3 years old. Importantly, these associations were observed independently of age and other cognitive abilities commonly associated with FBU, including language skills and executive function. These results highlight a nuanced relationship between resting-state EEG alpha asymmetry and FBU in early childhood and provide vital insights into the developmental trajectory of FBU and the role of resting-state EEG alpha asymmetry in its progression.

## 10. Evaluating Fraction Representations in Textbooks From a Conceptual Change Perspective

Tzyy-Yuh Maa<sup>1</sup>, Sabrina Schwarzmeier<sup>2</sup>, Andreas Obersteiner<sup>2</sup>

<sup>1</sup> National Taichung University of Education, Taiwan

<sup>2</sup> Technical University of Munich, Germany

The study evaluates fraction representations of K12 mathematic textbooks in Germany and Taiwan. Studies suggest that different representations have varied impacts on students' fraction learning. Specifically, continuous fraction representations may better support students' conceptual change from whole number concepts to fraction concepts than discrete or discretized representations. However, the use of representations may also depend on the cultural context. A better understanding of the use of fraction representations in textbooks may eventually contribute to designing effective textbooks for fraction learning. This study conducts content analysis to examine the distribution of both German and Taiwanese fraction representations (N = 907) used in mathematics textbooks. Based on a self-developed coding scheme, we examined continuous, discretized, and discrete area models as well as continuous and discretized number lines in the two countries' textbooks. Preliminary results showed that both countries have more discretized area models than other representations. The use of number line representations differs between the two countries. German textbooks utilize number lines to scaffold fraction concept understanding, while Taiwanese textbooks take number lines as individual learning content in fraction learning. Continuous and discrete area models are found more in Taiwanese textbooks than in German textbooks. We discuss the implications for future studies and the design of mathematics textbooks.

## 11. Intervention to Reduce the Conceptual Interference Effect in Mathematics and Science

Michael A. Meier<sup>1</sup>, Roland H. Grabner<sup>1</sup>, Stephan Vogel<sup>1</sup>

<sup>1</sup> University of Graz, Austria

A common obstacle to learning mathematics is conceptual interference. From a very early age, individuals construct pre-instructional naive theories that are not necessarily scientifically true. After learning the scientific theories – a process called conceptual change – the naive theories seem to coexist in memory and interfere with the scientific concepts, which reflects the conceptual interference effect. Recent research has shown that even experts suffer from this effect. Thus, an important question is how to reduce or eliminate conceptual interference. The main goal of the present work is to test whether a short instructional text on the process of conceptual change and the conceptual interference effect can influence performance in speeded reasoning tasks in mathematics and science. We are currently collecting data from 120 university students between the ages of 18 and 30, 60 of whom will receive such an intervention and 60 of whom will only receive instructions to solve mathematical and scientific statements as quickly and accurately as possible. All participants were presented with 100 statements from different areas of mathematics (i.e., fractions, algebra, units and geometry, and basic concepts) and 100 statements from science that are either congruent (naive and scientific true/false) or incongruent (naive true and scientific false or vice versa). In addition, mathematical achievement and intelligence will be assessed as control variables. Data collection will be completed in May 2024. It is hoped that this study will help us gain insight into how conceptual interference can be reduced.

## 12. Psychological Research Findings Do Not Exhibit More Hindsight Bias Than Other Academic Disciplines

Thomas Simacek<sup>1</sup>

<sup>1</sup> University of Trier, Germany

Laypeople often view psychology as less scientific than other academic fields. One source of skepticism is the belief that much of the evidence of psychological research is common knowledge and does not require detailed investigation. However, if individuals are asked to predict the outcomes of psychological research, the probability of correct answers is no greater than chance. This phenomenon is called the hindsight bias. Psychological research findings might be especially susceptible to hindsight bias because individuals can relate these findings to their naïve concepts and personal experiences more easily than in other academic fields. Although the existence of individuals' hindsight bias in psychological research findings has already been demonstrated, the question of whether academic psychology is more prone to hindsight bias than other academic fields has not been investigated yet. In the current study, participants ( $n = 57$ ) were presented with both real abstracts and manipulated abstracts stating the opposite finding in psychology and other academic fields. In the first block, participants had to state whether they would have predicted the presented finding of an abstract without knowing that some abstracts state incorrect findings. In the second block, the true and the manipulated abstracts were presented next to each other, and participants had to indicate the correct one. The results indicated that psychological research findings do not provoke more hindsight bias than findings from other fields. Hindsight bias appears to be a universal phenomenon that is equally important for communicators of psychology as well as communicators in other academic fields.

## 13. Conceptual Change in Preservice Teachers' Education

Manal Raoui<sup>1</sup>, Khadija Raouf<sup>1</sup>, Ines Langemeyer<sup>2</sup>

<sup>1</sup> Science and Technology Teaching-Learning Systems Research Group, Regional Centers for Education and Training Professions, Morocco

<sup>2</sup> Karlsruhe Institute of Technology, Germany

Moroccan preservice teachers may experience a conceptual change during their training since they come with prior BALTs (Vosniadou et al., 2020). Yet, some research found that traditional beliefs are predominant among preservice teachers (e.g. Wondifraw, Alemayehu & Asrat, 2018). We argue that metacognition reflection can enhance conceptual change. Indeed, the research of Kramarski and Michalsky (2009) showed that supporting preservice teachers' metacognition has a positive impact on BALTs. To explore the metacognitive learning aspects that can explain the perceived conceptual change, a case study (Merriam, 1988) of a cohort of preservice teachers of a CRMEF in math in Morocco during the 2022-2023 school year was conducted. Results reveal that the group of student-teachers who experienced a conceptual change has a richer metacognitive process and a bigger motivation compared to the group who conserved a traditional initial conception. All members had clear and precise learning goals, which related to several spheres (e.g. development of personality and self-recognition). Achieving these goals gave them self-satisfaction and the means were planned, enacted in an effective way (summaries and conceptual diagrams), and constantly reviewed in continuous teamwork. This shows the importance of the metacognitive dimension in conceptual change. Preservice teachers need to go through a complex experience not limited to assimilating and accommodating knowledge but focusing on objectives that interest them in a demanding and stimulating work environment, with support to cognitive and metacognitive reflection.

## 14. What Does ChatGPT Mean for the Motivation to Write?

Håvard Skaar<sup>1</sup>

<sup>1</sup> Oslo Metropolitan University, Norway

What does ChatGPT mean for the motivation to write? A discussion based on cognitive writing process models and self-determination theory ChatGPT's launch in late 2022 has sparked debate on the impact of AI on higher education writing. This discussion combines writing process models and self-determination theory to examine the role of writing in knowledge acquisition when students use ChatGPT. Research shows that the impact depends on how the technology is utilized. If used effectively, ChatGPT can enhance learning and knowledge acquisition. Conversely, misuse can lead to disengagement with the writing process and knowledge content. Learning isn't solely about the final text, but the writing process behind it. A cognitive model for the writing process outlines the prerequisites for learning through writing with ChatGPT. Students can generate a text while deciding the extent of their contribution. Good and bad uses of ChatGPT relate to writing motivation. With writing becoming an open choice, the quality of writing motivation becomes more critical. Self-determination theory differentiates between controlled motivation (external pressure-based) and autonomous motivation (choice-based). ChatGPT can foster a writing process heavily reliant on autonomous motivation. While this could enhance the writing process, it also presents challenges for educational institutions in writing instruction and learning.

## 15. Exploring Tetris in Virtual Reality: Cognitive Implications and Technological Advancements

Tova Michalsky<sup>1</sup> & Sharon Sofer Klein<sup>1</sup>

<sup>1</sup> Bar-Ilan University, Israel

This study explored the intricate relations between Tetris gameplays and cognitive processes, extensively investigated in cognitive psychology, while comparing traditional 2D play environments to virtual reality (VR), which heightens cognitive demands and enriches players' integration of sensory information and motor responses. The Tetris game engages players' attention, spatial perception, mental rotation, working memory, and executive control, while demanding rapid visual processing, decision-making, and problem-solving. Its mechanics foster cognitive flexibility and spatial reasoning, enhancing neuroplasticity and cognitive performance over time. Immersive Tetris experiences in VR are more cognitively demanding than in 2D because they require active monitoring, spatial anticipation, and adaptive strategies. Multisensory feedback in VR enriches cognitive experiences, offering insights into VR's potential impact on cognitive performance, visuospatial skills, and neuroplasticity. The current study examined 80 non-gamer adults (ages 20-30) who engaged in 30-minute weekly sessions of Tetris gameplay over four weeks in either a 3D VR environment (n=41) or traditional 2D computer-based environment (n=39). Pre- and post-training cognitive tests investigated effects on spatial perception, perceptual speed, and visual working memory. Findings indicated both groups' significant pre-to-post improvement in all cognitive processes, with the VR participants significantly outperforming their 2D counterparts. This research contributes to understanding fundamental cognitive principles and underscores VR's promising applications in cognitive training and rehabilitation.

## 16. Computer Science and Mathematics, an Appeal for Project-Oriented Math Education

Michael Fischer<sup>1</sup>

<sup>1</sup> University of Graz, Austria

What challenges and opportunities arise when analyzing mathematical simulations? As part of a project on the modelling and simulation of agent-based infection models in Microsoft Excel, students show good performance in the intuitive understanding of probability distributions in the course of enquiry-based learning. We analyze their work qualitatively with regard to current research questions on the acquisition of competences in the context of digital tools, link the results with possibilities from the curriculum, but also identify difficulties in implementing this teaching concept, mainly based on the knowledge in programming. We support our analyses with a quantitative evaluation of questionnaires concerning students' interest-development and self-assessment.

## 17. In-Depth or In-Breadth? How Do Children Explore to Learn New Information?

Hande Melis Altunary<sup>1</sup> & Azzurra Ruggeri<sup>1</sup>

<sup>1</sup> Technical University of Munich, Germany

From early on, children are naturally curious about the world around them. They eagerly explore and seek information to understand their surroundings. However, as they enter formal education, research suggests this curiosity diminishes over time, despite their inherent tendency to be active learners and explorers. To understand the exploration behaviors of school-age children fueled by their curiosity, we examined them within a self-directed learning setting, focusing on their learning patterns in both depth and breadth. In Experiment 1a, 8-12-year-olds (N = 75) explored various topics freely for 10 minutes, then answered questions about them. Experiment 1b addressed limitations such as controlling for the readability of each question and children's verbal ability and followed the same procedure with 8-13-year-olds (N = 35). Both experiments were conducted in Giza, Egypt. We investigated the interplay between learning patterns, motivation regulation for learning, active learning abilities, and socioeconomic status across developmental stages. In Study 1a we found that learning patterns, age and socioeconomic status, were linked to the extent of exploration, but not to information recall accuracy. Younger, higher SES children showed a greater tendency to explore new information, while older children from lower SES backgrounds tended to revisit same questions multiple times. The trends observed in Study 1b echoed these findings, suggesting consistency and robustness. These insights provide valuable directions for future research and practical implications for education.

## 18. “Aha” and “Hmm” Moments in Conceptual Learning in Pre-Service Physics Teacher Education

Terhi Mäntylä<sup>1</sup>, Anna-Leena Kähkönen<sup>1</sup>, Kati Järvinen<sup>1</sup>, Pasi Nieminen<sup>1</sup>

<sup>1</sup> University of Jyväskylä, Finland

Learning basic concepts of DC circuits is known to be challenging even at the university level. Here we examine the learning instances of pre-service physics teachers as they should be fluent in explaining the functioning of DC circuits at schools. We focus on the so-called moments of “Aha” and “Hmm” during the DC circuit inquiry tasks. These moments were identified through content analysis and vocological measures of voice from data, where two pairs of pre-service physics teachers solved Predict-Observe-Explain-type of tasks of DC circuits. The DC circuit task sessions (3x90 minutes) were videoed, and voices were recorded and the discussions of pre-service teachers during sessions were transcribed. We analysed the identified “Aha” and “Hmm” moments through content analysis. The results show that these moments supported pre-service physics teachers' conceptual understanding of basic DC circuit concepts.

## Symposium 3: Cognitive, Affective, and Behavioral Perspectives on the Natural Number Bias

Organizer and Chair: Jake McMullen  
Discussant: Frank Reinhold

16:00 – 18:00, Room 0602

The natural number bias, where individuals default to using natural number properties when dealing with rational numbers, has been a topic of considerable interest in mathematical cognition and conceptual change research. This symposium explores cognitive, affective, and behavioral aspects of this bias to further understand the nature of the bias and its manifestations in students' cognition, reasoning, and actions. From a cognitive perspective, contributions examine the domain-general and domain-specific contributions to the bias, including inhibitory processes (Paper 2), instructional influences (Paper 4), and knowledge integration perspectives (Paper 3). Affective elements are considered by examining the role of mathematics anxiety in the natural number bias (Paper 1). Finally, behavioral elements are accounted for through performance on novel tasks (Paper 3), strategy analyses (Paper 2), and response to intervention (Paper 4).

First, Van Dooren and colleagues examine the manifestation of state mathematics anxiety when completing a fraction comparison task that taps into the natural number bias. Second, Maricau and colleagues analyze the domain-general and -specific factors that influence individual differences in fraction magnitude processing. McMullen and colleagues examine the nature of cross-notation knowledge of fraction and decimal representations. Finally, D'Erchie and colleagues test the effectiveness of a digital learning environment aimed at enhancing students' fraction magnitude knowledge. In total, the symposium aims to further shed light on the nature of the natural number bias from a variety of innovative lenses.

### 1. Not Realizing Natural-Number Based Errors: A Conceptual Replication of Halme et al. (2023)

Wim Van Dooren<sup>1</sup>, Jo Van Hoof<sup>2</sup>, Hilma Halme<sup>2</sup>, Konstantinos Christou<sup>3</sup>, Nele Wijckmans<sup>1</sup>, Chloë Hoekx<sup>1</sup>

<sup>1</sup> KU Leuven, Belgium

<sup>2</sup> University of Turku, Finland

<sup>3</sup> Aristotle University of Thessaloniki, Greece

In a previous study, Halme et al. (2023) found that not all learners who perform low on mathematics show high state anxiety. Learners with a natural number bias (NNB) showed a lower anxiety while solving problems than learners with a similar low performance but without a natural number bias. The study of Halme et al. was done in Finnish learners and was based on a fraction arithmetic task. We conducted a conceptual replication of this study in Flemish learners who solved a fraction magnitude ordering task. In line with the findings of Halme et al., learners with a NNB reported significantly lower mathematical anxiety while solving the fraction ordering task than other low performing learners, while both groups did not differ in anxiety levels while solving a whole number ordering task. This suggests that learners with a natural number bias may not be aware of the fact that they make systematic errors, which may have implications for instruction.

## 2. The Role of Cognitive Processes and Individual Differences in Solving a Fraction Comparison Task

Flore Maricau<sup>1</sup>, Fien Depaepe<sup>1</sup>, Wim Van Dooren<sup>1</sup>, Bert Reynvoet<sup>1</sup>, Irene Oeo Morin<sup>1</sup>, Sameh Metwaly<sup>1</sup>

<sup>1</sup> KU Leuven, Belgium

Many children have difficulties with processing fractions. Fraction comparison tasks are commonly used to gain insight into children's fraction knowledge. Literature reveals that children's difficulties might stem from both domain-general (e.g., inhibition) and domain-specific (e.g., fraction magnitude processing) processes. However, previous research typically does not account for these distinct cognitive processes and individual differences regarding those processes. Reinhold and his colleagues (2023) made a first promising attempt to investigate the role of inhibition and benchmarking strategies in fraction comparison and how these processes interact on an individual level. The current study aims to replicate Reinhold et al.'s (2023) dual factor structure (i.e. inhibition and benchmarking), and whether the model should be extended with additional domain-specific processes (i.e., gap thinking and fraction magnitude processing measured by the distance-effect) (RQ1) and to investigate the existence of different student profiles regarding inhibition, benchmarking (i.e., a replication) and gap thinking for fraction trials with a large and small distance (i.e., an extension) (RQ2). To address these RQs, we administered a fraction comparison task consisting of 101 trials (including all 24 items of Reinhold's study) to 250-300 5th and 6th graders. We use a confirmatory MIRT analysis to address RQ1, and a non-explorative Bayesian classification approach for RQ2. We hypothesize that a model accounting for inhibition, benchmarking, gap thinking, and the distance effect best explains the complex relationship between fraction processing and the processes underlying it. Furthermore, we expect differences in students' profiles regarding children's underlying cognitive processes.

## 3. Cross-Notational Knowledge of Rational Numbers in High School Students

Jake McMullen<sup>1</sup>

<sup>1</sup> University of Turku, Finland

The phenomenon of a natural number bias has been extensively examined in students' actions, perceptions, and responses in recent years across many aspects of number concepts, such as the size of rational numbers, the density of the set of rational numbers, and operations with rational numbers. However, less work has examined concepts surrounding representations of rational numbers, especially the relation between fractions and decimals. The present study aims to examine the nature of high school students' cross-notational knowledge and its relation to other features of mathematical knowledge. High school students (N=447) completed a set of measures of their arithmetic knowledge with whole and rational numbers. Overall students exhibited limited cross-notational knowledge with rational numbers, especially on a novel task of their adaptive rational number knowledge. Cross-notational knowledge was related to performance on other items. One possible explanation is that students may not understand the interchangeable nature of fractions and decimals, something that may be valuable for future learning and may require undergoing conceptual change.

#### 4. Reducing the Natural Number Bias Through Magnitude-Based Reasoning: Results of an Intervention Study

Michael D'Erchie<sup>1</sup>, Johannes Rosenkranz<sup>2</sup>, Sabrina Schwarzmeier<sup>1</sup>,  
Andreas Obersteiner<sup>1,2</sup>

<sup>1</sup>Technical University of Munich

<sup>2</sup>University of Freiburg

Many students struggle with understanding fractions because they rely too strongly on their initial concepts of natural numbers. When comparing fractions, students often show a natural number bias, that is, they rely on reasoning about natural numbers (e.g.,  $2/4 > 1/2$  because  $2 > 1$  and  $4 > 2$ ) instead of reasoning about the fractions' magnitudes (the numerical size of  $1/2$  and  $2/4$ ). This bias has been documented in students and adults, suggesting it is resistant to change. However, it is not clear whether supporting students' fraction magnitude reasoning can reduce their natural number bias in fraction comparison. Participants were 331 students ( $M=11.45$  years). They were randomly assigned to an intervention group or one of two control groups. The intervention group received computer-based training to associate symbolic fractions with dynamic visual representations (to activate fraction magnitude). The first control group also received computer-based training on fractions but with a different tool not focussing on fraction magnitude. The second control group received no training. Unlike the control groups, students in the intervention group improved their accuracy in fraction comparison. Students displayed three distinct bias patterns (typical, reverse, or no bias). Most importantly, substantially more students from the intervention group than the control groups shifted from typical or reverse bias in the pretest to no bias in the posttest. Short-term training enhanced students' ability to activate fraction magnitudes in fraction comparison and reduced their natural number bias. Our findings challenge previous research that suggests that the bias is rather persistent.

## Symposium 4: Perspectives and Positionings in Teaching for Conceptual Understanding

Organizer and Chair: Gertraud Benke  
Discussant: Gertraud Benke

16:00 – 18:00, Room 0601

In this symposium, we foreground the role perspective and positions play when learning concepts. Some of the difficulties of learning concepts (such as understanding the concept of “the earth (as a sphere in space)”) go along with a change in the position of the learner. Having a perspective implies a particular positioning of actors when considering some idea or phenomenon of the world. Not all places or positions are equally attainable for all learners. Positions have prior requirements: competencies, ideas, images, and visual abilities. Positions might also be tied in with particular identities, which enable or hinder the attainment of positions needed to understand a specific concept (in a normative way). In this symposium, we compiled research from different subjects and perspectives (e.g., students and teachers) to highlight the broadness of the topic. We first theorize about the possible role of perspective and positions for conceptual learning. Next, we discuss the role of perspective in teaching history—a subject for which perspective thinking can be seen as a core competence. Afterward, we present an empirical paper about the change pre-service teachers undergo in their understanding of the concept of what English Teaching means through experiencing the Attentive Teaching approach. The process shown demonstrates the power of integrating reflections of one’s perspective in instruction. The final empirical paper, using the control-of-variable strategy in science teaching, asks students to position themselves in different imagined situations.

### 1. Perspective, Positions, and Identity in Conceptual Change Research

Gertraud Benke<sup>1</sup> & Yaron Shur<sup>2</sup>

<sup>1</sup> Klagenfurt University, Austria

<sup>2</sup> David Yellin Academic College, Israel

This first symposium presentation discusses the role perspectives, positions, and identities have in concepts and learning for conceptual understanding. We argue that positions and perspectives are inherent to concepts and should be integrated into teaching for conceptual understanding. A perspective implies a particular positioning of learners when considering some idea or phenomenon of the world. While some might be easy to attain, others might be hard to conceive. Positions have prior requirements: competencies, ideas, images, and visual faculties. Additionally, positions are tied in with identities. In this presentation, we will discuss a case in which a student who migrated to a new country needed to integrate her being there before understanding the concept of the earth not as an abstract entity but as also denoting her position in space.

## 2. Challenges for Integrating Perspective Into Classroom Teaching. Lessons From a Failed Study

Christian Mathis<sup>1</sup>

<sup>1</sup> PH Zürich, Switzerland

The principle of Multiple Perspectives provides a framework for interpreting and planning teaching processes (Köhnlein et al., 2013). It aims to facilitate multi-layered examinations of reality and demonstrate pathways to understanding, emphasizing the ability to change positions and concepts. Mathis & Duncker (2018) created a "Matrix of Discursive Didactics", delineating four dimensions of multiple perspectives' quality: Affirmativity, Plurality and Relativity, Discursivity, and Positionality. An international study conducted in German and Swiss primary schools revealed that most teachers predominantly operate at the level of subjective-appropriating Plurality and Relativity, with only a few reaching the level of an objectifying-academic Discursivity. The study highlights the importance of embracing diverse perspectives and fostering discursive engagement within educational settings for conceptual change.

## 3. Changing Conceptualization of Pre-service Students on Teaching English Through Attentive Teaching

Yaron Schur<sup>1</sup> & Shira Farby<sup>2</sup>

<sup>1</sup> David Yellin Academic College, Israel

<sup>2</sup> David Yellin Teachers College, Israel

In order to enable students to go through deeper learning, one has to combine mastery, creativity, and identity (Mehta & Fine, 2019). In this study, we enabled pre-service English teachers to experience Attentive Teaching as a means to enable them to change their concept of teaching and experience deeper learning. We exposed 20 pre-service English teachers to Attentive Teaching and observed changes in their conceptualization of English teaching and learning. In Attentive Teaching, students are repeatedly asked to create visual representations of their conception of a topic and to explain their meaning. This method allows the teacher to observe conceptual change processes over time, to evaluate students' progress, and to adjust his mediation to students' needs and identities. Mediation includes classroom discussions in which all participants present their views, reasoning, and questions and respond respectfully yet critically to those of the other learners. The students produced drawings and explanations of the concept of "teaching English" at the beginning and at the end of the course. In the first drawings, the students expressed their experiences as English learners. At the end of the course, they portrayed teaching and learning as an enjoyable, collaborative endeavor in which all participants teach and learn from each other; the students create innovative products, and the teacher contributes mastery as a mediator. This shows the conceptual changes of the students in their understanding of English teaching and learning in the eyes of the learners. The students expressed their satisfaction and joy of learning in this way.

#### 4. Vary One Thing at a Time: The Control of Variable Strategy in Physics Learning

Christian Thurn<sup>1</sup>, Sonja Peteranderl<sup>1</sup>, Peter Edelsbrunner<sup>1</sup>, Anne Deiglmayr<sup>2</sup>, Elsbeth Stern<sup>1</sup>, Julie Keller<sup>3</sup>, Ralph Schumacher<sup>1</sup>

<sup>1</sup> ETH Zürich, Switzerland

<sup>2</sup> University of Leipzig, Germany

<sup>3</sup> FernUni Schweiz, Switzerland

The control-of-variable strategy (CVS) is a milestone in science education that often needs explicit training. Otherwise, misconceptions persist, such as the idea that a fair design of an experiment cannot be evaluated independently of its outcome. The impact of explicit trainings, however, is controversially discussed. We investigated whether a targeted CVS training enables long-term transfer to contexts outside of the training material. In a randomized controlled field trial 189 primary school students received either an inquiry-based CVS training or a control training. About five months later, all students received a content training on the topic of magnetism, accompanied by pre- and posttests. Whereas the tests contained items about magnetism, they also contained items on the conclusiveness of experiments. Students had to decide about the conclusiveness and write down their reasons. We coded students' answers on these items in five levels, from incorrect answer to correct principle-based justification. We used a Bayesian adjacent-category multilevel model to account for the ordinal nature of the dependent variable and the nested data structure. Students who received the CVS training used higher levels of justification in the ensuing magnetism test more often than the control group, both at pre-test and at posttest. Students who did not receive a CVS training based their answers on more concrete justifications. Students who received a CVS training were able to apply the CVS strategy on a higher and more abstract level to another context (magnetism). These benefits were secured despite the substantial temporal distance between the learning events.

# Thursday, August 29

09:00 – 10:30

Paper Session 3:  
Teacher Education (0601)

- Pre-service Teachers' Epistemic and Educational Beliefs and Their Impact on Educational Practices
- University Teachers' Professional Vision & Conceptual Change as a Dynamic Interplay
- Learning Processes in a Field-Based Geology Environment

Paper Session 4:  
Analyzing Conceptual Change Patterns (0670)

- Patterns of Conceptual Change: Play in a Constructivism/Affect-Focused Mathematics Virtual Classroom
- Learning Analytics and the Universal Design for Learning (UDL): A Clustering Approach in Chemistry
- How Consistently Do Students Make Typical Errors? An Analysis of Errors in the Domain of Functions

Roundtable 2:  
The Conceptual Change Perspective in (Science) Teaching and Education: Past, Present, and Future (0602)

10:30 – 12:00

Keynote 3: Garvin Brod (0602)

12:00 – 13:00

Lunch

13:00 – 14:30

Paper Session 5:  
Fostering Conceptual Change in Undergraduate Students (0602)

- Two Ways of Fostering Epistemological Belief Change – Indirect and Direct Intervention Approaches
- Testing the Microscopic Teaching of Entropy to Undergraduates to Promote Conceptual Change
- Role of Prior Knowledge in Learning Biology Over the First Undergraduate Years

Paper Session 6:  
Technology-Enhanced Learning (0670)

- How to Improve Conceptual Understanding in Science Education With Real, Virtual, and VR Experiments
- Supporting Understanding of Thermodynamics: Adaptive Guidance in Tech-Enhanced Classroom Interaction
- Augmented Reality in a Pedagogical Scenario Based on Analogical Reasoning for Biodiversity Learning

Paper Session 7:  
Modelling Knowledge Structures and Conceptual Change (0601)

- Describing Conceptual Knowledge in Concept Maps by Network Analysis
- Rethinking the Relationship Between Fractions and Algebra Using Network Analysis
- Analyzing and Comparing Conceptual Change Models Through KLI Framework

14:30 – 16:00

Paper Session 8:  
Learning and Practice Environments in Higher Education (0602)

- Raising the Quality of Students' Presentation in Higher Education With a Blended Learning Environment
- Student Teachers' Conceptual Understanding on the Loss of Bio-Diversity in an Online Reading Context
- Practice Environment and Deliberate Practice

Paper Session 9:  
Dealing with Misinformation & Persistence of Intuitive Conception (0670)

- A Lateral Reading Training Against Misinformation Based on Cognitive Apprenticeship
- Predictors of Neurofacts and Neuromyth – A Model-Selection Approach
- Intuitive Conceptions as Category Prototypes: Insights From Arithmetic Problem-Posing

Paper Session 10:  
Fostering Conceptual Change Using Comparing and Contrasting (0601)

- Comparing and Contrasting Promotes Sustainable Understanding of Chemical Bonding
- Supporting Students' Knowledge Integration: Design Characteristics of Critique Artifacts
- Comparison of Incorrect and Correct Solution Examples to Simulate Conceptual Change

16:00 – 16:15

Coffee (Foyer)

16:15 – 19:00

Excursions

19:00

Conference Dinner (Augustiner Keller, Arnulfstraße 52)

## Paper Session 3: Teacher Education

Chair: Manal Raoui

09:00 – 10:30, Room 0601

### 1. Pre-Service Teachers' Epistemic and Educational Beliefs and Their Impact on Educational Practices

Anastasia/Natassa Kyriakopoulou<sup>1</sup> & Irini Skopeliti<sup>2</sup>

<sup>1</sup> National & Kapodistrian University of Athens, Greece

<sup>2</sup> University of Patras, Greece

During their teaching training, preservice teachers are instructed on the benefits of constructivist teaching methods, which they initially embrace. However, research indicates that they often hold conflicting beliefs about the effectiveness of constructivist learning, leading them to adopt teaching practices aligned with a teacher-centered model. The present study investigated (a) pre-service teachers' educational belief system about learning, self-regulated learning, teaching and cognitive engagement (EdB), (b) the possible impact of pre-service teachers' epistemic beliefs on their EdB and (c) the interaction of these belief systems and their impact on pre-service teachers' teaching practices. Two hundred and thirty-one pre-service teachers were administered (a) a questionnaire investigating epistemic beliefs, (b) a questionnaire investigating beliefs about learning and teaching, (c) a questionnaire investigating beliefs about teaching practices and cognitive engagement, and (d) four teaching scenarios representing different modes of cognitive engagement. It was hypothesized that epistemic and educational belief systems would not be coherent and naïve and sophisticated beliefs would coexist. It was also hypothesized that epistemic beliefs would have a direct and indirect impact on educational beliefs and both belief systems would predict pre-service teachers' choices regarding teaching practices. The results confirmed these hypotheses, revealing that pre-service teachers' epistemic beliefs directly influenced their beliefs about learning and teaching, as well as their choices regarding teaching practices. Furthermore, an indirect effect of epistemic beliefs through educational beliefs on teaching practices was observed. These findings will be discussed in light of the framework theory approach of conceptual change, with implications for pre-service teaching training.

### 2. University Teachers' Professional Vision & Conceptual Change as a Dynamic Interplay

Neea Heinonen<sup>1</sup>, Nina Katajavuori<sup>1</sup>, Elina E. Ketonen<sup>1</sup>, Mari Murtonen<sup>2</sup>, Ilona Södervik<sup>1</sup>

<sup>1</sup> University of Helsinki, Finland

<sup>2</sup> University of Turku, Finland

This study investigated the transformation of life science university teachers' professional vision and (mis)conceptions of teaching and learning during pedagogical training, drawing upon the theories of professional vision and conceptual change. In the context of teaching and learning, this theory suggests that less sophisticated conceptions should evolve towards more advanced perspectives to support the development of

pedagogical expertise among teachers. A total of 127 life science university teachers from the University of Helsinki filled in a questionnaire and completed a video interpretation task, utilizing a pre-test / post-test design. Data were analyzed using confirmatory factor analysis (CFA), correlations, a paired-samples t-test, and cluster analysis. The results of this study align with conceptual change theory, as participants exhibited a shift in their (mis)conceptions towards more sophisticated understandings following pedagogical training. There was a notable increase in viewing learning as a constructive activity, indicating a conceptual shift away from traditional views of teaching as merely transmitting subject knowledge. This evolution in (mis)conceptions is indicative of cognitive restructuring, wherein teachers integrate new pedagogical theories and practices into their existing frameworks. The correlation between professional vision and (mis)conceptions underscores the interconnectedness of these constructs. Teachers with more sophisticated conceptual understandings demonstrated higher levels of professional vision, suggesting that advanced pedagogical beliefs may facilitate a more nuanced perception of teaching and learning interactions. The findings of this study provide empirical support for the theory of conceptual change in the context of teacher development, highlighting the importance of fostering pedagogically informed perspectives to enhance professional practice.

### 3. Learning Processes in a Field-Based Geology Environment

Lauren Barth-Cohen<sup>1</sup>, Adrian Adams<sup>1</sup>, Lynne Zummo<sup>1</sup>, Sarah Braden<sup>1</sup>, Holly Godsey<sup>1</sup>

<sup>1</sup> University of Utah, United States

Field-based learning experiences are widely valued by Geoscience instructors, but there is a limited understanding of learning processes that occur in outdoor settings where individuals observe complex geological formations to build an understanding of the historical processes that formed them. We use a theory of Conceptual Change known as Coordination Class Theory along with qualitative video analysis to describe the moment-to-moment learning in this setting. The learners are secondary science teachers in a professional learning experience who participated in a semester-long online geology course and then spent a week doing field geology in Capitol Reef National Park, Utah, USA. Using qualitative video analysis of small group conversations, we present a case study of shifts in understanding over time. Specifically, we document shifts in the relationship between participants' observations and inferences about the historical geological record. The results shed light on learning processes in an understudied area, outdoor field-based learning, and were facilitated by applying a theory of conceptual change to a new learning environment.

## Paper Session 4: Analyzing Conceptual Change Patterns

Chair: Michael Fischer

09:00 – 10:30, Room 0670

### 1. Patterns of Conceptual Change: Play in a Constructivism/Affect-Focused Mathematics Virtual Classroom

Mei-Shiu Chiu<sup>1</sup>

<sup>1</sup> National Chengchi University, Taiwan

This study aims to identify patterns of student conceptual change from the process data of playing in a constructivism/affect-focused mathematics virtual classroom. The pedagogy of the virtual classroom (app) follows a constructivist pedagogical approach, relying on learners' prior knowledge to reorganize the concept of prime and composite numbers. The app can detect student's detailed evolution of conceptual change process and identify student misconceptions. The data were from 61 students, conducting 107 trials in playing the major game of the app, which were used by three teachers in their four mathematics classes. A mixed-method approach incorporating both qualitative and quantitative analyses was utilized to examine the data. The analysis finds four patterns of conceptual change: limited change, vague change (unstable correctness, showing misconceptions), positive change (from incorrectness to correctness), and perfect change (with all correctness). Pattern 1 (limited change) has the lowest scores. Pattern 4 (perfect change) has higher scores than Patterns 1 (limited change) and 2 (vague change). More trials of playing the game are correlated with higher scores. Data from students' word responses on the app reveal that Pattern 2 (vague change) students have misconception and Pattern 4 (perfect change) has clear concept. The results suggest that the constructivism/affect-focused pedagogical design using virtual classrooms can assist in identifying student misconception and detect their conceptual change patterns. This information is potentially valuable for productive pedagogical intervention.

### 2. Learning Analytics and the Universal Design for Learning (UDL): A Clustering Approach in Chemistry

Andreas Nehring<sup>1</sup>, Marvin Roski<sup>2</sup>, Anett Hoppe<sup>3</sup>, Ralph Ewerth<sup>3</sup>

<sup>1</sup> Gottfried Wilhelm Leibniz Universität Hannover, Germany

<sup>2</sup> Leibniz University of Hannover, Institute for Science Education, Germany

<sup>3</sup> TIB – Leibniz Information Centre for Science and Technology, Germany

In the context of inclusive education, Universal Design for Learning (UDL) is a framework used worldwide to create learning opportunities accessible to all learners. While much research focused on the design and students' perceptions of UDL learning settings, studies on students' usage patterns in UDL-guided elements, particularly in digital environments, are still scarce. Therefore, we analyze and cluster the usage patterns of 9th and 10th graders in a web-based learning platform called I3Learn. We collected the temporal usage patterns of UDL-guided elements of 384 learners in detailed log files as well

as data on social, affective and cognitive variables – particularly on students' conceptions using the bonding representations inventory (BRI) in pre- and post-measurements.

The collected data includes the time spent using video and/or text as a source of information, working on learning tasks with or without help and working on self-assessments. We used Exploratory Factor Analysis (EFA) to identify relevant factors in the observed usage behaviors. Based on the factor loadings, we extracted features for k-means clustering and named the resulting groups based on their usage patterns and learner characteristics. The EFA revealed four factors suggesting that learners remain consistent in selecting UDL-guided elements that require a decision. Based on these four factors, the cluster analysis identifies six different groups. They differ systematically regarding social, affective and cognitive variables including students' conceptions assessed through the BRI. We discuss these results as a starting point to provide individualized learning support through further artificial intelligence applications and inform about learner activity through a dashboard.

### 3. How Consistently Do Students Make Typical Errors? An Analysis of Errors in the Domain of Functions

Christian Schons<sup>1</sup>, Michael Nickl<sup>1,2</sup>, Kirsten Brunner<sup>3</sup>, Andreas Obersteiner<sup>1</sup>,  
Timo Leuders<sup>3</sup>

<sup>1</sup> Technical University of Munich, Germany

<sup>2</sup> IPN Kiel, Germany

<sup>3</sup> University of Education Freiburg, Germany

This study investigates the consistency of typical errors made by students in the domain of functions and graphs. While prior research has focused on procedural errors, there is limited understanding of the consistency of errors in conceptual mathematical tasks. Using data from 168 eighth-grade students, we examined the occurrence and combinations of three typical errors: slope-height confusion error, graph-as-picture error, and slope-root confusion error. Results indicate that students make the slope-root confusion error consistently across tasks, but other errors occur less consistently. Cluster analysis revealed distinct groups of students making different combinations of typical errors. Accordingly, students should benefit from tailored support. Teachers should be aware of these individual differences and provide adaptive support to enhance students' conceptual learning.

## Roundtable 2: The Conceptual Change Perspective in (Science) Teaching and Education: Past, Present, and Future

09:00 – 10:30, Room 0602

Erik Meij<sup>1</sup>, David Treagust<sup>2</sup>, Tamer Amin<sup>3</sup>, Patrice Potvin<sup>4</sup>, Ilona Södervik<sup>5</sup>, Stella Vosniadou<sup>6</sup>

<sup>1</sup> Windesheim University of Applied Sciences, Netherlands

<sup>2</sup> Curtin University, Australia

<sup>3</sup> American University of Beirut, Lebanon

<sup>4</sup> Université du Québec à Montréal, Canada

<sup>5</sup> University of Helsinki, Finland

<sup>6</sup> Flinders University, Australia

A round table discussion in memory of Reinders Duit.

Despite many theoretical differences, there is a great deal of consensus regarding the difficulties students face in situations of learning that require conceptual changes and about the teaching practices that can bring it about. It is worthy that the lessons from conceptual change research become more widely known and used both in the context of general theories of learning and in the context of teacher education and teacher practices. An earlier panel discussion was held on the question 'Why conceptual change theory is not a leading learning theory'. We have decided to organize a follow-up in the form of a round table discussion. We have asked David Treagust, who collaborated with Reinders Duit on conceptual change research for more than 40 years, to give a main presentation.

The presentation will be followed by a commentary by four members of the SIG 03 research community. The following set of questions was given to the participants to provide a structure for the discussion:

1. What are some of the most important theoretical contributions of the CC perspective on research in learning?
2. What are some of the most important practical contributions of the CC perspective on instruction?
3. How do you think it can be achieved that pre- and in-service teachers shift more towards conceptual change based pedagogical reasoning?
4. What do you think is the future of CC research in education?

## Paper Session 5: Fostering Conceptual Change in Undergraduate Students

Chair: Thomas Simacek

13:00 – 14:30, Room 0602

### 1. Two Ways of Fostering Epistemological Belief Change – Indirect and Direct Intervention Approaches

Eric Klopp<sup>1</sup> & Robin Stark<sup>1</sup>

<sup>1</sup> Saarland University, Germany

Epistemological beliefs are a major prerequisite for scientific thinking and argumentation. Evaluativist epistemological beliefs are especially beneficial for adequate scientific argumentation. Thus, evaluativist epistemological beliefs should be fostered. This study examines the effects of two intervention approaches, the indirect and the direct approach, on the change in epistemological beliefs and the argumentation of psychology students. In the indirect approach, participants are confronted with resolvable scientific controversies intended to elicit epistemological change. The direct approach draws on instructional principles, provides participants with instructions on epistemological belief theories, and encourages them to reflect on their own epistemological beliefs, thus inducing epistemological change. This study compares the effects of these two approaches on epistemological change and the level of psychology students' argumentation. We assume that both interventions reduce absolutism and multiplicity and foster evaluativism and argumentation. In an experimental pre-post-test-design, we investigated the effects of both intervention approaches on two measures of epistemological beliefs. Using two epistemological beliefs assessments and an argumentation measure, the results from a sample of N=81 indicate that both intervention types may induce change in epistemological beliefs as hypothesized. However, the effects differed between the two measures, indicating that the results depend on the applied measure, thus complicating the findings' generalization. Concerning the argumentation measure, the results show that both intervention types increase the level of argumentation, but only from a multiplicity to a pre-evaluativist level. Overall, the results demonstrate the intervention's potential to change epistemological beliefs and to positively affect students' argumentation but also reveal methodological issues.

### 2. Testing the Microscopic Teaching of Entropy to Undergraduates to Promote Conceptual Change

Vincent Natalis<sup>1</sup>, Loïc Quinton<sup>1</sup>, Bernard Leyh<sup>1</sup>

<sup>1</sup> University of Liège, Belgium

Teaching entropy in an introductory thermodynamics course at university is a challenging task. Since confronting alternative conceptions (AC) is key to promoting conceptual change, we used a microscopic-approach teaching to tackle AC-inducing aspects of entropy during a lecture, an exercise tutorial and a laboratory with university students

cohort and measured the impact of this teaching with a pre-test/post-test, intervention/control setup with N=186 students in 2023, and a final post-test. Testing was conducted using a MCQ with written justifications questionnaire including exam-like “classical” questions and conceptual questions. Our results show that the cohorts were indistinguishable in the pre-test, and that the intervention helped the intervention group to perform better on the questionnaire, as measured by  $d_{ppc2} = 0.41$ , analogous to Cohen's  $d$ , highlighting the fact that students in the intervention group improved more than students in the control group, especially on conceptual questions. Conceptual change was also monitored by the analysis of the written answers of students and the detection of use of 10 known alternative conceptions concerning entropy: preliminary results show that some conceptual change can be hypothesized in the evolution of justifications in correct answers.

### 3. Role of Prior Knowledge in Learning Biology Over the First Undergraduate Years

Tomi Kiviluoma<sup>1</sup>, Ilona Södervik<sup>1</sup>, Riitta Savolainen<sup>1</sup>, Helene Aström<sup>1</sup>

<sup>1</sup> University of Helsinki, Finland

Undergraduate students enroll to university with diverse levels of prior knowledge and intuitive conceptions about essential biological topics, such as metabolic processes, ecosystem dynamics and Darwinian evolution. This longitudinal study explored the development of conceptual understanding about these topics and how domain-specific prior knowledge affects this learning progression. Undergraduate students (N = 50) of biological and environmental sciences participated in three measurement points where the same questionnaire with open-ended procedural tasks was three times: baseline (2019), follow-up 1 (2020), and follow-up 2 (2021). A mixed method approach was used for quantitative scoring of the answers and qualitative thematic analysis to describe the development of individual students' conceptual understanding. The effect of prior knowledge was studied by dividing the students into two groups based on median splitting the baseline scores. During the first two years, the students' understanding generally improved as demonstrated by the statistically significant increases in mean scores. Students with lower prior knowledge performed poorer in both follow-up measurements despite them experiencing more knowledge gains. The differences between baseline answers were the greatest in tasks about evolution. Students with lower prior knowledge experienced desirable shifts in their explanatory models about evolutionary processes, but an equal amount exhibited a fragmented learning progress. Students with a more robust prior understanding of such a complex, emergent phenomenon are more likely to perform better and can integrate more scientific concepts to their knowledge framework. Implications for teaching will be discussed in the presentation.

## Paper Session 6: Technology-Enhanced Learning

Chair: Flore Maricau

13:00 – 14:30, Room 0670

### 1. How to Improve Conceptual Understanding in Science Education With Real, Virtual, and VR Experiments

Salome Flegr<sup>1</sup> & Jochen Kuhn<sup>1</sup>

<sup>1</sup> Ludwig-Maximilians-Universität (LMU), Germany

One fundamental aim of science education is fostering students' conceptual understanding. The instructional approach of inquiry learning has proven to be one possibility to effectively foster this understanding of concepts. Inquiry learning can be implemented using real (hands-on) experiments, 2D-virtual experiments (e.g., on iPads), or 3D-Virtual Reality (VR) experiments. Recent research suggests that sequenced combinations of real and virtual experiments are more effective for improving students' conceptual understanding than single experimentation formats alone. Whether this holds true for parallelly used combinations has not been investigated intensively so far. Moreover, VR experiments might minimize the split attention effect that occurs in combined real and virtual experiments; however, this has not been investigated systematically yet. In the present study, 172 middle school students were involved in inquiry learning in a physics lesson. They worked either with a (a) real experiment alone, (b) virtual experiment alone, (c) parallelly combined real and virtual experiment, or (d) VR experiment. In line with our hypotheses, inquiry learning fostered students' conceptual understanding in physics (H1), real and virtual experiments lead to similar conceptual understanding (H2), and students in the combination condition learned more than students in the single experiment conditions (H3). However, the VR experiment did not lead to higher conceptual understanding than the combination of a real and a virtual experiment (contrarily to H4). In conclusion, this study suggests that combinations of real and virtual experiments can be recommended for inquiry learning in science education, also when used parallelly.

### 2. Supporting Understanding of Thermodynamics: Adaptive Guidance in Tech-Enhanced Classroom Interaction

Sarah Bichler<sup>1</sup>, Libby Gerard<sup>2</sup>, Brian Riordan<sup>3</sup>, Jonathan Lim-Breitbart<sup>2</sup>, Marcia Linn<sup>2</sup>

<sup>1</sup> Ludwig-Maximilians-University (LMU), Germany

<sup>2</sup> University of California, Berkeley, United States

<sup>3</sup> ETS, United States

Adaptivity is a core principle of student-centered instruction. Systems and teachers alike can utilize students' ideas to guide them in developing understanding. Natural language processing (NLP) allows for real-time insight into complex student thinking, which can be used to create pedagogically inspired adaptations. In a research-practice-partnership, we designed and tested classroom instruction that takes advantage of NLP to

automatically score students' thinking expressed in written explanations. We study the effectiveness of branching students to guidance that builds on their initial understanding and promotes the integration of ideas. Two middle school science teachers and their 208 students used a web-based Thermodynamics curriculum. Students complete a formative assessment, and their responses are automatically scored for the level of knowledge integration (KI). Students complete an adaptive activity including an example peer response, guiding question, and interactive model, all uniquely aligned with an idea typical for the detected KI level. Students revise their own explanation and get a second chance to revise after teacher-led classroom activities. We found that students did not improve their explanation at first but from initial to the second revision. More detailed analyses will follow. We observed considerable variability in students' level of understanding mid-way into the unit. This study underscores the value of adapting instruction to the prior ideas of the students and highlights the value of NLP for this purpose. The results illustrate the significance of using a web-based curriculum in conjunction with teacher orchestration of classroom instruction.

### 3. Augmented Reality in a Pedagogical Scenario Based on Analogical Reasoning for Biodiversity Learning

Laura Leon Perez<sup>1</sup>, Catherina Audrin<sup>2</sup>, Emmanuel Sander<sup>1</sup>

<sup>1</sup> University of Geneva, Switzerland

<sup>2</sup> University of Teacher Education Lausanne, Switzerland

The urgency to understand biodiversity considering alarming climate change has led to its integration into curricula worldwide. However, biodiversity's complexity, blending scientific and political dimensions, presents significant challenges. Various ethical frameworks exist. Among them, preservationism prioritizes nature's intrinsic value over human benefits, demanding its protection despite human interests. Innovative pedagogical approaches are crucial for effective biodiversity education, with analogies proposed to facilitate understanding. Analogical reasoning, combined with Augmented Reality (AR) technology, holds promise for optimizing outcomes. AR enables exploration of nature and visualization of abstract concepts, enhancing learning experiences. The study aims to evaluate the impact of AR on learning outcomes and nature exploration among school pupils. In a study involving 170 students aged 12 to 17, significant differences were found in knowledge acquisition between groups using AR and non-digital means, suggesting the effectiveness of AR in enhancing learning outcomes. However, further investigation is needed to explore the potential distractions AR might pose, potentially leading to disconnection from the natural environment. Nevertheless, the pedagogical scenario combining analogical reasoning with AR emerges as a promising approach for effectively teaching the intricate concepts of biodiversity, fostering engagement with environmental concepts among students. Continued exploration and refinement of this pedagogical strategy hold significant promise for advancing biodiversity education and nurturing environmentally conscious individuals equipped to tackle future challenges.

## Paper Session 7: Modelling Knowledge Structures and Conceptual Change

Chair: Michael D'Erchie

13:00 – 14:30, Room 0601

### 1. Describing Conceptual Knowledge in Concept Maps by Network Analysis

Simona Daguati<sup>1</sup>, Bruno Rüttsche<sup>2</sup>, Christian Thurn<sup>1</sup>

<sup>1</sup> ETH Zürich, Switzerland

<sup>2</sup> PH Schwyz, Switzerland

Whereas conceptual change research has identified how concepts can impede or support learning, there is no consensus on a standardized method for evaluating the quality of knowledge structures. Identifying indices of the quality of knowledge networks would help to derive a more general theory of how knowledge structures hinder or facilitate learning. One method to assess learners' knowledge structures is concept mapping. As concept maps represent networks of concepts and their relations, they can be analyzed via network analysis. To this end, we developed a R Shiny dashboard that allows students to draw and analyze their maps. To judge the validity of different network indices, we accompanied the use of this dashboard in three university courses by the Learning Strategies of University Students questionnaire. From a convergent validity perspective, we will evaluate which network indices are indicative of elaborate learning strategies, and thus meaningful learning.

### 2. Rethinking the Relationship Between Fractions and Algebra Using Network Analysis

Claire Forsmann<sup>1</sup>, Michael D'Erchie<sup>2</sup>, Andreas Obersteiner<sup>2</sup>, Michael Schneider<sup>1</sup>

<sup>1</sup> University of Trier, Germany

<sup>2</sup> Technical University of Munich, Germany

Students who perform well in fractions were frequently found to also perform well in algebra, specifically in equations. This relationship is unclear, but understanding it increases researchers' and educators' knowledge and improves instruction, leading to future student success. In this study, we examined which specific facets of fraction and algebra knowledge are related by using network analysis. Network analysis displays partial correlations between variables. Participants were 571 ninth and tenth graders from Germany who took two tests assessing their conceptual and procedural knowledge about fractions and algebra, respectively. Implementing the *EBICglasso* estimator, the returned network consists of two "islands" of fractions and algebra variables, connected specifically by a strong partial correlation between the part-whole understanding of fractions and setting up and solving linear equations ( $r_{\text{part}} = .141$ ) and a moderate relationship between extending/simplifying fractions and solving linear equations ( $r_{\text{part}} = .080$ ). The most

central node in this network is setting up and solving linear equations. These preliminary findings are encouraging concerning a better understanding of the relationship between fractions and algebra. They are important to understanding how to facilitate change in schools' math curricula by focusing on specific areas within fractions (e.g., part-whole relations and extending and simplifying).

### 3. Analyzing and Comparing Conceptual Change Models Through KLI Framework

Tommi Kokkonen<sup>1</sup>

<sup>1</sup> University of Turku, Finland

Consensus regarding the nature or mechanisms of conceptual change is lacking, as it has been examined from multiple theoretical perspectives. Therefore, comparing different conceptual change-based teaching approaches is difficult, as different theories may yield different educational implications and ways of assessing them. Here, we apply the Knowledge – Learning – Instruction (KLI) framework to conceptually analyze different conceptual change models. KLI aims at scrutinizing how specific teaching methods are linked to specific learning mechanisms and outcomes and ways of assessing them. With the analysis, we aim to identify potential conceptual change mechanisms that are linked to generalizable teaching principles and identify potential commonalities and contradictions across and within the different models. Our analysis of prominent conceptual change models implies that they provide elaborate descriptions of students' knowledge. Also, some teaching methods (e.g., refutational texts) are provided that are linked to specific types of learning mechanisms (e.g., belief revision). However, less attention is paid to how conceptual change is assessed, which undermines comparing and testing different models. We argue that KLI provides a fruitful framework for analysis conceptual change research and discuss the implications for future research and practice.

## Paper Session 8: Learning and Practice Environments in Higher Education

Chair: Andreas Nehring

14:30 – 16:00, Room 0602

### 1. Raising the Quality of Student Presentations in Higher Education with a Blended Learning Environment

Noell Röhrig<sup>1</sup>

<sup>1</sup> University of Trier, Germany

Presentations are widely used and well-established in and outside academia. We aimed to create an efficient and cost-effective training for students in higher education by including easy-to-implement advice and criteria strongly related to academic achievement. Structurally, the presentation training is a blended learning environment with an online section to acquire knowledge on giving presentations and a 90-minute offline class to practice presentations. The online section includes texts, audio, videos, images, and multiple-choice questions on dealing with presentation anxiety, presentation preparation, and presentation methods. In the offline class, students practice giving presentations and moderating discussions. After these, students receive peer feedback. The current study aims to evaluate the presentation training via a randomized controlled trial. Depending on the group, the student presentations were either assessed before or after the training. For the evaluation, students answered questionnaires and gave online presentations on “learning by conditioning” for 20 minutes. *t*-tests revealed a significantly higher presentation quality ( $d = 1.78$ ) in the intervention group and significantly more knowledge on giving presentations ( $d = 0.71$ ). This knowledge predicted presentation quality ( $\beta = 0.36$ ). Looking at specific aspects of presentation quality, the intervention group performed significantly better regarding structure ( $d = 1.74$ ), slide design ( $d = 0.65$ ), performance ( $d = 0.64$ ), and methods ( $d = 1.06$ ), but not teaching goals, discussions, and comprehension. The training successfully conveys presentation knowledge and is highly effective in raising presentation quality. The high effectiveness and efficiency of the presentation training speaks to its implementation in higher education.

### 2. Student Teachers' Conceptual Understanding on the Loss of Biodiversity in an Online Reading Context

Mirjamaija Mikkila-Erdmann<sup>1</sup>, Mirva Heikkilä<sup>1</sup>, Miira Häkkinen<sup>1</sup>, Anni Vidbäck<sup>1</sup>

<sup>1</sup> University of Turku, Finland

The purpose of this study is to investigate how student teachers construct conceptual understanding when they prepare a primary school science lesson. The student teachers' task was to apply online text sources to write a synthesis on the loss of biodiversity,

which is an important topic in science education. The participants were 74 first semester primary student teachers in a Finnish university in 2023. They participated in a task in an online learning environment, including four relevant texts and six irrelevant texts of which two were fake texts. Half of the participants received refutational texts and half of the participants non-refutational ones. As preliminary findings, only few student teachers had used all four relevant sources, and much irrelevant and fake content was used. The phenomenon and its causes and implications had not been understood from many perspectives. In terms of the coherence of the syntheses, some student teachers had integrated both relevant and fake content, and, as consequence, the syntheses were highly incoherent in terms of content. The role of the refutational text proved out to have an effect: students who had refutational texts available, had better scores. As a conclusion, the findings indicate a need to further develop digital learning environments where student teachers can practice their scientific literacy and multiple text comprehension skills.

### 3. Practice Environment and Deliberate Practice

Victoria Jacobi<sup>1</sup> & Michael Schneider<sup>1</sup>

<sup>1</sup> University of Trier, Germany

Many studies have investigated the impact of deliberate practice on learners' performance levels and found medium-strong relations. In these studies, deliberate practice is typically conceptualized as a form of practice which is the same in all domains and under all circumstances. In the current study, we questioned this view and investigated how the content domain, the presence of an instructor, and the presence of a learning group modulate how learners implement deliberate practice in their life. A convenience sample of 591 musicians and athletes gave self-reports of their practice behavior, context factors, and performance levels in an online questionnaire. We used the new Deliberate Practice Inventory (DPI) with the subscales Goal Setting, Improvement Focus, Adaptation, Feedback, Concentration, Repetition, Instructor, Unpleasant, and Monitoring (Schneider et al., in preparation) to assess how similar learners' practice was to prototypical deliberate practice. Learners with instructors practiced more in line with prototypical deliberate practice overall, received more feedback, and were more willing to endure unpleasant practice tasks than learners without instructors. Learners in teams received more feedback than solo learners. Athletes practiced more in line with prototypical deliberate practice overall and displayed higher levels of concentration and monitoring than musicians did. Overall, the DPI displayed good reliability and allowed for a novel approach to measuring deliberate practice behavior. The results demonstrate the usefulness of the concept of deliberate practice and show that models of practice and expertise acquisition need to account for domain-differences and context factors, like instructors and team

## Paper Session 9: Dealing With Misinformation and the Persistence of Intuitive Conceptions

Chair: Lauren Barth-Cohen

14:30 – 16:00, Room 0670

### 1. A Lateral Reading Training Against Misinformation Based on Cognitive Apprenticeship

Marvin Fendt<sup>1</sup>, Benedikt Artmann<sup>1</sup>, Christian Scheibenzuber<sup>1</sup>, Peter Edelsbrunner<sup>1</sup> & Nicolae Nistor<sup>1</sup>

<sup>1</sup> Ludwig-Maximilians-Universität Munich, Germany

In our information-driven society, readers need to be able to focus their attention on valuable information. Otherwise, they often risk consuming and believing misinformation, which can have undesirable behavioral consequences, such as ignoring and opposing climate change policy measures. Lateral reading is a strategy that can help filter information analytically by not reading the content, but instead checking third-party sources to infer the credibility of a source. Teaching this complex skillset requires an appropriate instructional design like the well-established cognitive apprenticeship. In our preregistered randomized controlled study, N = 344 participants received either cognitive apprenticeship-based lateral reading training or short written instructions on the technique. We found that our lateral reading training, even more than our reading material, helped people discern the credibility of sources and consequently ignore unreliable sources. Furthermore, content knowledge moderated the training effect, indicating that teaching both may further enhance the effectiveness of the intervention. More analytic processing of the information further increased the intervention effects. Future studies can explore the potential for mixing lateral reading training with other methods in a longitudinal study as well as short school curricula on the technique. Addressing participants with a more conspiracist mindset could also be of interest.

### 2. Predictors of Neurofacts and Neuromyth – A Model-Selection Approach

Eric Klopp<sup>1</sup> & Robin Stark<sup>1</sup>

<sup>1</sup> Saarland University, Germany

Neuromyths are misconceptions generated by misunderstanding, misreading, or misquoting scientifically established facts by brain research to create a case for using these facts in educational contexts (OECD, 2002). There are also neurofacts, i.e., valid scientific concepts that can be considered in educational contexts. However, designing interventions to mitigate misconception and foster factual knowledge (neurofacts) requires knowledge about its possible antecedents. The aim of this study is to investigate possible predictors of both neuromyths and neurofacts from the domains of media usage, personality, motivation, and epistemological beliefs using a model-selection approach. Using a sample of 131 students (31 psychology students and 100 teacher education

students), a best subset regression using the AIC as model selection criteria revealed that the participants' sex, consumption of science-related media (e.g., textbooks or peer-reviewed journals), personal justification, and justification by authority were predictors for the endorsement of neurofacts. Predictors for the endorsement of neuromyths, were study type, with psychology students being more likely to reject neuromyths, participants' sex and interest in science. The results show that constructs related to science, in particular some epistemological beliefs and the motivation to engage with science, are vital with respect to neurofacts and neuromyths. However, the results show that both should be treated separately because of different predictors. Thus, when designing interventions, an adaptive approach is advisable depending on the goal, either to foster knowledge about neurofacts or to mitigate neuromyth.

### 3. Intuitive Conceptions as Category Prototypes: Insights From Arithmetic Problem-Posing

Katarina Gvozdic<sup>1</sup>, Lucas Raynal<sup>1</sup>, Stéphanie Naud<sup>1</sup>, Emmanuel Sander<sup>1</sup>

<sup>1</sup> Université de Genève, Switzerland

The current study aimed to test if the influence of intuitive conceptions among adult populations can be explained by the graded structure of mental categories. We propose that intuitive conceptions are prototypical exemplars of a target notion, which should lead to observing typicality effects. Drawing on previous literature highlighting the persistence of intuitive conceptions even among experienced individuals, the study explores how participants generate arithmetic problems congruent and incongruent with intuitive conceptions of arithmetic operations. A total of 501 participants, including bachelor students, high-school teachers and teacher trainers, engaged in two problem-posing tasks: one involving a free production task and the other an explicit constraint to pose incongruent problems. The results revealed that most of the participants produced problems congruent with intuitive conceptions, with only a minority who succeeded in posing incongruent problems despite explicit instructions to do so. These results were systematic among all four arithmetic operations and all the involved populations. The findings align with research on typicality effects and can thus explain both why on the one hand students are biased by the constraints imposed by intuitive conceptions, and on the other hand why adults are challenged when faced with situations incongruent with the intuitive conception. The study thus sheds light on the cognitive mechanisms underlying the persistence of intuitive conceptions and discusses a path for fostering conceptual change.

# Paper Session 10: Fostering Conceptual Change Using Comparing and Contrasting

Chair: Tommi Kokkonen

14:30 – 16:00, Room 0601

## 1. Comparing and Contrasting Promotes Sustainable Understanding of Chemical Bonding

Adrian Zwyssig<sup>1</sup>

<sup>1</sup> ETH Zürich, Switzerland

Is a salt crystal comprised of molecules? 39% of science undergraduates falsely assume so as they overgeneralize the covalent bonding type. Overgeneralization is a major challenge in science education. Typically, students neglect the differences between the three types of chemical bonding, i.e. covalent, ionic, and metallic bonding. This overgeneralization was confirmed by assessing undergraduates' conceptual understanding of chemical bonding before attending lectures at a Swiss university (N = 1946). This assessment revealed the prevalence of various misconceptions such as the overgeneralization of the model of covalent bonding. Thus, the question arises, how can we promote a better understanding of chemical bonding theory? Comparing and contrasting activities have been proven effective for learners to keep the differences between similar concepts in mind (Alfieri et al., 2013). Therefore, I designed teaching materials (23 lessons) containing multiple comparing and contrasting activities, introducing the three types of chemical bonding simultaneously. The materials' effectiveness was evaluated in a pre- and post-test classroom intervention study at Swiss Gymnasiums (N = 326, grade 10). Comparing and contrasting activities fostered students' conceptual understanding more strongly ( $0.60 < d < 1.05$ ) and were better suited to promote conceptual change than the conventional sequential introduction of the different bonding types.

## 2. Supporting Students' Knowledge Integration: Design Characteristics of Critique Artifacts

Katharina M. Bach<sup>1</sup>, Sarah Bichler<sup>1</sup>, Marcia Linn<sup>2</sup>

<sup>1</sup> Ludwig-Maximilians-University (LMU), Germany

<sup>2</sup> University of California, Berkeley, United States

Revising science explanations gives students the opportunity to sort out their own, often intuitive ideas and normative ideas introduced in science class. It is thus a key step in supporting students' efforts to develop a coherent understanding of scientific phenomena. Critiquing peer explanations can help prepare students for revising their own explanations. However, students often uncritically adopt ideas from critique artifacts. In this study, we compared three critique artifact designs: example peer response with intuitive and normative ideas (Partial); example peer response with highlighted intuitive ideas and a prompt that the response needs improvements (Highlight); and two example peer responses featuring contradictory ideas (Contrast). In a Thermodynamics activity, 556

middle school students wrote an initial explanation, were randomly assigned to one of the three critique guidance conditions, and revised their explanation. Students' initial and revised explanations were scored using a knowledge integration rubric that rewarded linking claims and evidence. A linear mixed model with post-hoc tests revealed a statistically significant difference between the Highlight and Partial and Highlight and Contrast conditions, indicating that pointing out intuitive ideas is less effective than providing a mix of intuitive and normative ideas or allowing students to compare and contrast conflicting ideas. The effects were not dependent on students' prior knowledge. These results indicate that opportunities to weigh multiple ideas against each other fosters conceptual understanding. Further, the classroom practice of critically evaluating scientific information is likely to be recognized as important when the classroom mirrors students' everyday experience of encountering contradicting information.

### 3. Comparison of Incorrect and Correct Solution Examples to Stimulate Conceptual Change

Cagla Dikme<sup>1</sup>, Kirsten Brunner<sup>1</sup>, Timo Leuders<sup>1</sup>, Katharina Loibl<sup>1</sup>

<sup>1</sup> University of Education Freiburg, Germany

Research on conceptual change implies that learning can involve dealing with errors and misconceptions, especially when the target concept requires the reconstruction of prior knowledge. The transition from misconception to conceptual understanding can be induced by an instruction with the comparison of incorrect and correct solution examples. To explore the role of the fit between learners' own erroneous solution attempts and the incorrect example solutions given in an instruction, we investigated conceptual change within a composite instructional design called problem solving prior to instruction (PS-I) in a computer-based learning environment. In the PS-I design, the learners generated solutions for a fraction comparison problem in the problem solving phase and received an instruction in the subsequent instruction phase depending on the condition they were randomly assigned to: 1) adaptive condition where learners received an incorrect solution example that resembled their own erroneous solution attempts to compare, 2) contra-adaptive condition where learners received a typical incorrect solution that did not resemble their own erroneous solution attempts to compare, and 3) control condition where they received only the correct solution. Preliminary results support the conceptual change approach to learning by showing significantly better learning outcomes for adaptive comparisons compared to contra-adaptive comparisons; but non-significant results regarding the control condition call for a further investigation of learner profiles to tailor learning to meet individual needs.

# Friday, August 30

09:00 – 10:30

Symposium 5:  
Understanding the Prerequisites for Learning From Hypothesis Testing  
(0601)

- Better Than Control-of-Variable? Confounded Comparisons in Children's Hypothesis Testing
- Conflict Monitoring Ability Develops Across Childhood and Predicts Learning From Hypothesis Testing
- Motivated Information Search: The Impact of Context on Hypothesis Testing

Symposium 6:  
Beyond the Surface: Investigating Conceptual Difficulties in Statistical Graph Interpretation (0670)

- Conceptual Change and Cognitive Processes with Comparing Box Plots
- Students' Conceptual Difficulties When Interpreting Statistical Graphs
- Misinterpretations When Dealing With Statistical Graphs – In Light of Conceptual Change

10:30 – 11:00

Coffee (Foyer)

11:00 – 12:30

Panel Discussion:  
Digital Transformation: Potentials and Challenges (0360, Thierschbau)

12:30 – 13:00

Farewell (0360, Thierschbau)

## Symposium 5: Understanding the Prerequisites for Learning From Hypothesis Testing

Organizer and Chair: Garvin Brod  
Discussant: Beate Sodian

09:00 – 10:30, Room 0601

Testing one's own hypotheses is a key part of many inquiry-based learning approaches, in science education and beyond. Particularly for children, however, it is also a challenge. Ideally, learners select the most informative question or intervention that allows them to distinguish between the different hypotheses they're entertaining. This requires learners to simultaneously consider competing hypotheses and their relationships to the possible outcomes. Additionally, after receiving feedback, learners need to determine whether the observed outcome deviates from their expectations and adjust their next hypothesis accordingly. These comparative processes require cognitive and metacognitive skills, both of which improve considerably in the first decade of life and could be prerequisites for learning from hypothesis testing. Furthermore, the ability for children to effectively test hypotheses is further hindered by ulterior context-dependent goals. The three presentations therefore take a developmental perspective on learning from hypothesis testing and thereby shed light on the prerequisites and contexts that need to be in place for children to learn effectively from hypothesis testing.

### 1. Better than Control-of-Variable? Confounded Comparisons in Children's Hypothesis Testing

Lucas Lörch<sup>1</sup>, Elizabeth Bonawitz<sup>2</sup>, Garvin Brod<sup>1</sup>

<sup>1</sup> DIPF | Leibniz Institute for Research and Information in Education, Germany

<sup>2</sup> Harvard Graduate School of Education, United States

The control-of-variables strategy (CVS) is often considered to be the superior strategy when children learn from hypothesis testing. Accordingly, much effort has been put into finding ways to foster children's CVS skills. However, by simulating Bayesian likelihoods of outcomes from a water displacement task, we show that certain confounded comparisons may support belief revision even better than controlled comparisons. To test this assumption, we conducted an experiment in a virtual learning environment in which children ( $N = 137$ , age range 6- to 9-yrs) predicted which of two balls would displace more water. Balls differed in size and material. We experimentally varied the types of comparisons in this task. In the Size, Material, and Mixed conditions we presented controlled comparisons manipulating either Size, Material, or alternating. In the Confounded Incongruent Condition, we presented confounded comparisons in which the larger ball was made of the lighter material. In line with our hypotheses, children in the Confounded Incongruent Condition revised their beliefs more than children in the other conditions, as indicated by higher transfer test scores. These findings suggest that confounded comparisons may in fact sometimes provide more optimal information for learning than following the CVS. We conclude that the type of comparison that is presented to children constitutes an important contextual factor for learning from hypothesis testing.

## 2. Conflict Monitoring Ability Develops Across Childhood and Predicts Learning From Hypothesis Testing

Elfriede Holstein<sup>1</sup>, Maria Theobald<sup>1</sup>, Leonie Weindorf<sup>1</sup>, Garvin Brod<sup>1</sup>

<sup>1</sup> DIPF | Leibniz Institute for Research and Information in Education, Germany

This study examined whether the developmental trajectory of conflict monitoring improves during childhood, and whether this improvement leads to faster theory revision. A cohort of children aged five to nine ( $N = 177$ ,  $M_{\text{age}} = 7.02$ ) completed a series of computer-based learning tasks focusing on the concept of water displacement, an area prone to misconceptions among children. Each task prompted participants to predict which of two presented objects would displace more water prior to receiving corrective feedback. Findings indicated a developmental improvement in conflict monitoring. With increasing age, children showed (1) longer response times when making an incorrect (vs. correct) prediction and (2) a stronger pupil dilation in response to unexpected compared to expected outcomes. These age-related differences in conflict monitoring were correlated with children's subsequent belief revision. We found that a larger pupil dilation response after unexpected outcomes predicted a higher likelihood of subsequently switching to the correct concept, suggesting that children use their conflict monitoring to revise an incorrect belief. In addition, there was a greater increase in learning across the learning phase with increasing age. All in all, these findings indicate that as children grow, their capacity to monitor conflicts enhances, consequently amplifying the advantages of hypothesis testing for revising theories. The results of this research contribute to our understanding of developmental changes in conflict monitoring and its impact on hypothesis testing in science learning.

## 3. Motivated Information Search: The Impact of Context on Hypothesis Testing

Ohan Hominis<sup>1</sup> & Azzurra Ruggeri<sup>1</sup>

<sup>1</sup> Central European University, Austria

This study explores the influence of social contexts on the efficiency of information search in children (6-14 years), adolescents (15-17 years), and adults. In particular, how contexts can constrain the possible hypotheses individuals entertain as they navigate socially-relevant environments. In both studies, participants were told they were competing in a sporting event. At the end of the event, the participant's team has either won or lost. Participants are then informed that there is evidence of foul-play and are tasked with playing a 20-Questions game to try to find the culprit. Beyond the developmental trajectory in their ability to select the most informative questions, we found that all participants actively biased their search strategies, choosing more or less efficient questions as they accounted for the potential consequences of their information-search behavior. For example, participants were more likely to select the most efficient questions when it was in their team's best interest to find the culprit. Overall, our findings suggest that social contexts play a strong role in modulating the efficiency of information search, and call attention to the impact of motivation on hypothesis testing.

## Symposium 6: Beyond the Surface: Investigating Conceptual Difficulties in Statistical Graph Interpretation

Organizer and Chair: Saskia Schreiter, Wim Van Dooren  
Discussant: Stefan Ufer

09:00 – 10:30, Room 0670

In our data-driven world, data literacy is crucial, particularly in understanding statistical graphs like boxplots, histograms, dotplots, and case-value plots. Yet, students often struggle with their interpretation demonstrating systematic difficulties. This symposium examines recent research on common misinterpretations of statistical graphs, focusing on the underlying conceptual difficulties. With three different methodological approaches, the symposium's contributions adopt a conceptual change perspective to explain and discuss the conceptual difficulties that underlie systematic misinterpretations of common statistical graphs. In the first presentation, Abt et al. present the results of a cluster analysis, considering conceptual change as a source for errors when comparing data sets with boxplots. In the second presentation, Seker & Boels present the results of an eye-tracking study where 50 secondary school students interpreted histograms and case-value plots. Conceptual difficulties underlying students' misinterpretations are discussed. In the third presentation, Heursen et al. present the results of a systematic literature review on misinterpretations of common statistical graphs, namely boxplots, histograms, dotplots, and case-value plots. Conceptual change is used as a theoretical approach to explain many of the misinterpretations reported in research.

### 1. Conceptual Change and Cognitive Processes When Comparing Box Plots

Martin Abt<sup>1</sup>, Timo Leuders<sup>1</sup>, Katharina Loibl<sup>1</sup>, Wim van Dooren<sup>2</sup>, Frank Reinhold<sup>1</sup>

<sup>1</sup> University of Education Freiburg, Germany

<sup>2</sup> KU Leuven, Belgium

One main reason for errors when comparing data sets with boxplots is the counterintuitive meaning of the box area: it is inversely related to the distribution's density and not proportionally related to the represented part of the sample—as in other representations. We conducted a study ( $N = 296$ ) to investigate whether the occurrence of an area bias depends on incomplete conceptual change. Via cluster analysis we identified a first group, who showed no area bias, a second group who systematically answered with area bias, and a third group with intermediate knowledge—answering specific items (i.e., when comparing the salient median led to the correct answer) without area bias. The results are in line with our hypotheses: the first group, in contrast to the second group, fully completed the conceptual change necessary, and the incomplete conceptual change in the third group prevents the area bias only in certain tasks. We therefore consider conceptual change theory appropriate to explain the area bias in comparing data sets with boxplots.

## 2. Students' Conceptual Difficulties When Interpreting Statistical Graphs

Vuslat Seker<sup>1</sup> & Lonneke Boels<sup>1</sup>

<sup>1</sup> Utrecht University of Applied Sciences, Netherlands

This study examines the conceptual challenges that secondary school students face when interpreting histograms and case-value plots, an area in which misinterpretations are common. Despite their statistical training, students often confuse graphical representations such as histograms and case-value plots, leading to fundamental misunderstandings of key statistical concepts such as data and distribution. We conducted an eye-tracking study with 50 students to observe their strategies for interpreting these graphs. The analysis revealed that students often misapplied strategies appropriate for case-value plots to histograms, leading to incorrect conclusions. We observed specific misapplied strategies, such as making all bars in a histogram equal in height to estimate the mean and reading off values from the vertical axis as if they represented the data values, not the frequencies. This misapplication, observed in many items, suggests a significant conceptual gap in understanding statistical graphs. Specifically, the study confirms that students have difficulties with the statistical key concepts data and distribution. The study highlights the need for educational interventions to address the conceptual difficulties underlying these misinterpretations and help educators guide students toward a more accurate understanding of statistical graphs. This will provide a basis for more effective teaching strategies to facilitate conceptual change in statistics education.

## 3. Misinterpretations When Dealing With Statistical Graphs – In Light of Conceptual Change

Ayline Heursen<sup>1</sup>, Vuslat Seker<sup>2</sup>, Markus Vogel<sup>1</sup>, Lonneke Boels<sup>2</sup>, Wim van Dooren<sup>3</sup>, Frank Reinhold<sup>4</sup>, Martin Abt<sup>4</sup>, Saskia Schreiter<sup>5</sup>

<sup>1</sup> University of Education Heidelberg, Germany

<sup>2</sup> Utrecht University of Applied Sciences, Netherlands

<sup>3</sup> KU Leuven, Belgium

<sup>4</sup> University of Education Freiburg, Germany

<sup>5</sup> University of Schwäbisch Gmünd, Germany

Data distributions and their graphical representations are essential in today's data-driven world. However, interpreting these graphs, such as histograms, boxplots, dotplots, and case-value plots, can often lead to misinterpretations. Despite the prevalence of these misinterpretations, there is a limited comprehensive analysis and explanation for their occurrence. This systematic literature review presents initial results aimed at providing an overview of these misinterpretations with an eye for conceptual change. Up to now the analysis revealed key misinterpretations categorized into four overarching themes: "variability-shape confusion", "area-density confusion", "looking at a wrong parameter", and "local/contextual difficulties". Our findings highlight common errors within these categories, such as the misinterpretation of 'more area-higher frequency' in boxplots, and the 'height for mean' misinterpretation in histograms. These insights underscore the potential use for conceptual change theory to effectively address these misinterpretations.

# Panel Discussion: Digital Transformation: Potentials and Challenges

11:00 – 12:30, Room 0360

Moderator: Andreas Obersteiner, Technical University of Munich

Participants:

1. Enkelejda Kasneci, Professor for Human-Centered Technologies for Learning, Technical University of Munich, Germany
2. Stefan Bäuml, School Principal of the Oskar-Maria-Graf-Gymnasium Neufahrn, Germany, Pilot School of "Digital Schools of the Future"
3. Garvin Brod, Keynote Speaker, Frankfurt, Germany
4. Fien Depaepe, Keynote Speaker, Leuven, Belgium
5. Erno Lehtinen, Keynote Speaker, Turku, Finland

The goal of this panel discussion is to reflect on the conference theme (conceptual change in the era of digital transformation) and to discuss it from a broader perspective. Prof. Kasneci, will provide an impulse talk about her research on the use of generative AI in educational contexts and her often-cited commentary paper (Kasneci et al., 2023). Dr. Bäuml, physicist, and principal of a pilot school for digital media, will share his experience and lessons learned with the use of digital media in school practice. The three keynote speakers, Garvin Brod, Fien Depaepe, and Erno Lehtinen, will share their views during the discussion, based on their research presented in the keynote lectures. The discussion will be structured by three guiding questions, followed by an open discussion.

Guiding Questions:

1. What are the opportunities and risks of using modern technologies (e.g., generative AI) in teaching and learning?
2. How can we use modern technologies to specifically support learners' conceptual understanding and conceptual change?
3. How do we need to reconsider educational settings? How will educational settings look like in the future?

Structure:

5 min:	Introduction of the topic and the speakers
15 min:	Impulse Talk by E. Kasneci
15 min:	Impulse Talk by S. Bäuml
5 min:	Questions
30 min:	Discussion of 3 guiding questions (10 min each)
20 min:	Open discussion with the audience

Reading:

Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günnemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeffer, J., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., Stadler, M., Weller, J., Kuhn, J., & Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences*, 103, Article 102274.  
<https://doi.org/10.1016/j.lindif.2023.102274>

# Important Addresses and Phone Numbers

	Address	Phone Number
Taxi		+49 21 610 +49 19 410
Conference venue (Summer School)	Marsstraße 20-22 80335 Munich	
Conference venue (Main conference)	Arcisstraße 21 80333 Munich	
Conference chair	Heinz Nixdorf - Chair of Mathematics Education Prof. Dr. Andreas Obersteiner Marsstraße 20-22 80335 Munich	
Emergencies		
Ambulance and Fire		112
Police		110
Tourist Information Center Munich	Marienplatz 8 80331 Munich	+49 89 233 96500
Medical Doctors		116117

# Acknowledgments

Local Organization:

Technical University of Munich  
TUM School of Social Sciences and Technology  
Heinz Nixdorf-Chair of Mathematics Education  
Prof. Dr. Andreas Obersteiner  
Marsstraße 20-22  
80335 Munich

E-Mail: [sig03-2024.ma@sot.tum.de](mailto:sig03-2024.ma@sot.tum.de)

We appreciate the time and consideration our reviewers took to consider the submissions:

Martin Abt, Katharina M. Bach, Lauren Barth-Cohen, Michel Bélanger, Gertraud Benke, Sarah Bichler, Garvin Brod, Mei-Shiu Chiu, Konstantinos Christou, Fien Depaepe, Michael D'Erchie, Peter Edelsbrunner, Michael Fischer, Salome Flegr, Claire Forsmann, Katarina Gvozdic, Eric Klopp, Natassa Kyriakopoulou, Tommi Kokkonen, Shuting Li, Cecilia Lundholm, Sarah Lundt, Helen Margaritou-Andrianessi, Erik Meij, Michaela A. Meier, Jake McMullen, Terhi Mäntylä, Charlotte Müller, Vincent Natalis, Andreas Nehring, Andreas Obersteiner, Patrice Potvin, Frank Reinhold, Christian Schons, Saskia Schreiter, Irini Skopeliti, Ilona Södervik, Christian Thurn, Stefan Ufer, Xenia Vamvakoussi, Vesta Vančugovienė, Wim Van Dooren, Jo Van Hoof

We thank our session chairs:

Lauren Barth-Cohen, Gertraud Benke, Michael D'Erchie, Michael Fischer, Alexandre Hagan, Tommi Kokkonen, Annika Sophie Krüger, Flore Maricau, Andreas Nehring, Manal Raoui, Thomas Simacek, Wim Van Dooren

We thank the Technical University of Munich for their support.

We thank our sponsors of the conference:



Springer Verlag



Waxmann Verlag

SIG Coordinators:

Natassa Kyriakopoulou, Jake McMullen

JURE Coordinator:

Christian Thurn

## Notes

## Notes

## Notes

## Notes