SIG 3 & 20 Conference Turku Finland

Turun yliopisto
University of Turku

Bridging Conceptual Change and Inquiry: Pathways to meaningful learning

The Joint SIG 3 and 20 Conference on Conceptual Change

Programme & Abstracts

Turku, Finland – 25–27 August 2026

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Tuesday 25 August

Keynote 1

Chair: Marjaana Puurtinen

Room: Calonia 1

Paths to epistemic change through inquiry and explanation

Clark Chinn (Rutgers University)

Abstract:

In this talk I address two interrelated topics of common interest to SIG 3 and SIG 20.

First, I argue that learning to think and reason is a form of conceptual change: epistemic conceptual change. Drawing on the Apt-AIR framework, I treat epistemic growth as the development of causal models of how reliable processes of knowledge formation yield products that meet epistemic aims and ideals. These models are built from concepts, and epistemic conceptual change occurs when those concepts shift fundamentally — in what they pick out and in what they license us to infer. I discuss several major dimensions along which this change occurs, beginning with the development of an interpretive theory of mind.

Second, given that epistemic growth involves conceptual change, I ask how it can be fostered — and in particular whether inquiry-based or direct-instruction approaches are more effectie. Drawing again on Apt-AIR, I argue that epistemic growth requires working out a rich network of knowledge that enables learners bring epistemic concepts to bear on real tasks and situations. Building that network requires constructive or interactive sense-making. But such sense-making can be achieved through methods labelled either as direct instruction or as guided inquiry. I propose a way of analyzing any instruction aimed at epistemic growth, in terms of three questions: What is told to students? What is left to be worked out? And how authoritative is the telling? The analysis shows how guided inquiry and direct instruction are combined within the same learning activities, rather than merely alternated

Parallel Session 1 A: Mathematical Curricula & Numeracy

Chair: Heli Nurminen

Room: Educarium 2

A Comparative Analysis of Finnish Mathematics Curricula (1970–2014)

Sari Yrjänäinen, University of Turku, Finland

This presentation examines the key changes in the Finnish national core curricula for basic education from 1970 to 2014, with a particular focus on mathematics, and the latest two curricula. The aim is to identify the conceptual demands the curricula place on teachers' work and expertise. By comparing content

emphases, the analysis highlights which concepts, teaching methods, and forms of assessment were considered important in different decades. Comparative content analyses using previous curriculum research was used to recognize the goals of mathematics teaching, mathematics key concepts and content emphases in the mathematics curricula in Finland in year 1970, 1984, 1994, 2004 and 2014. Through a comparison of curriculum content, pedagogical expectations, and assessment practices, the analysis highlights how the understanding of mathematics—and the required teacher expertise—shifted over time. Overall the development of Finnish curricula contents and emphases reflects the trends in the development of international curricula, with some exceptions related to details presented.

Spontaneous Focusing On Numerical Order as a unique predictor of early numeracy

Minna Hannula-Sormunen , University of Turku, Finland, Heidi Harju, University of Turku, Finland, Eugenia Cristina Nanu, 1 Decembrie 1918 University of Alba Iulia, Romania

Integration of cardinal and ordinal aspects of number is a crucial conceptual development in early numeracy (Fuson, 1988). Moreover, children's tendency to spontaneously focus and use mathematical aspects in their surroundings supports their mathematical development (McMullen et al., 2019). Here we investigate whether 3.5-4.5 –year old children (N = 144) have individual differences in spontaneous focusing on numerical order (SFONO), and how these individual differences are associated with their early numerical skills and working memory assessed 1.5 years later. Children's SFONO tendency was assessed by three play situations that offered possibilities to spontaneously (i.e. self-initiated way) recognize and produce a numerical order from sets of toys. Apart from SFONO, children's spontaneous focusing on numerosity and numerical ordering, were measured in the beginning of the follow-up, while at the end of it, our measures targeted verbal arithmetic, number sequence elaboration, digit knowledge and working memory. Results show that children had substantial individual differences in their SFON and SFONO tendencies, numerical skills and working memory. Hierarchical regression analyses demonstrate SFONO's unique contribution to verbal arithmetic, number sequence elaboration and digit knowledge but not working memory after controlling for age, SFON and numerical ordering skills. Overall, our findings give further support for SFONO tendency being a relevant, distinguishable component of early numerical development (Harju et al., 2024). Could strong SFONO tendency be regarded as a signal of successful conceptual change in the early number concept from cardinality based understanding to fully integrated cardinal-ordinal number concept, will be discussed in the presentation.

ECE professionals' professional vision on children's mathematical behaviour related to numeracy

Joona Moberg , The University of Turku, Finland, Markus Hähkiöniemi, University of Jyväskylä, Finland, Erno Lehtinen, University of Turku, Finland, Minna Hannula-Sormunen, University of Turku, Department of Teacher Education, Finland

Early childhood is a crucial period for children to develop counting skills and exact number recognition skills. Early childhood education professionals may not recognize children's mathematical behaviour related to counting and numeracy (e.g., engagement in exact number recognition). Professional vision guides what ECE professionals recognize and how they interpret perceived phenomena. However, the professional vision of ECE professionals has rarely been researched. This ongoing study investigates ECE professionals' (N = 100), who participated in an online in-service education course on mathematical play and action environments, observations on ten short video tasks. In these tasks, the professionals watched children engaging in mathematical behaviour during play and teacher-led activities. They then viewed and compared their observations to those made by early mathematical experts. Theory-driven content analysis was used to identify the educators' observations and descriptions of their observations in each task.

Frequency variables are computed. These indicate the number of instances in each task where the ECE professionals recognized the mathematical behaviour highlighted by the experts and the professionals' level of description of their observations. Initial findings show that recognizing and describing children's engagement in mathematical behaviour is challenging for educators, especially when no verbal signs of mathematical behaviour appear. It remains to be seen how ECE professionals' performance in various tasks is associated and whether individual differences in their ability to recognize and describe children's mathematical behaviour impact their performance. Also, it will be investigated whether the professionals can be clustered into groups based on how they describe their observations.

Semantic Recoding vs. Competing Representations: Comparing classroom interventions

Katarina Gvozdic , Université de Genève, Switzerland, Stéphanie Denervaud, HEP Lausanne, Switzerland, Emmanuel Sander, University of Geneva, Switzerland

Students' informal strategies play a central role in arithmetic word problem solving but may also lead to superficial representations and inefficient solutions. This study investigates whether supporting students' representational processes through semantic recoding improves conceptual understanding, and whether engaging students with competing representations (pivot problems) provides additional benefits. A classroom intervention was conducted over seven weeks with 276 2nd and 3rd grade students, assigned to three conditions: business-as-usual, semantic recoding intervention, and competing representations intervention (semantic recoding with pivot problems). Students were assessed at three time points (pre-, intermediate, and post-test) on conceptualization, multiple representation, and problem-solving tasks. Data were analysed using generalized linear mixed-effects models. Results consistently showed that the recoding condition led to significantly greater gains than the control group across all three measures. In contrast, the competing representations condition did not yield additional improvements beyond recoding alone. These findings suggest that conceptual development in word problem solving primarily relies on students' ability to restructure initial representations, rather than on exposure to multiple representations. Instructional approaches should therefore prioritize tasks that induce the need for representational transformation.

Parallel Session 1 B:
Social Science and Political Contexts of Conceptual Change

Chair: Natassa Kyriakopoulou

Room: Educarium 3

A conceptualization of students' understanding of disagreement in controversial issues

Saskia Arbon , University of Amsterdam, Netherlands, Tessa van Schijndel, University of Amsterdam, Netherlands, Jaap Schuitema, University of Amsterdam, Netherlands, Geerte Savenije, University of Amsterdam, Netherlands, Stephan Venmans, University of Amsterdam, Netherlands, Carla Van Boxtel, University of Amsterdam, Netherlands

Adolescents regularly encounter controversial issues (e.g., in classrooms, on social media, and in everyday conversations). Teaching students to engage thoughtfully with such issues is a key objective of education (Council of Europe, 2018). While existing research has focused on students' reasoning and argumentation (e.g., Romine et al., 2017), a more foundational question remains underexplored: do students actually understand what the disagreement in a discussion is about? This study conceptualized and measured students' Understanding of Disagreement in Discussions about Controversial Issues (UDD-C). Method. We developed a measurement instrument consisting of eight versions (four science-related and four history-related). Each version featured a video of two adolescents discussing a controversial issue, followed by questions. The instrument was administered to 659 Dutch secondary school students (Mage = 14.60 years). Each participant was assigned to complete four out of eight versions. This made it possible to compare their UDD-C across issues and domains. Results. Confirmatory factor analyses showed that UDD-C is best described by two conceptual components: (1) identifying values and knowledge embedded in arguments, and (2) identifying consensus and (core) disagreement(s) about values and knowledge used in discussions. Moreover, students responded similarly across issues and domains (i.e., science and history). Conclusion. The results imply that teaching about controversial issues could incorporate generic principles (i.e., about values, knowledge, consensus and disagreement) to support students in making sense of such discussions. This is a promising direction for cross-curricular citizenship education.

Simulating Structural Poverty: Conceptual Change Through a Modified Monopoly Game

Aster Van Mieghem , University of Antwerp, Belgium, Stiene Van Leemput, University of Antwerp, Belgium, Tailah Baert, University of Antwerp, Belgium, Stamatia Savvani, University of Antwerp, Belgium

Game-enhanced learning is well established in educational research, yet its application to teaching about complex social phenomena such as poverty and inequality remains comparatively underexplored. Moreover, little is known about how game-enhanced approaches can support conceptual change processes in the social domain. This study examines whether structured interim reflection during gameplay supports students' conceptual change about opportunity poverty, understood as poverty induced by unequal starting positions, institutional rules, and power relations. Approximately sixty students aged 15–16 in general secondary education are participating in a quasi-experimental study using a modified, age-appropriate version of Development Monopoly (Ansoms & Geenen, 2012). The game externalizes opportunity structures by modeling unequal starting positions and rule-based constraints on agency. Two conditions are compared: gameplay without interruptions and gameplay with structured reflection moments every five minutes, inspired by the Serious Gaming Lemniscate Model (Koops & Hoevenaar, 2012). Conceptual change processes are investigated through a mixed-methods design, including pre- and post-tests assessing students' understanding of opportunity poverty and focus group interviews exploring students' interpretations of the game experience. It is hypothesized that interim reflection facilitates transitions from intuitive game engagement to reflective conceptual reasoning, resulting in more extensive conceptual change processes. This study aims to contribute to conceptual change research for educational purposes and to inform the design of vernacular or other types of games addressing structural inequality.

Patients' Perspectives on Barriers and Facilitators to Teach-Back in Diabetes Prevention in Ethiopia

Hailu Abraha , KU Leuven - University of Leuven, Belgium, Chantal Vanaudenhove, KU LEUVEN, Belgium, Jan Elen, KU Leuven, Belgium, Afework Mulugeta, Mekelle University, Ethiopia, Tesfay Gebregzabher, Mekelle University, Ethiopia, Tim Smits, KU LEUVEN, Belgium

Background: Health literacy is essential for effective diabetes self-care, particularly in low-resource settings where educational disparities limit patient understanding. Teach-back, a communication strategy used to confirm patient comprehension, has shown promise in improving diabetes education but has not been explored in Tigray, Ethiopia.

Objective: This study aimed to explore patients' perspectives on the barriers and facilitators to implementing Teach-back in diabetes education among individuals with type 2 diabetes in selected hospitals in Tigray.

Methods: An exploratory qualitative design was used. Semi-structured interviews were conducted with 29 purposively selected patients with type 2 diabetes from three hospitals. Interviews explored perceived barriers and facilitators to Teach-back, as well as its acceptability and effectiveness in diabetes treatment and prevention education. Interviews were conducted in Tigrigna, audio-recorded, transcribed verbatim, translated into English, and analyzed using thematic analysis supported by NVivo software. An inductive coding approach guided theme development.

Results: Participants perceived Teach-back as acceptable, feasible, and effective in enhancing understanding and engagement in diabetes care. Facilitators included strong community networks, peer-to-peer education, and media-supported health education. However, barriers included low patient health literacy, limited counseling time, resistance from some healthcare providers, and broader systemic constraints. Participants emphasized the need for provider training, culturally appropriate educational materials, peer-led support, increased healthcare resources, and financial investment.

Conclusion: Teach-back appears feasible and contextually appropriate for improving diabetes health literacy in Tigray. Sustainable implementation requires addressing structural and interpersonal barriers through targeted training, adequate resources, and strengthened health system support.

Economics education that supports conceptual understanding of climate polices: using experimental method and a design-based approach.

Cecilia Lundholm , Stockholm University, Sweden, Caroline Ignell, Stockholm University, Sweden, Anna Bendz, University of Gothenburg, Sweden, Andreas Bergh, University of Lund, 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 carbon tax. In an on-going project we develop instruction that supports conceptual understanding of policies (tax, subsidies, bans), using a design-based approach with cycles of comparative interventions in year 9 and 7. The main intervention draws on conceptual change theory of understanding economic phenomena as part of a system, and visualisation activities were designed using concept maps in steps, supporting students' inquiry on how climate policies reduce greenhouse gases. Results from cycle 1 show a significant increase in students' understanding of tax from T1 to T3, and in cycle 2 and 3 from T1 to T2. Further, with the interest to develop policy understanding among students also in year 7, an intervention using cards with words and concept maps was conducted. The alternative intervention in each cycle was designed with teachers in social science, and do not show significant increase of policy understanding. Results from the project are important in the light of lack of studies on instruction that support students' knowledge of economic aspects and solutions on mitigation in climate change education.

Parallel Session 1 C: AI and Inquiry Learning

Chair: Tomi Jaakkola

Room: Educarium 244

Determinants of Human-Level Argumentation Scoring in LLMs in Inquiry Learning Tasks

Yoana Omarchevska , University of Potsdam, Germany, Costanza Rasi, University of Potsdam, Germany

Inquiry learning can support students' scientific reasoning, but many struggle to formulate high-quality hypotheses and arguments, highlighting the need for adaptive feedback. Large language models (LLMs) offer new possibilities for providing such feedback, but their effectiveness depends on their ability to accurately evaluate students' hypotheses and arguments. This simulation study examined how much additional knowledge out-of-the-box LLMs require to approximate human judgments of hypothesis and argumentation quality. Using data from two prior inquiry-learning studies, trained human raters had scored 298 student hypothesis and argumentation pairs. Twelve LLMs were tasked with scoring a subset of 43 pairs using the same coding scheme, and inter-rater reliability with the human ratings was assessed using Krippendorff's α. Few-shot prompting improved reliability compared to zero-shot prompting, but agreement remained below acceptable levels (α up to .30), with substantial variability across scoring categories. Larger models showed improved alignment (α = .34–.58), though difficulties remained for complex sub-categories such as reasoning and evidence. Supervised fine-tuning of a small model on 255 human-coded responses yielded the highest agreement (α = .72), substantially improving performance across all categories. These findings suggest that LLM assessment accuracy benefits the most from concrete examples of student input and their correct assessment values. Establishing a reliable assessment of students' hypothesis and argumentation quality is a necessary step toward using LLMs for valid, adaptive feedback in inquiry-based learning.

How the Structure of AI-Generated Summaries Shapes Learning from Scientific Texts

Peter Seban , Institute of Psychology of the Czech Academy of Sciences, Czech Republic, Kamila Urban, Institute for Research in Social Communication, Slovak Academy of Sciences, Slovakia, Aneta Vebr Pospíšilová, Institute of Psychology of Czech Academy of Sciences, Czech Republic, Veronika Hein, Chales University in Prague, Czech Republic, Radovan Šikl, Institute of Psychology of Czech Academy of Sciences, Czech Republic, Marek Urban, Institute of Psychology of Czech Academy of Sciences, Czech Republic

The rapid adoption of generative AI tools has transformed how students engage with academic texts, with AI-generated summaries increasingly used as substitutes for full-text reading. However, existing research typically treats such summaries as a uniform category, overlooking potential differences in how information is structured and presented. The present study examines whether the format of AI-generated summaries influences learning from scientific texts. In a two-session experimental design (N = 159), university students were randomly assigned to one of four conditions: Full Text, Concise Summary, Bullet-Point Summary, or Narrative Summary. Participants completed an open-ended comprehension test immediately after reading and again after a three-day delay. Subjective measures of perceived difficulty and interest were also assessed. Results showed that summary format significantly influenced learning outcomes. Bullet-point and narrative summaries led to higher comprehension than concise summaries, while the full text did not outperform the best-performing summary formats. All summaries were perceived as less difficult than the

full text, and structured formats (bullet-point, narrative) were associated with higher interest. These findings suggest that AI-generated summaries are not interchangeable and that their structural properties play a critical role in shaping learning outcomes and learners' experience.

Exploring High School Students' Use of ChatGPT Study Mode in Physics

Leo Aleksander Siiman , University of Tartu, Estonia

Estonia's AI Leap 2025 initiative seeks to integrate generative artificial intelligence (GenAI) tools such as ChatGPT into general education to modernise teaching and support AI-assisted learning. This case study examines how high school students perceive ChatGPT's "Study Mode" when learning physics, with a focus on understanding and motivation. Seven 11th-grade students in Estonia used Study Mode to assist with textbook work and homework on collisions and explosions. They then completed an open-ended questionnaire and shared their chatbot interaction transcripts. Qualitative analysis showed that students regarded ChatGPT as a supportive and motivating learning partner. They reported that it helped clarify difficult concepts, provided structured step-by-step guidance, generated practice tasks, and offered feedback on errors. Many students also described increased confidence and engagement, attributing this to personalised, low-pressure interactions and the use of real-world examples. However, transcript analysis revealed that students mainly used ChatGPT for procedural problem-solving rather than for deeper conceptual exploration or inquiry. This suggests a possible gap between students' perceptions of usefulness and the actual depth of their learning. The findings highlight the importance of teacher guidance to ensure GenAI is used as a tool for inquiry and dialogue rather than simply as a solution provider. Future research should examine measurable learning outcomes to determine which forms of GenAI interaction most effectively support learning.

GenAI and Meaningful Studying: The Impact of LLMs

Lari Launonen , University of Helsinki, Finland

This theoretical paper examines how generative artificial intelligence (GenAI), particularly large language models (LLMs), affects the intrinsic meaningfulness of studying. Meaningfulness here is understood both as a subjective experience and as an objectively valuable feature of our lives and various engagements. It is argued that three dimensions of meaningful studying are particularly impacted by GenAI: (1) exercising and developing cognitive capacities, (2) peer relationships, and (3) self-esteem and recognition. First, while inquiry-based learning fosters meaningful engagement through intellectual struggle and growth, GenAI can encourage cognitive offloading and uncritical reliance on outputs, potentially hindering epistemic development. However, LLMs may also enhance meaningful learning by supporting reflection and creative exploration. Second, GenAI reshapes the social dimension of studying, as reliance on AI may reduce peer interaction and weaken belonging. While LLMs can also function as accessible conversational partners that support early-stage idea development, such interactions lack the reciprocity that makes human collaboration uniquely meaningful. Third, heavy reliance on AI may undermine students' self-esteem and sense of recognition, as pride is typically tied to self-authored achievement. While mastering AI tools may become a valued competence deserving recognition, such skills may not provide as strong a basis for self-esteem as the skills required in persistent intellectual inquiry or a deep understanding of a topic that results. The paper concludes that safeguarding the meaningfulness of studying is essential for education aimed at human flourishing in an AI-rich world.

Symposium 1 A
Conceptual Change in Astronomy Education

Chair: Aishwarya Girdhar , LMU, Germany,

Discussant: Stella Vosniadou , Flinders University, Australia

Room: Educarium 2

Abstract

When learning about astronomy concepts, students often rely on naïve ideas that differ from scientific explanations (Plummer & Maynard, 2014; Vosniadou & Brewer, 1992). However, little is known about how students´ intuitive ideas about central topics, such as the reason for seasons or the apparent motion of the Sun develop and how instruction can effectively support conceptual change (Lelliott & Rollnickm, 2010). The contributions to this symposium investigate students' prior intuitive conceptions and their development in astronomy learning. Study 1 examines students' explanations of the Sun's apparent motion through task-based think-aloud interviews with the students, who used 3D materials to articulate their understanding of the Sun's daily path and its seasonal and latitudinal variations. Study 2 looks into how students make meaning of spatial scales in astronomy through engagement with physical 3D models and planetarium simulations, identifying communicative strategies in students' reasoning. Study 3 investigates how the use of immersive technology can support conceptual change about the reason for seasons, considering different levels and types of students' initial intuitive ideas. The studies exemplify novel approaches to understanding and supporting learners` construction and revision of explanations for astronomical phenomena, providing ground for discussion of the different affordances and limitations that external manipulatives and novel technologies may hold in fostering conceptual change.

Student Reasoning About the Sun's Apparent Motion: Why Parallel Rays Matter

Mieke De Cock , KU Leuven - Department of Physics and Astronomy, Belgium, Rebecca Raskin, KU LEUVEN, Belgium, Hans Van Winckel, KU LEUVEN, Belgium, Wim Van Dooren, KU LEUVEN, Belgium

Understanding the Sun's apparent motion remains challenging for many secondary school students, even though they are familiar with basic observations such as sunrise in the east and sunset in the west. To explore the mental models that underlie students' reasoning, we conducted task-based think-aloud interviews with 22 Flemish students (aged 16–18). Students were asked to explain the Sun's daily path, as well as its seasonal and latitudinal variations, using 3D materials to articulate their thinking. Our analysis revealed difficulties clustered around five conceptual areas, with this presentation focusing on sunrays and lines of sight. Only a small number of students recognized that sunrays reaching Earth can be treated as parallel due to the large Earth–Sun distance. Most drew or reasoned with diverging or converging rays or angled lines of sight, which led to incorrect explanations of culmination height or sunrise and sunset directions. Several students treated lines of sight and sunrays as conceptually distinct, despite their geometric equivalence. These findings highlight that students often rely on implicit assumptions that conflict with the scientific model. Making such assumptions explicit may be essential for supporting coherent mental models of the Sun's apparent motion. This research is funded by the Science Foundation Flanders (FWO) under contract number G037824N.

The Scale of it all: Students struggle to understand of the size of the Solar System

Urban Eriksson , Dept of physics and astronomy, Uppsala University, Sweden, Christopher Robin Samuelsson, Uppsala University, Sweden, Jenny Hellgren, Umeå University, Sweden

Understanding spatial and temporal scales far beyond everyday experience is a major challenge in space science education. This study investigates how students make meaning of solar system scales and how embodied engagement with 3D models and planetarium simulations supports this process. Using a mixed-methods design grounded in social semiotics and embodied cognition, data are collected through interviews, questionnaires, and written responses. Preliminary findings show that learners rely on communicative strategies such as metaphors, analogies, anchoring, and relational reasoning when communicating large and small scales. These insights will inform the development of educational materials aimed at improving scale reasoning and communication.

The Role of Virtual Reality in Conceptual Change in Learning about Reason for Seasons

Zoya Kozlova , Ludwig-Maximilians-Universität (LMU), Croatia, Aishwarya Girdhar, LMU, Germany, Christoph Hoyer, Ludwig-Maximilians-Universität (LMU), Germany, Sarah Bichler, Ludwig-Maximilians-Universität (LMU), Germany, Jörg-Henrik Heine, Universität der Bundeswehr München, Germany, Jochen Kuhn, Ludwig-Maximilians-Universität (LMU), Germany, Sarah Hofer, Ludwig-Maximilians-Universität (LMU), Germany

Students' knowledge structures can simultaneously include scientifically correct conceptions and naïve ideas, resulting in heterogeneous conceptual understanding. Since different types of conceptions may require different instructional approaches, learning environments that support conceptual change are of particular interest. Immersive virtual reality (iVR) offers affordances such as embodiment and a strong sense of presence that may facilitate conceptual learning and the refutation of misconceptions. This study investigated how technological affordances influence two aspects of conceptual learning about seasonal change: the refutation of the misconception that seasons are caused by changes in the Earth–Sun distance and the development of correct understanding that seasons result from Earth's axial tilt. A sample of 169 secondary school students completed a learning unit in one of three conditions: iVR, a 360° learning environment, or a desktop condition. Results revealed no significant differences in overall learning outcomes between conditions. However, prior knowledge consistently predicted post-test performance. Exploratory analyses indicated that students holding the distance misconception showed stronger misconception reduction in the iVR condition compared to the other learning environments. Although iVR produced higher levels of embodiment and sense of presence, these variables did not mediate learning outcomes. The findings suggest that immersive environments may not universally enhance learning performance but may influence how prior knowledge shapes conceptual change.

Symposium 1 B: Engaging with Others' Information in Formal and Informal Settings: The Roles of Content and Context

Chair: Kalypso Iordanou , University of Central Lancashire, Cyprus,

Discussant: Iris Tabak , Ben-Gurion University of the Negev, Israel

Room: Educarium 3

Abstract

Engaging with others' information can enable and accelerate learning, while also exposing us to perspectives we might not develop alone—sometimes challenging what we think we know or even constraining how openly we process what we encounter. In both formal and informal settings, individuals judge how far they can rely on such information as a meaningful source of knowledge, and these judgements are shaped by both content and context. This symposium brings together diverse approaches to understanding how people engage with others' information. The contributions span different content domains (scientific, political and historical topics) and contexts (learning in schools and museums, and opinion formation on social media). They employ a range of methods, including content analyses, experimental designs, survey-based regression modelling, and visual journeys based on eye-tracking data. In school settings, the symposium examines how a communicator's profession and mode of error correction shape pupils' evaluations of transparency and trustworthiness, highlighting the value of an open error culture. In museum settings, it explores how young adults' epistemic aims, gaze patterns and historical interpretations combine into distinct engagement profiles. Within social media, one contribution reveals a dual-process interplay between emotion-driven and evidence-based trust in climate-change posts, influencing both online and offline behavioural intentions, while another shows how platform architecture—comment versus threaded structures—can foster adversarial amplification rather than productive deliberation. Together, the contributions illuminate how content and context in formal and informal contexts shape trust, reasoning and behavioural intentions.

When Teachers or Scientists Admit Mistakes: Pupils' Evaluations of Transparency and Trustworthiness

Dorothe Kienhues , University of Münster, Germany, Patricia van Rüth, University of Münster, Germany

This study focuses on learning from others and the unintentional errors that can occasionally arise during knowledge communication. Using a 2 × 2 between-subjects design, it examines how a person's profession and the way errors are communicated influence pupils' evaluations of the communicator's transparency and trustworthiness. To this end, 167 pupils (age: M = 17.07 years; SD = 0.90) first read a short vignette about a communicative situation concerning a controversial vaccine. This situation was varied with regard to the communicator's profession (biology teacher vs biologist) and whether the error was corrected by the communicator themselves or by another person (self-correction vs correction by others). Participants then rated the communicator's transparency and trustworthiness. The results show, among other things, that participants rated individuals who corrected their own errors independently significantly higher on the dimensions of disclosure, integrity, and benevolence, while assessments of expertise remained largely unaffected.The communicator's profession had no significant main effect. However, interaction effects between profession and error communication emerged for the dimensions of disclosure and benevolence: ratings were most positive when a teacher corrected themselves. The findings encourage an open error culture both in schools and in science communication.

Learning from, or yearning for the past? How young adults engage with historical milieus

Marjaana Puurtinen , University of Turku, Finland, Jan Löfström, University of Turku, Finland

This study conceptualizes history museums as environments of both learning and "yearning," where cognitive and affective approaches to the past intertwine. The aim of this study is to identify profiles of young adults' engagement with the past by examining the combination of participants' epistemic aims, visual inspection patterns, and historical interpretation in a museum context. The case-study data were collected in a museumized residential block representing early 20th-century living conditions. Participants (N = 12) inspected two rooms briefly, while mobile eye-tracking glasses were used to record gaze data. These data were transformed into so-called visual journeys that capture the sequence of attended objects. The participants also wrote tempting advertisements about the interiors for a school visit based on their observations. A data-driven content analysis of the advertisements focused on descriptive expressions and ways of encountering the past. Finally, stimulated interviews that drew on participants' written responses and gaze recordings were analyzed to identify participants' epistemic aims. Participant profiles were then constructed by integrating findings across data sources. Preliminary findings indicate variation in how participants observe and interpret the past. The study advances understanding of situated historical interpretation in museum settings and introduces a simple qualitative tool, visual journeys, for analyzing mobile eye-tracking data.

Trust and Intent to Act on Climate Change: The Role of Emotions and Sense of Responsibility

Eleni Kyza , Cyprus University of Technology, Cyprus, Christiana Varda, UCLan Cyprus, Cyprus

Encouraging the public to take personal action to mitigate climate change can be challenging, because its impact seems distant. Research suggests that climate-related emotions and perceived personal responsibility support engagement with climate issues, but it is unclear how these connect with trustworthiness assessments of information on social media. This study reports on findings from a representative sample (n=491), presented with a social media post, presenting information by a scientist regarding the impact of livestock on carbon emissions, and advocating the reduction of meat consumption. Demographic (age, gender, vegetarian status) and psychological (climate-related emotions) data were collected and analyzed against ratings of post trustworthiness using regression models, while a Mann-Whitney U test examined differences in post trustworthiness and the epistemic nature of the justifications. Findings indicate that trustworthiness assessments were influenced by climate-related emotions (specifically, anxiety, optimism, and guilt), and sense of responsibility for climate change. Emotional reactions and greater sense of responsibility also positively influenced the intention to reduce meat consumption. Higher trustworthiness ratings were associated with epistemic justifications. These findings point to a dual process approach to trust on social media, suggesting the existence of both heuristic (emotion-driven) trust and epistemic (evidence-based) trust. Social media posts that elicit emotions and responsibility for climate change can be perceived as more trustworthy, and influence subsequent actions both online (via follow-up epistemic actions), and offline (via intended behavioral change).

From Deliberation to Amplification: How Social Media Structure Shapes Online Discourse

Kalypso Iordanou , University of Central Lancashire, Cyprus, Vasiliki Christodoulou, UCLan Cyprus, Cyprus

This paper examines how the architecture of social media discussion—comment-structures versus threaded-structures—affects the content and quality of engagement with others' views in immigration debates. Drawing on 904 idea units from two datasets within a single Reddit r/ChangeMyView discussion, we compared direct replies to the original post (Dataset 1; comment-structure) with nested exchanges beneath the most-upvoted comment (Dataset 2; threaded-structure), using thematic analysis and manual reasoning coding. The comment-structure produced thematically diverse discourse, whereas the threaded-structure yielded significantly more conspiratorial statements, pseudo-scientific racism, and a shift from emotional to pseudo-analytical claims. These results suggest that social media discussions, where the norms of dialogic argumentation are absent, might restrict rather than broaden reasoning on a topic, especially in closed threaded-structures. Closed social media discussions lacking strong counter-argumentative voices could become fertile ground for adversarial amplification rather than fruitful deliberation.

Parallel Session 2 A: Teachers' Conceptions

Chair: Ilona Södervik

Room: Educarium 2

Are teachers' learning assignment design skills related to student systems thinking skills?

Heli Aomets , Tallinn University, Estonia, Grete Arro, Tallinn University, Estonia

Teachers were asked to design a learning task. The learning tasks were evaluated based on six criteria that were based on conceptual change (Vosniadou, 2013), ICAP framework (Chi & Wylie, 2014) and productive failure (Kapur, 2016) that resulted in a skillfulness score. Out of the 35 teachers in the study, 15 had their students (n=234) data gathered by the time of these results being written. Students were tested with the authors' unpublished complex system properties identification test of which identification results of the property "structure enables and disables functions" are analysed. They were also assessed with a cognitive flexibility test which is able to assess conceptual development from the Vygotskian perspective. Generalized linear mixed-effects models were used to account for the hierarchical data structure. Teachers' skillfulness did not relate to their students' ability to identify the system property, however a marginal trend was indicated between teacher skillfulness and student flexibility. This may refer to that the depth of learning tasks that happen within the classroom shape students' thinking more broadly. More research is required to make more certain claims.

Validated tool to study conceptual change in university teachers' pedagogical understanding

Neea Heinonen , University of Eastern Finland, Finland, Vilhelmiina Harju, University of Helsinki, Finland, Veera Kallunki, University of Helsinki, Finland, Päivi Kinnunen, University of Helsinki, Finland, Åsa Mickwitz, University of Helsinki, Finland, Ilona Södervik, University of Helsinki, Finland

University teachers' pedagogical conceptual understanding plays a crucial role in shaping their teaching practices and professional development. Unlike schoolteachers, university teachers often engage in pedagogical training on a voluntary basis and bring diverse disciplinary backgrounds, and prior conceptions to their teaching. This heterogeneity makes it crucial to understand which aspects of teachers' conceptions are more susceptible to change and how they relate to the development of pedagogical expertise. This study presents a validated instrument designed to measure multiple dimensions of university teachers' pedagogical conceptions. The instrument includes four subscales: beliefs that learning is a constructive activity (CON), the role of pedagogical theory (PEDA), teaching as an innate ability (BETE), and teaching as knowledge transmission (TRAN). Data were collected from 238 university teachers who had applied for pedagogical training at the University of Helsinki, using an online questionnaire. Confirmatory factor analysis supported a four-factor structure. Analyses revealed that teaching experience was associated with differences in the PEDA and TRAN dimensions, while CON and BETE remained more stable. Less experienced teachers reported higher scores in knowledge transmission, whereas teachers with a more pedagogical background emphasized the importance of theory in supporting learning. The findings highlight the value of using validated instruments to investigate conceptual change among university teachers, offering a tool suitable for cross-sectional, longitudinal, and intervention studies. This instrument enables systematic exploration of how pedagogical training and reflective practices shape teachers' conceptions

over time, providing insights into the design and evaluation of higher education pedagogical development initiatives.

Factors related to teachers' knowledge restructuring during an online PD course

Joona Moberg , The University of Turku, Finland, Markus Hähkiöniemi, University of Jyväskylä, Finland, Minna Hannula-Sormunen, University of Turku, Finland, Pauliina Salonen, University of Turku, Department of Teacher Education, Finland, Els Boshuizen, Open Universiteit Nederland, Netherlands, Erno Lehtinen, University of Turku, Finland

It has been suggested that teachers with extensive experience and accumulated high-quality knowledge may have formed “teaching scripts” which allow them to scan classrooms effectively and perceive, interpret and react fast in different situations. Experience and reasoning through cases and past experiences may lead to script development. However, the specific mechanisms that catalyse knowledge restructuring into scripts remain poorly understood. We investigated whether factors believed to be linked with knowledge restructuring could be identified in responses from 182 primary school teachers to 33 assignments and two survey questions during an online professional development course on flexible mathematical thinking. Based on earlier script and conceptual change research, a hypothetical model was built to explain how factors potentially related to knowledge restructuring may be associated with teachers’ inclination to change their teaching. The model also aimed to explain how changes in teachers’ inclination to alter their teaching during the course might be related to their reports of having altered their teaching by the course’s end. Structural equation modelling revealed that encountering new knowledge, relating it to personal experiences, beliefs, or practices, and experiencing positive emotions were associated with teachers’ reported willingness to change their teaching during the course. Willingness to change was also positively linked to teachers’ reports that the course had impacted their teaching by the course’s end. Furthermore, teachers' responses indicated that providing them with novel knowledge, coupled with reflection and practical teaching assignments, could support knowledge restructuring. These findings offer theoretical and practical means to support teachers' professional development.

Supporting Pre-Service Teachers’ Systems Thinking in Science Education

Merike Kesler , University of Helsinki, Finland, Yan Wang, Shenzhen University, China, Anni Loukomies, University of Helsinki, Finland

Concept learning is central in science education because concepts help explain and interpret observations of real-world phenomena. Connecting scientific concepts with everyday phenomena requires teachers to understand how concepts relate to broader systems and processes. These abilities are closely linked to systems thinking skills, which enable individuals to recognize relationships within complex phenomena and connect observations with scientific explanations. This study explores how pre-service teachers’ systems thinking can be examined and supported in science teacher education. Drawing on the coherent science instruction framework and the predisciplinary phenomenological approach, a tool called the Phenomena Explorer was developed. Based on this tool, a survey was designed in which participants analyzed a photograph of a real-world environment by identifying observable phenomena, related measurement units, and possible inquiry questions for pupils. A pilot study was conducted with 13 pre-service teachers at Shenzhen University in October 2025. Participants identified between three and ten phenomena in the photograph. Most participants were able to connect phenomena with relevant measurement units, but only few formulated inquiry questions clearly linked to observable phenomena and experimental investigation. The results suggest that while pre-service teachers

can identify phenomena in their environment, they may have difficulty connecting these observations to inquiry-based investigations and conceptual learning. The findings highlight the need for instructional tools that support the development of systems thinking in science teacher education.

Parallel Session 2 B: Subject-Specific Learning

Chair: Jo Van Hoof

Room: Educarium 3

Measuring components of reading development in Finnish: evidence from the MUREA project

Raymond Bertram , Centre of Learning and Research, University of Turku

Although Finland has long excelled in reading, recent OECD PISA results show a continued decline in students' reading proficiency since 2006. The Multilingual Reading Assessment (MUREA) project develops tools to assess component skills of reading fluency and comprehension and tracks students from Grades 1–9, while examining the roles of gender and home language. Its goal is to provide research-based solutions to strengthen Finnish pupils' reading abilities. This presentation outlines the development of a vocabulary and morphology assessment test. The vocabulary test was created through three lexical decision experiments with 27,000 students in Grades 3–9 using the ViLLE educational platform used by 70% of Finnish schools. It includes low- to medium-frequency words, with item numbers reduced from 102 to 41 using item response theory (IRT). The morphology test, designed for Grades 2–4, assesses morphosyntactic and derivational knowledge through multiple-choice tasks with 9,000 pupils, again with IRT analysis guiding item selection. Both tools show high internal consistency and high correlations with other tests and self-ratings. Vocabulary results indicate steady growth from Grades 3 to 9, alongside an emerging gender gap: girls demonstrate larger vocabularies and faster lexical retrieval. Besides, pupils from Finnish-only homes outperformed those from bilingual Finnish homes, who in turn outperformed those from non-Finnish homes. Similar patterns appear in morphology. Moreover, both vocabulary and morphology strongly correlate with reading comprehension. These findings highlight the importance of robust assessment tools and the role of background factors in reading development, underscoring the need for targeted instructional support

Developmental Differences in Sensitivity to Statistical Structure in a Shallow Writing System

Tomi Rautaoja , University of Turku, Finland, Noam Siegelman, The Hebrew University of Jerusalem, Israel, Tuomo Häikiö, University of Turku, Finland, Santeri Holopainen, University of Turku, Finland, Petra Enges, University of Turku, Finland, Jay Rueckl, University of Connecticut, United States, Ken Pugh, Yale University, United States, Pekka Räsänen, Helsinki University Hospital, Finland, Rosa Salmela, University of Turku, Finland, Raymond Bertram, Centre of Learning and Research, University of Turku

Statistical learning has been proposed as a key mechanism underlying reading development and contributing to individual differences in reading outcomes. Although this view has gained substantial

attention, empirical support remains inconsistent, particularly in orthographically shallow languages such as Finnish, where systematic letter–sound correspondences may reduce the need for statistical learning. The present study examines Finnish students' orthotactic sensitivity, a form of statistical learning reflecting knowledge of permissible letter patterns, and its association with vocabulary development.

A lexical decision task was administered to assess students' sensitivity to Finnish orthotactic regularities and its relation to vocabulary skills across grade levels. The sample consisted of 876 students from Grades 3, 4, and 7. Results revealed a clear developmental progression: older students demonstrated stronger orthotactic sensitivity than younger students. Moreover, substantial within-grade variation was observed. Students with higher vocabulary proficiency showed greater orthotactic sensitivity, indicating that statistical learning mechanisms contribute meaningfully to individual differences in reading development. These findings support the hypothesis that statistical learning and reading development are interconnected. Crucially, the observed relationship emerged in a shallow orthography, challenging the assumption that statistical regularities primarily aid reading in deep orthographies with less transparent phonology–orthography mappings. As such, the study carries practical implications for literacy instruction in shallow orthographies. Approaches fostering greater sensitivity to orthographic patterns may support reading development even in languages with highly transparent writing systems.

Lay Evaluation of Science-related Information: Influence by Evidence in Personal Anecdotes

Toshio Mochizuki , Waseda University, Japan, Clark Chinn, Rutgers University, United States, Etsuji Yamaguchi, Kobe University, Japan, Hiroki Oura, Tokyo University of Science, Japan

As science-related information circulates on the web and social media, citizens have to explore and integrate conflicting claims ranging from personal anecdotes to rigorous research to make their daily decisions. Although personal anecdotes can trigger bias, it remains unclear when anecdotal evidence could inevitably influence individuals in guiding causal decision-making, particularly when scientific findings contradict them. Grounded in the Grasp of Evidence framework (Duncan et al., 2018), this study examined how evidence in anecdotes impacts reasoning under conflicting information. A total of 172 Japanese undergraduates were randomly assigned to one of three conditions and read three topic sets, each pairing (1) a personal supplement anecdote posted on a social media with (2) a social-media-style summary of a randomized controlled trial showing no significant differences between the supplement and the placebo groups. Anecdotal evidential strength varied by conditions: temporal proximal (immediate onset), temporal distal (delayed onset after continued use), or informal single-subject design (effects appear, disappear after stopping, and reappear after resuming). After each set, participants rated the accuracy of the anecdote's symptoms, causal attribution, and generalizability. The results showed that accuracy ratings did not differ by conditions across the topics; however, causal attribution and generalizability were higher in the informal single-subject design condition than in the temporal distal condition, and the temporal proximal condition sometimes produced similarly elevated judgments as the informal single-subject design condition did. These results suggest that causal cues in anecdotes can lead laypeople to disregard contradictory systematic scientific information, underscoring a key target for scientific information literacy education.

Eye on Visuocognitive Processing in History: Placing History on the Expertise Research Map

Marjaana Puurtinen , University of Turku, Finland, Hans Gruber, University of Regensburg, Germany

In this presentation, we introduce a theoretical framework on expert visuocognitive processing in history. We aim to consolidate fragmented research and position history as a vital yet underexplored domain within expertise studies. We argue that history is a particularly compelling expertise domain due to its ill-defined nature, involving complex problems with no singular correct answers. In addition, the shift from text-centered historical sources to visual and multimodal materials—such as images, audiovisual media, and digital artifacts—allows enriching the study of expertise in history with theoretical and methodological tools developed in visual expertise and scene perception research. Our framework conceptualizes expert visuocognitive processing through three nested layers: (1) historians' cognitive structures; (2) historians' cognitive processes—the heuristics and strategies used in source analysis; and (3) historians' visuocognitive processes—how historians engage with visual sources. After a review of relevant empirical literature, we identify critical research gaps, such as the need for longitudinal studies, deeper analysis of cognitive and visuocognitive processes, and integration of empirical data beyond self-report measures. This framework invites interdisciplinary collaboration to enhance understanding of historical expertise and to equip citizens with skills to critically engage with complex visual representations of the past.

Parallel Session 2 C: Embodied Learning and Physics

Chair: Koen Veermans

Room: Educarium 244

Designing Embodied Learning Activities to Transform Intuitive Knowledge and Conceptions

Ipek Paksoy , ETH Zurich, Switzerland, Martina Rau, ETH Zurich, Switzerland

Embodied learning emphasizes that our sensory interactions and bodily actions are integral to learning processes and conceptual understanding. Yet, implicit connections between bodily actions and concepts may fail to address students' alternative conceptions, which emerge from intuitive knowledge developed through interactions with the physical world. This study investigates the effectiveness of concept-experience alignment and of prompts aiming to make this connection more explicit for students in hands-on physics experimentation. Targeting students' intuitive conceptions about force and motion, we conducted a randomized experiment. University students were assigned to three conditions: Control (unaligned bodily action), Implicit Alignment (congruent bodily action), and Explicit Alignment (congruent action and verbal prompts making the alignment salient). Students in all conditions conducted guided-inquiry physics experiments following an instructional handout. Quantitative and qualitative analyses of student test responses revealed that the embodied learning intervention caused conceptual shifts, especially when the alignment between the bodily actions and the targeted physics concepts was explicit. The analysis of student drawings demonstrated a dramatic reduction in alternative conceptions, notably regarding the "motion implies force" conception. These findings advance embodied learning theory by demonstrating that aligned physical interaction alone may not suffice for conceptual change. Therefore, to successfully transform students' intuitive understandings, instructional designs should explicitly scaffold the cognitive mapping between their bodily experiences and the target concepts.

Effects of different parameters in fluid mechanics tasks on the activation of conceptions

Daša Červeňová , Faculty Of Mathematics, Physics And Informatics, Comenius University, Slovakia, Peter Demkanin, Comenius University Bratislava, Slovakia, François Thibault, Université du Québec à Montréal (UQAM), Canada

This study investigates how variations in different task parameters influence the activation of pupils' conceptions about fluid flow. Tasks were developed using the Gorilla platform and administered to 56 upper-secondary pupils. Pupils were asked to choose between two alternative situations, while accuracy and reaction times were recorded. Responses were analysed using a generalised linear mixed model with a binomial link function. The results revealed a significant interaction between differences in water levels and hole positions in alternative situations. As the difference in water levels increased, predicted accuracy improved and converged across conditions, which indicates a shift towards scientifically accurate reasoning.

Inquiry Learning for Conceptual Change – The Fallacy of Authenticity

Tommi Kokkonen , University of Turku, Finland

Authenticity is a key concept, for example, when justifying inquiry-based approaches in science education. Authenticity can be understood both as the goal of teaching (i.e., learners are conveyed an accurate picture of science and its contents) and as a means (i.e., teaching mirrors scientific content or processes). When authenticity is understood as a means, inquiry-based approaches are justified, for example, by viewing the learner's knowledge and knowledge-formation processes as analogous to scientific knowledge and scientific knowledge-formation processes. In this theoretical presentation, I explore these analogies from philosophical and learning theoretical perspectives. I will argue that these analogies are not valid because scientific inquiry and knowledge are socially constructed and cannot be reduced to individual's knowledge or learning processes. When examining individual learning, the key question is what kinds of learning processes teaching methods activate and how these support learning. I therefore ask whether authenticity is a meaningful justification for pedagogical decisions, as it links teaching methods to external factors—namely, how well teaching aligns with the presumed characteristics of science—rather than how these characteristics support learning. Finally, I consider the practical and theoretical implications of rejecting authenticity as a justification for pedagogical solutions.

Mathematical theory coordinating conceptual change of photon concept in quantum theory of light

Aku Pajula , University of Helsinki, Finland

This study investigates how, in the learning of abstract concepts in physics, mathematical structures coordinate conceptualization and the formation of their meaning. In that, as a learning theoretical framework, I use diSessa's Coordination Class Theory (CCT). The CCT is adapted to examine the role of mathematics in understanding the concept of the photon within the quantum theory of light, where photon is treated as a mathematically constituted abstract concept, more specifically a quantum state (i.e Fock state), thus avoiding the well-known and documented problems that arise when photon is conceived as an entity-like object. This way the meaning of the concept of the photon arises through its coordination with mathematical formalism in experimental contexts. The study was conducted in an introductory quantum physics course for pre-service physics teachers (N= 26), emphasizing a quantum optics approach. Data consisted of pre- and post-intervention multiple-choice questionnaires probing students' way of using natural-language about photons, alongside with rubric analysis of course assignments requiring students to

describe quantum-state evolution using Dirac's bra-ket notation. These assignments followed the principles of the epistemic game of mapping meaning to mathematics. The analysis reveals a positive correlation between students' mastery of mathematical structures and shifts in their conceptualization of the photon from an entity-like object toward a mathematically grounded quantum-state perspective. The results suggest that learning mathematical structures plays a central role in coordinating abstract concepts in quantum physics and supports conceptual change when transitioning from naïve classical physics-based views to advanced views in agreement with quantum physics.

Wednesday 26 August

Symposium 2 A: Rethinking Beliefs about Learning and Teaching: Conceptual Change across Teacher Education

Chair: Irini Skopeliti , National & Kapodistrian University of Athens, Greece

Discussant: Anastasia/Natassa Kyriakopoulou , National & Kapodistrian University of Athens, Greece

Room: Educarium 3

Abstract

Across contexts of teacher education and professional development, a challenge concerns the transformation of teachers' beliefs about learning and teaching. The contributions to this symposium converge on the view that such beliefs form complex systems shaped by prior experiences, which may be internally inconsistent and undergo gradual reorganization. Drawing on perspectives from conceptual change and research on teacher learning, the studies examine how teachers' and pre-service teachers' beliefs develop, how conflicting ideas coexist within broader belief systems, and under what conditions more coherent understandings emerge. The contributions address this issue from complementary angles, focusing on the coexistence and consequences of opposing beliefs, the role of instructional interventions in promoting belief reorganization, the developmental progression of implicit conceptions of learning, and the potential of inquiry into practice to foster changes in pedagogical and epistemological thinking. Across studies, participants frequently endorse both constructivist and transmissive conceptions, indicating that change involves gradual restructuring rather than replacement. Differences in coherence are reflected in participants' approaches to learning, as well as in pedagogical reasoning and instructional practices, suggesting that belief systems shape both learning and teaching. The findings point to the limits of conventional instructional and professional development approaches. Short interventions appear insufficient to reorganize belief systems, whereas approaches that promote sustained engagement—such as refutational texts, reflection, and inquiry into practice—show potential to support more integrated understandings. Overall, the symposium advances a view of teacher learning as a process of conceptual and epistemic reorganization rather than the simple adoption of new practices.

Taking a conceptual change approach in the studies of teachers' beliefs: The case of SRL

Stella Vosniadou , Flinders University, Australia

We argue that the investigation of teachers' beliefs from a conceptual change perspective can provide a better understanding of the nature of these beliefs and their relations with teachers' practices in general and with respect to beliefs about the self-regulation of learning (SRL) in particular. A series of studies will be presented which developed and validated a Beliefs about Learning and Teaching (BALT) questionnaire and used structural equation modelling to investigate relations amongst beliefs and their effects on preservice teachers' study strategies and teaching practices.The results confirmed the co-existence of opposing beliefs in the preservice teachers' belief systems and demonstrated that the presence of beliefs inconsistent with SRL can inhibit preservice teachers' use of sophisticated learning strategies, can interfere with their school performance and can influence their teaching practices. The findings demonstrate the gains of adopting a conceptual change point of view in the study of teachers' belief systems and the importance of these belief systems becoming the focus of further attention in research and in the education and professional development of preservice and practicing teachers.

Promoting Conceptual Change in Pre-Service Teachers' Beliefs About Self-Regulated Learning

Irini Skopeliti , National & Kapodistrian University of Athens, Greece, Anastasia/Natassa Kyriakopoulou, National & Kapodistrian University of Athens, Greece

Pre-service teachers enter teacher education programs with well-established beliefs about learning and teaching that are largely shaped by their prior school experiences. These beliefs often reflect teacher-centered views and may conflict with contemporary perspectives that emphasize self-regulated learning (SRL). From a conceptual change perspective, such beliefs form part of broader belief systems in which intuitive and scientific ideas may coexist. Supporting the reorganization of these belief systems therefore requires instructional interventions that explicitly address prior conceptions and facilitate the understanding of alternative perspectives. The present study investigated whether instructional texts designed to induce conceptual change could influence pre-service teachers' beliefs about SRL. A total of 161 pre-service teachers completed the Beliefs About Learning and Teaching (BALT) questionnaire before and after reading one of four texts about SRL: explanatory or refutational text, with or without instructional analogy. Results showed overall improvements in beliefs consistent with SRL, particularly in relation to transmissive conceptions of teaching. Importantly, the combination of refutational structure and instructional analogy produced the largest reduction in the coexistence of conflicting beliefs. These findings suggest that combining refutational structures with instructional analogies may support the reorganization of pre-service teachers' belief systems, reducing conflicting beliefs and promoting more coherent perspectives consistent with self-regulated learning.

How young adults' ideas about principles of learning develop during a teacher education programme

Erik Meij , Windesheim University of Applied Sciences, Netherlands

Previous research indicates that teachers at all stages of their careers possess prior knowledge and beliefs concerning basic principles of learning. This study examined the development of these principles during a teacher education programme. The question is whether such development can be described in terms of conceptual change; from "naïve knowledge" of learning principles to more consistent frameworks over the course of a teacher education trajectory. Participants (N = 49) comprised two groups of secondary school students—those who enrolled in a teacher education programme and those who explicitly did not—and a group of final-year teacher education students assessed before and after an eight-week intervision intervention. All participants responded to six vignettes depicting everyday situations in chemistry

classrooms. Principles of learning were inferred from the written responses using a qualitative lexical approach. Three overarching conclusions emerged. First, prospective teachers who intended to pursue a teaching career already hold prior knowledge and beliefs about learning producing more elaborated responses than their counterparts. As they had not been taught principles of learning, their prior knowledge and beliefs likely formed inductively, through their own classroom experiences. Second, a clear distinction emerges between beginning and final-year students: the latter shift from fragmented, teacher-centred thinking towards more integrated, student-focused pedagogical reasoning based on more framework-like knowledge. Third, the eight-week focused intervision programme does not appear to produce a substantial change in the knowledge of final-year students; however, it may have contributed to slightly more coherent pedagogical reasoning. Overall, intention may have influenced conceptual change.

Teacher-Led Inquiry as a Catalyst for Changes in Science Teachers' Beliefs and Practices

Bénédicte Boissard , Université du Québec à Trois-Rivières, Canada, Eric Durocher, Université du Québec à Montréal, Canada, Vivianne Plourde, Université du Québec à Montréal (UQAM), Canada, Patrice Potvin, Université du Québec à Montréal, Canada

Professional development (PD) plays a key role in supporting science teachers in aligning their practices with contemporary goals of science education, which often require teachers to view learning as the active construction of knowledge. However, PD initiatives often struggle to produce sustained changes in teachers' beliefs and classroom practices (Baillet & Therriault, 2021; Timperley et al., 2009). This study examines whether sustained engagement in teacher-led classroom inquiry can support changes in teachers' pedagogical and epistemological conceptions. The study was conducted within a long-term PD initiative in Québec that brings together researchers, teachers, and educational advisors to support teacher-led inquiry cycles. Using a convergent mixed-methods design (Creswell & Creswell, 2018), the study combined quantitative and qualitative data. 48 secondary science teachers completed a pre- and post-questionnaire measuring conceptions of teaching and learning and epistemological beliefs about scientific knowledge. In addition, semi-structured interviews were conducted with 18 teachers to explore their perceptions of the teacher-researcher stance, and reported changes in practice. Quantitative data were analyzed using paired-samples t-tests, while interview data were analyzed through thematic analysis. Results indicate modest but significant shifts toward more constructivist conceptions of teaching and more sophisticated epistemological beliefs. Interview data provide deeper insight into these changes: teachers emphasized student-centered learning, questioning practices that support conceptual understanding, and more intentional, reflective pedagogical choices. These findings suggest that engaging teachers in systematic inquiry about their practice may foster conceptual change. PD may therefore be understood as an inquiry-based process that supports reflective and evidence-informed teaching.

Symposium 2 B:
Tracing Conceptual Change in Fractions: Interventions and Tracking Learner Behaviour and Strategies

Chair: Jo Van Hoof , University of Turku, Finland

Discussant: Erno Lehtinen , University of Turku, Finland

Room: Publicum 5

Abstract

Fractions are a core part of mathematics curricula worldwide and often represent students' first formal encounter with a number system beyond natural numbers. A solid understanding of fractions is a key milestone in mathematical development and supports later learning in algebra, statistics, and geometry. Despite their importance, students' understanding of fractions is frequently marked by persistent misconceptions. Conceptual change theory offers a prominent explanation: because children encounter natural numbers far more often in early life and schooling, they develop an initial number concept dominated by natural-number properties. When fractions are introduced, these properties are no longer sufficient, yet many learners continue to apply them. This natural number bias produces systematic errors, such as adding numerators and denominators separately (e.g., 1/4 + 1/3 = 2/7). This symposium brings together three studies examining conceptual change in fraction learning. Specifically, we address: (1) how particular intervention features (e.g., task types and visualizations) and students' behavioral indicators (e.g., time on task), captured through log data, relate to conceptual change; (2) how learners' strategy profiles develop across a wider age range than is typically investigated, using a theory-driven Bayesian classification approach that derives profiles from accuracy patterns and reaction-time patterns; and (3) whether students show gains in conceptual understanding of fractions in an adaptive intervention targeting fraction misconceptions.

Mapping fraction strategy profiles across grades 5-12 using a theory-driven Bayesian classification

Flore Maricau , KU Leuven KULAK, Belgium, Wim Van Dooren, KU LEUVEN, Belgium, Bert Reynvoet, KU Leuven KULAK, Belgium, Fien Depaepe, KU Leuven, Belgium

Understanding how students compare fractions provides insight into the development of their fraction magnitude knowledge. Fraction comparisons may draw on intuitive, albeit biased strategies (e.g., natural number-based reasoning or gap thinking), as well as more advanced, magnitude-based strategies. These differences reflect substantial interindividual variation in students' conceptual fraction understanding. While previous studies have identified distinct strategy profiles using person-centered approaches, they have focused largely on narrow age ranges, leaving open questions about how such profiles evolve over time. The present study therefore examines fraction comparison strategies across three cohorts of Flemish students in primary and secondary education (Grades 5–6, 8–9, and 11–12; ages 10-18; N = 889). Using a theory-driven Bayesian classification approach, we identified distinct strategy profiles based on accuracy patterns and, for high-performing students, based on reaction time patterns. To assess age-related differences in profile prevalence, we compared cohorts using multinomial logistic regression.
Accuracy-based classifications revealed significant cohort differences: younger students were more likely to rely on biased strategies, while older students were more frequently identified as proficient. However, a small subset of older students continued to show biased profiles, indicating that a fully coherent understanding of fraction magnitudes is not guaranteed even in final years of secondary education.

Reaction-time-based classifications indicated substantial implicit bias activation across all cohorts, but no clear age-related differences emerged. Together, these findings show substantial interindividual variation in strategy use both within and across cohorts, pointing to the need for targeted instruction that addresses specific misconceptions.

Tracking conceptual change in understanding fraction magnitudes through log data analysis

Michael D'Erchie , Technical University of Munich, Germany, Michael Nickl, Technical University of Munich, Germany, Johannes Rosenkranz, Technical University of Munich, Germany, Thomas Dresler, University of Tuebingen, Germany, Andreas Obersteiner, Technical University of Munich, Germany

The natural number bias in fraction comparison refers to students' tendency to focus on the natural number components rather than on the holistic numerical magnitude (e.g., judging 4/9 as larger than 3/5 because 4 > 3 and 9 > 5). A recent intervention using the Fraction Magnitude Trainer (FMT), a digital tool promoting magnitude-based reasoning, substantially reduced this bias in sixth graders relative to two control groups. This study uses log data from that intervention to examine when and how bias change occurs. We analyzed data from 85 sixth-grade students who completed 18 FMT sessions over six weeks, addressing three questions: 1) How is time spent in the FMT related to improvements in bias patterns? 2) How do specific FMT features (types of tasks and visualizations) affect bias change? 3) How can we characterize participants' bias pattern changes (rapid vs. slow and gradual) depending on their pre-intervention bias patterns? Results revealed no significant main effects of time-on-task on bias change. However, a likelihood ratio test revealed a significant interaction between time-on-task and pre-intervention bias pattern ($\chi^2(2) = 9.01$, $p = .011$): for students with a reverse bias or gap-thinking pattern, more time was associated with greater likelihood of bias change, whereas for students with a typical bias, it was not. Neither task type nor visualization type significantly predicted bias change. This study offers the first real-time characterization of fraction bias change, with implications for understanding conceptual change in mathematics and for designing more targeted interventions.

Targeting Fraction Misconceptions With an Adaptive Online Fraction Learning Environment

Heli Nurminen , University of Turku, Turku Research Institute for Learning Analytics, Finland, Simo Korkolainen, University of Turku, Finland, Sabrina Di Lonardo Burr, University of Sheffield, United Kingdom, Jake McMullen, University of Turku, Finland, Florence Gabriel, Adelaide University, Australia, Jo Van Hoof, University of Turku, Finland

Fractions are often viewed as the most challenging math content in the elementary school curriculum and as an important stepping stone towards more abstract mathematical content. Despite their importance, students often struggle with fractions. One reason why fractions are difficult for students to learn is the natural number bias, where students overapply the properties of natural numbers to rational numbers. In this pre-post-test intervention study we targeted students' biased reasoning with an adaptive intervention in the digital learning platform, ViLLE. Building on conceptual change research showing that visual representations and refutation texts support more accurate mathematical understanding and help remediate persistent misconceptions, the present adaptive intervention integrates both approaches to promote conceptual change. Based on pre-test fraction responses, students were assigned to one of the following intervention groups: misconception (typical, reverse or gap), high achiever, and mixed/low achievers.

When wrong feels right: why confidence matters for the link between misconceptions and state anxiety

Jo Van Hoof , University of Turku, Finland, Heli Nurminen, University of Turku, Turku Research Institute for Learning Analytics, Finland, Simo Korkolainen, University of Turku, Finland, Hilma Halme, University of Oulu, Finland, Finland, Wilma Tulijoki, University of Turku, Finland, Jake McMullen, University of Turku, Finland

Fractions are a stumbling block in mathematics education. A key source is the natural number bias misconception (NNB), in which learners inappropriately apply properties of natural numbers to fractions, producing systematic errors (e.g., such as reasoning that 1/4+1/3=2/7). Overcoming the NNB requires conceptual change, namely adapting one's number concept to include rational numbers. Recently, NNB has been discussed in relation to state mathematics anxiety: students who respond consistently with NNB report lower state anxiety than similarly low-performing peers without NNB, possibly because they misjudge their performance and remain unaware of their difficulties. This explanation fits within the ongoing debate on how aware students are of their NNB misconception. To inform this debate, we combined students' task responses, self-reported confidence and state anxiety to distinguish between highly confident misconceptions and low-confidence incorrect responding that may reflect recognized uncertainty. Data were collected in spring 2026 from 468 Finnish fifth graders who completed an 18-item fraction comparison task. After the task, students rated their state anxiety and confidence (1–5 Likert scales). Using a theory-driven Bayesian classification approach, 238 students were classified as showing a consistent NNB. Within this group, 77 reported high and 30 reported low confidence in their fraction magnitude answers. State anxiety differed strongly between these profiles, $t(105) = 5.44$, $p < .001$, $d = 1.17$; the high-confidence group reported lower anxiety ($M=1.45$, $SD=0.83$) than the low-confidence group ($M=2.53$, $SD=1.12$). These findings suggest that consistent NNB is heterogeneous and that the NNB–anxiety link depends on students' awareness of their misconception.

Keynote 2:
Implementing guided inquiry-based learning in the classroom: Linking theories and practice

Carla van Boxtel (University of Amsterdam)

Chair: Salome Flegr

Room: Calonia 1

Abstract

In this talk, I address the question of what contributes to the implementation of guided inquiry-based learning in the classroom. Drawing on research on inquiry-based learning in history and social science education, I show how theories concerning the aims, core activities, and pedagogical approaches of inquiry-based learning can support teachers in implementing guided inquiry-based learning in their lessons, as well as what challenges may arise in doing so.

I argue for the importance of a clear conceptualization of complex knowledge and skills, including why they matter and how they are co-constructed and used in inquiry and dialogic activities in the classroom. I illustrate the potential of educative curriculum materials that focus on inquiry-based learning practices in which explicit instruction in complex skills, guidance, and dialogue are embedded in authentic tasks. Finally, I emphasize that enriching and transforming teachers' views and insights, as well as experimenting with new approaches in the classroom, are not enough. Professionalization programs must engage teachers in professional dialogue in which theories, empirical evidence and practical wisdom and classroom experiences come together and attend to how teachers can achieve agency in implementing guided inquiry-based learning in interaction with the school context and the broader educational context (e.g. national curriculum frameworks and debates about what should be taught).

Posters

Room: Educarium Hallways 2nd and 3rd Floors

2nd Floor:

1. Effects of Conceptual Change-Based Chatbot Prompting on Students ´ Understanding in Chemistry

Christian Schumburg , Gottfried Wilhelm Leibniz Universität Hannover, Germany, Andreas Nehring, Gottfried Wilhelm Leibniz Universität Hannover, Germany, Inken Beeneken, Gottfried Wilhelm Leibniz Universität Hannover, Germany

2. Modeling Heterogeneous SRL Adaptation in Medical Diagnosis: A First-Order Markov Analysis

Shasha Li , McGill University, Canada, Tingting Wang, Renmin University, China, Susanne Lajoie, McGill University, Canada, Nikki Lobczowski, McGill University, Canada

3. Primary students' conceptions of animal adaptation – lessons learned from a science literacy project

Anni Vidbäck , University of Turku, Department of Teacher Education, Finland, Tuike Iiskala, University of Turku, Department of Teacher Education, Finland, Eero Laakkonen, University of Turku, Finland, Norbert Erdmann, University of Turku, Finland, Mirjamaija Mikkila-Erdmann, University of Turku, Finland

4. An ecological lens for analyzing a self-organizing process of open-ended collaborative inquiry

Simona Pesaresi , KU LEUVEN, Belgium, Jianwei Jianwei Zhang, University at Albany, State University of New York, United States

5. Prediction, Surprise, and Conceptual Learning Across Cultures: Evidence from Germany and Uganda

Carlo Vreden , DIPF | Leibniz Institute for Research and Information in Education, Germany, Eunice Ndyareeba, Kabale University, Uganda, Garvin Brod, DIPF | Leibniz Institute for Research and Information in Education, Germany

3rd Floor:

6. Generative AI and Conceptual Change: Rethinking Cognitive Scaffolding in Inquiry-Based Learning

Francisca Beroíza , Universidad de las Américas, Chile

7. Teaching over Four Years and Enabling Learners to Move from Personal to Scientific Understanding

Yaron Schur , David Yellin Academic College, Israel

8. “Think of the Wrong Answer”: Extending Inhibition Effects in Chemistry Multiple-Choice Questions

Vincent Natalis , University of Liège, Belgium

9. Teacher-researcher stance: the evolution of science teacher conceptions of teaching and learning

Eric Durocher , Université du Québec à Montréal, Canada, Patrice Potvin, Université du Québec à Montréal, Canada, Martin Riopel, Université du Québec à Montréal, Canada, Bénédicte Boissard, Université du Québec à Trois-Rivières, Canada

10. Effects of inquiry learning across chemistry and mathematics on students’ conceptual understanding

Nobuyuki Fujimura , The University of Tokyo, Japan, Haruna Tachibana, Nagoya University, Japan, Hidetoki Ishii, Nagoya University, Japan, Kumi Ishikawa, Nagoya University Affiliated Upper and Lower Secondary School, Japan, Kiwa Tomaru, Nagoya University Affiliated Upper and Lower Secondary School, Japan

11. Children’s Conceptualizations of Religious Agents Across Domains: A Conceptual Change Study

Anastasia/Natassa Kyriakopoulou , National & Kapodistrian University of Athens, Greece, Irini Skopeliti, National & Kapodistrian University of Athens, Greece, Katerina Parise, University of Patras, Greece, Ageliki Nicolopoulou, Lehigh University, United States, Sofia Douklia, University of Patras, Greece, Rebekah Richert, California University, United States, Kathleen Corriveau, Boston University, Greece

Interactive Sessions

Room: 244

Interdisciplinary Inquiry-Based learning to debunk myths about Prehistory

ISABEL BANOS-GONZÁLEZ , UNIVERSITY OF MURCIA, Spain, LAURA ARIAS, University of Murcia, Spain, ALEJANDRO EGEA-VIVANCOS, University of Murcia, Spain, PEDRO FÉREZ, University of Murcia, Spain, J. GINÉS ESPIN, University of Murcia, Spain

The Interdisciplinary Didactic Intervention (IDI) "Who could Paloma have been?" constitutes a structured secondary education programme explicitly designed through an inquiry-based learning (IBL) framework. Anchored in the female Neanderthal skeleton called 'Paloma' from Sima de las Palomas (Murcia, SE Spain), it systematically challenges students' preconceptions and myths about Prehistory via evidence-driven, interdisciplinary scientific inquiry. The IDI adheres to a rigorous IBL cycle: problem presentation, elicitation of prior knowledge through brainstorming, student-generated question formulation (as: "When did she live? What resources did she have? What was her role? How was the ecosystem surrounding Paloma?"), collaborative planning of fieldwork with source criticality evaluation, subject-integrated resolution (Social Sciences, Biology-Geology, English, Mathematics), and a culminating multimedia exhibition ("Myth or Reality? What we don't know about Prehistory"). Worksheets facilitate metacognitive comparison of initial hypotheses against empirical findings, fostering critical scientific reasoning.

Central to the approach is the cultivation of scientific thinking: students evaluate archaeological sources for bias, test hypotheses on Neanderthal physicality, environment, diet, and gender roles using primary data (e.g., paleontological records), and debunk sociocultural myths through evidence analysis. Tasks prioritise analytical skills, such as comparative source scrutiny and hypothesis revision, promoting conceptual change via falsifiable claims and peer-reviewed validation. This IDI bridges conceptual change and inquiry by operationalising IBL to transform stereotypical views into scientifically grounded understanding within interdisciplinary settings.

Meeting Learners’ Prior Knowledge: Integrating Perspectives on Theory, Inequality, and Research

Peter Edelsbrunner , LMU Munich, Germany

Research on the effects of prior knowledge on learning is at a point of newfound interest; however, surprising and inconsistent findings as well as missing comprehensive theoretical models continue to pose significant challenges for advancing our understanding of the role of prior knowledge in learning. This roundtable aims to generate new research directions on the role of prior knowledge in learning by addressing three key questions: (1) Under which conditions do interventions or experimental manipulations designed to align with learners’ prior knowledge enhance or diminish learning outcomes? (2) How do such interventions affect initial heterogeneity among learners; do they amplify, reduce, or maintain differences? (3) Can we identify overarching constructs, theories, or models that help integrate and simplify the currently fragmented evidence base on prior knowledge and learning? Using a structured jigsaw format, participants will engage in think–pair–share activities to collaboratively develop concrete ideas for future research. The session aims to conclude with promising and actionable research directions.

Parallel Session 3 A:
Climate Change and Sustainablity

Chair: Cecilia Lundholm

Room: Publicum 5

Systems and critical thinking in the face of climate change: trends among Primary future teachers

ISABEL BANOS-GONZÁLEZ , UNIVERSITY OF MURCIA, Spain, UXÍO PÉREZ, Departamento Didáctica de las Ciencias Experimentales de la Universidade de Vigo, Spain, MERCEDES VARELA-LOSADA, Departamento Didáctica de las Ciencias Experimentales de la Universidade de Vigo, Spain, MARÍA A. LORENZO, Didáctica de las Ciencias Experimentales de la Universidade de Vigo, Spain, PEDRO VEGA-MARCOTE, Departamento Didáctica de las Ciencias Experimentales. Universidad de A Coruña, Spain, NURIA CASTIÑEIRA, University of Vigo, Spain

Teacher education is a key context for promoting conceptual change about climate change (CC), although pre-service teachers often show fragmented understandings and difficulties in fostering critical and systemic perspectives in classrooms. This study investigates how Primay school pre-service teachers position themselves towards a critical and systemic framing of CC, focusing on attitudinal patterns that may either support conceptual change in their learning and future teaching. A total of 984 students enrolled in the Degree Primary Education at five Spanish universities completed the Critical and Systemic Thinking Scale (9 Likert type items). Descriptive and inferential analyses examined their stances on: alarming versus downplaying climate risks in the classroom; addressing systemic socio political and economic drivers; and integrating intersectional dimensions such as gender. Overall, participants strongly endorsed the importance of critically analysing consumption, questioning the socio-economic system, and encouraging participation in climate related mobilisations; on contrast, they were more ambivalent about explicitly alarming students or integrating gender perspectives. Statistically significant gender differences appeared in several items, systematically favouring women on positions more consistent with a critical and systemic view of climate change. We interpret these differentiated profiles as markers of ongoing, and sometimes fragile, conceptual change processes, in which scientific ideas about CC coexist with everyday beliefs and socio-political tensions. The findings inform the design of initial teacher education interventions that deliberately target conceptual change in beliefs, emotions and epistemic stances regarding CC, with the aim of strengthening pre-service teachers' ability to cultivate critical and systems thinking in their future classrooms.

Comparison of Four Treatments to Teach Seasons

Pierre Chastenay , Université du Québec à Montréal (UQAM), Canada, Patrice Potvin, Université du Québec à Montréal, Canada, François Thibault, Université du Québec à Montréal (UQAM), Canada, Yannick Skelling Desmeules, Université du Québec à Montréal (UQAM), Canada, Lucia Mason, University of Padova, Italy

We present the results of an 2x2 factorial design experiment conducted with 182 undergraduate students in education in which we compared four treatments to teach the astronomical concept of seasons: an expository text, a refutation text, an expository video and a refutation video. Both videos have the same length, present similar geocentric and allocentric (space-based) perspectives and use the expository and refutation texts as voice-over. Pretest results were similar for the four treatment groups. Results of a mixed-design ANOVA show a robust learning effect between the pre- and post-test with a clear advantage for refutation, and a more modest but significant effect of the video format. These results suggest that

refutation plays a more decisive role than the presentation medium (i.e., video vs. text) in fostering conceptual learning. Complete results, limitations of the study and future directions will be presented.

Swedish Upper Secondary Social Studies Teachers' Conceptions of Sustainability Education

Amanda Norling , Linköping University, Sweden

Environmental and Sustainable Education (ESE) has long been part of Swedish schooling, yet its role in social studies remains insufficiently explored. While sustainable development-related content is present in both overarching curricula and subject syllabi, research indicates that social studies teachers often struggle to determine how ESE should be integrated into their teaching. This study investigates how Swedish upper secondary social studies teachers conceptualise ESE and how sustainability issues are addressed in their instructional practices. Data were collected through an online survey distributed to 870 teachers across 300 randomly selected schools, yielding 214 responses (24.6%). Descriptive statistics and parametric analyses (independent t-tests, one-way ANOVAs) were used to examine potential differences based on gender, teaching experience, and school characteristics, complemented by a thematic analysis of open-ended responses. Findings show that although teachers vary in how frequently they use terms such as sustainable development (SD) and education for sustainable development (ESD), nearly all report teaching content related to ESE. Economics, globalization, human rights, and democracy emerge as the content areas most frequently linked to SD. No significant differences were found across gender, experience, or school location; however, teachers in higher education preparatory programs address climate-related issues more than teachers in vocational programs. Thematic analysis further reveals that teachers view fostering pupils' agency as central, often merging democratic and sustainability-related aims. The study with contributes empirical insights on how ESE is enacted in social studies and highlights the need for guidance on integrating climate issues, particularly regarding economic content.

Scientific Reasoning Across Content Areas: Experiment Sequences and Students‘ Conceptions in the Lab

Andreas Nehring , Gottfried Wilhelm Leibniz Universität Hannover, Germany, Marco Reith, Leibniz University Hannover, Germany

Scientific reasoning competencies are a central learning goal of laboratory education in higher chemistry education. However, little is known about how sequencing experiments across different content areas influences competency development and students' reasoning processes. In this experimental study, 97 undergraduate students participated in laboratory learning sequences structured according to the "CAAT structure". We randomly assigned them to either a homogeneous sequence (content area: kinetics) or a heterogeneous sequence (content areas: kinetics, thermodynamics, redox). We analysed scientific reasoning competencies based upon the competency triad (distinguishing between three knowledge facets within dispositions, processes, and products) using paper–pencil tests, think-aloud protocols, and laboratory reports.

Our results showed significant improvements in procedural and laboratory-technical knowledge facets and in the quality of students' investigations, but no significant differences between the sequences regarding overall competency development. Qualitative indepth analyses revealed differences in content-related reasoning: Students in the heterogeneous sequence frequently activated knowledge from previous experiments, particularly thermodynamics concepts such as equilibrium and Le Chatelier's principle when reasoning about reaction kinetics, as well as assumptions about temperature and activation energy. These

findings highlight the importance of experiment sequencing for conceptual transfer and demonstrate how conceptual change-oriented research provides an differentiated perspective research on laboratory education.

Parallel Session 3 B
Mathematics and Rational Numbers

Chair: Katarina Gvozdic

Room: Educarium 2

Investigating the Natural Number Bias in Adults' Equation Solving: Evidence from Eye-Tracking

Dimitra Pericharou , National and Kapodistrian University of Athens, Greece, Irini Skopeliti, National & Kapodistrian University of Athens, Greece

The Natural Number Bias (NNB) is described as the tendency to conceptualize all numbers and mathematical operations based on the properties of natural numbers, even when such properties are not applicable. According to the framework theory of conceptual change, the NNB reflects an intuitive knowledge structure that may coexist with formal mathematical knowledge, often leading to misconceptions and difficulty in evaluating the correctness of mathematical operations. This study investigates NNB in adults during equation solving through eye-tracking. Two experiments involved participants of different mathematical backgrounds (strong vs. weak). In Experiment-1, participants evaluated whether multiplication equations, which provided one factor and the product, could be solved. In Experiment-2 similar equations were presented with three possible solutions. Participants had to decide whether the equation could be solved and, if so, to select the correct solution. Equations were categorized based on the type of solution (natural vs. rational number) and on the multiplication result (increase vs. decrease of the given factor). Results from both experiments confirmed the NNB. Participants showed higher accuracy and less reaction time for equations consistent with intuitive assumptions, and increased fixation counts for non-consistent ones. Interestingly, participants with strong mathematical backgrounds achieved higher overall accuracy, yet showed markedly increased visual attention when solving counter-intuitive equations. These findings support the coexistence of intuitive and sophisticated mathematical knowledge and gives particular emphasis on the persistence of intuitive biases, even among experts. The study also highlights the challenge of conceptual change in adults and the value of eye-tracking in revealing mathematical reasoning.

Math talk supporting rational number understanding in NanoRoboMath game lessons

Tomi Kärki , University of Turku, Finland, Minna Hannula-Sormunen, University of Turku, Department of Teacher Education, Finland

Previous studies show that many students and adults inappropriately apply natural-number-biased reasoning in fraction and decimal tasks, for example, by assuming that multiplication always produces a larger outcome. Fully grasping the inconsistencies between natural and rational number reasoning may require substantial conceptual change. Although serious games have been designed to tackle this challenge, little is known about the math talk occurring in classroom discussions during game-based lessons. Yet, mere playing does not seem to optimally support students' mathematical development. In this case study, we examined the math talk of a teacher and his students (n =18) in seven video-recorded classroom discussions related to playing NanoRoboMath, a digital game designed to improve rational number knowledge. The data included 1.03 hours of video-recorded discussions, which were first analysed

using TIMMS-R Video Math Coding Manual to identify the structure of the math-related excerpts. Second, all math-related words and expressions were extracted and categorized, and mathematical problem posing was analysed in greater depth. The results showed that the discussions were strongly problem-centered. The students and the teacher articulated their mathematical thinking in diverse ways using mathematical terminology, including 77 different arithmetic concepts or terms. The discussions centered on mathematical topics arising from the game, such as decimal calculations and calculation strategies. These findings provide interesting insights into how a game-based learning environment can stimulate math talk in the classroom and thereby foster rational number understanding. Further quantitative and qualitative studies are needed to elaborate on content-specific aspects of math talk related to game-based learning.

Unbounded Number Lines Reflect the Complexity of Rational Number Knowledge

Sofia Vanhatalo , University of Turku, Department of Teacher Education, Finland, Jake McMullen, University of Turku, Finland

Number line estimation tasks have been found to be beneficial for strengthening rational number knowledge, but there are many open questions regarding the kinds of rational number knowledge that are needed to be proficient in these tasks. In this study, we aimed to deepen our understanding of a previously less explored unbounded number line estimation task by examining 9th graders' (N=95) qualitatively different answers to unbounded number line estimation tasks, as well as the connections between this and other measures of rational number knowledge. Our results show that students' rational number knowledge, reflected in the unbounded number line estimation tasks, appeared fragmented and that performance in the unbounded number line estimation tasks was able to explain variance in students' adaptive rational number knowledge. This indicates that students' rational number knowledge may be number (context) dependent, and that unbounded number line estimation tasks could be used to examine and develop students' adaptive expertise with rational numbers.

Parallel Session 3 C
Contextualizing Concepts

Chair: Tommi Kokkonen

Room: Educarium 3

Contextualizing Concepts: Worlds, Positions, and Perspectives in Conceptual Understanding

Gertraud Benke , University of Klagenfurt, Austria, Christian Thurn, ETH Zurich, Switzerland, Yaron Schur, David Yellin Academic College, Israel

In this theoretical contribution, we present a structured account of how contextual information plays a role in concept learning and conceptual understanding. Building on research in conceptual change and ecological psychology (Gibson, 1986), we argue that understanding any phenomenon involves an implicit sequence of choices: locating oneself in an experiential or imagined world, adopting material and social positions within that world, taking up perspectives that these positions afford, and focusing attention on selected aspects. Learners frequently not only consider conceptual contents but also move across contexts—from an experiential world grounded in perception to imagined or abstract object worlds, such as hypothetical scientific or fictional settings. In each, they occupy material and social positions that afford distinct perspectives and determine which features become salient. Our framework enriches theories of conceptual change by making these often-overlooked contextual dimensions explicit. It provides a vocabulary for describing how learners' vantage points affect conceptual understanding, why some conceptual shifts are particularly demanding, and how instruction can scaffold productive transitions between these levels. The model thus supports conceptual change research, instructional design, and assessment through an integrated account of worlds, positions, and perspectives.

The limits of cognitive conflict for conceptual learning

Elfriede Holstein , DIPF Frankfurt, Germany, Maria Theobald, Trier University, Germany, Joseph Colantonio, Harvard Graduate School of Education, United States, Elizabeth Bonawitz, Harvard Graduate School of Education, United States, Garvin Brod, Leibniz-Institut für Wissensmedien (IWM), Germany

Exposing misconceptions by having learners generate predictions before receiving corrective information has been shown to heighten cognitive conflict and facilitate belief revision. However, the efficacy and durability of prediction-driven learning in complex domains requiring the integration of multiple dimensions remain unclear. This study examined whether generating predictions promotes children's conceptual learning about balance—a concept requiring the integration of weight and distance. Children (N = 164, ages 7–10, 45.73% girls) completed the task in either a prediction or post-hoc evaluation (postdiction) condition. Data were collected in 2023 and 2024. We found that children in the prediction condition exhibited stronger pupil dilation responses following incorrect predictions, suggesting that generating predictions boosted cognitive conflict. Children in the prediction condition showed better posttest performance than those in the postdiction condition, indicating improved short-term learning in a more complex domain. However, this advantage did not persist after a week, as demonstrated by two novel Bayesian model-based measures of conceptual knowledge, and did not lead to a deeper conceptual understanding. Together, these results indicate that cognitive conflict alone appears insufficient for revising misconceptions and should rather be thought of as an initial step requiring subsequent processes enabling resolution and conceptual restructuring.

Confidence and sustainable conceptual change

Erno Lehtinen , University of Turku, Finland, Ilona Södervik, University of Helsinki, Finland, Vesta Vančugovienė, Vytautas Magnus University, Lithuania, Patrice Potvin, Université du Québec à Montréal, Canada

Studies on conceptual change reveal that learning new scientific ideas is a gradual, process rather than an immediate replacement of misconceptions with scientifically accurate knowledge. Many students demonstrate understanding immediately after instruction but later regress to earlier misconceptions. Learners' confidence in their conceptions has emerged as a meaningful predictor of conceptual change. 73 9th grade students participated a conceptual change intervention. Their conceptual understanding and confidence was measured in pre-, post- and delayed postest. Three profiles were formed on the basis of achievement and confidence ratings. The accuracy of confidence ratings was strong predictor of the sustainable conceptual change. Realist confident group strongly developed during the intervention and continued improving three months after the experiment. Underconfident group developed during the intervention but regressed to initial concepts after the experiment. Overconfident group did not develop during the experiment.

Concept Learning Through Bridging Analogies: Integrating Coherence and Fragmentation Perspectives

Danielle Jreije , American University of Beirut, Lebanon, Tamer Amin, American University of Beirut, Lebanon

The strategy of bridging analogies has been recognized as a promising instructional strategy to support learning of challenging scientific concepts, such as force. Different accounts have been offered in the literature regarding how this strategy supports learning with some researchers assuming a coherence perspective and others assuming a fragmentation perspective on conceptual change. This study adopts an integrated theoretical perspective combining coherence and fragmentation perspectives. It recognizes that learners activate many knowledge elements during science learning, but also assumes that some elements can play particularly important roles in many learners' thinking giving rise to some coherence and presenting particular learning challenges. Using detailed microanalytic and microgenetic analyses, this study sought to identify the similarities and differences in the knowledge elements that five middle and five high school students activated when taught about the concept of normal force using the bridging analogies strategy. While the study identified individual differences in the knowledge elements activated and how students reasoned about the concept of normal force, we also identified a set of common knowledge elements activated by many students and which posed common obstacles to learning. Specifically, these elements - support, solidity, agency, and unsupported objects fall -can be traced to core cognition in infancy which constrains physical reasoning. The findings support the need for an integrated perspective on science concept learning combining elements from both coherence and fragmentation perspectives.

Business Meetings

SIG 3

Room: 357a

SIG03 JURE Outstanding Publication Award

Gennen, T. (2023). Conceptual change and education: The neglected potential of developmental teaching approaches

Research on conceptual change (CC) has revealed that students face difficulties when learning that requires sig- nificant changes to their prior knowledge. Researchers have documented the challenges in education to promote CCs and concluded that conventional teaching does not facili- tate these changes. However, while designing educational methods to address CC challenges is a central aim of CC research, it is an area of research that still requires refine- ment. I show that developmental teaching (DT) approaches, including El'konin-Davydov's developmental education and Gal'perin's method of stage-by-stage formation of mental actions and concepts, are promising for addressing CC challenges but are absent from CC research literature. I first review the CC challenges revealed in CC research, the way in which three CC research trends – framework theory, onto- logical theory, and knowledge-in-pieces theory – interpret them, and their educational recommendations to foster CC. Next, I present CC challenges and educational recommen- dations to foster CC from a DT perspective. I delineate convergences and divergences between the three CC re- search trends and DT research concerning both educational design and theories of CC. I conclude by suggesting artic- ulations between DT research and CC research in general and the three CC research trends in particular.

SIG 20

Room: 359

Thursday 27 August

Keynote 3
Modeling Knowledge: Yesterday, Today, Tomorrow

Peter Edelsbrunner (Ludwig-Maximillians-Universität-Munchen)

Chair: Natassa Kyriakopoulou

Room: Publicum 3

Abstract:

Learners` knowledge is a central predictor and outcome across a variety of educational contexts. I discuss how knowledge has been represented and examined in statistical models throughout the last decades, connecting statistical developments such as factor-, mixture-, multilevel-, network- and cognitive modeling to theoretical shifts in the fields of inquiry-based learning and conceptual change. Engaging in informed clairvoyance, I discuss future developments that may help us further refine our models to better represent our assumptions and aims regarding learners` knowledge. One principle I bring forward is that in setting up statistical models of knowledge, our theories and aims are generally more important than the details of empirical data, although there may be boundaries to this perspective – but where are these exactly? Let`s discuss.

Parallel Session 4 A:
Mathematics Education

Chair: Jake McMullen

Room: Educarium 2

Understanding task affordances for scaffolding adaptive rational number knowledge

Xiaoshan Huang , University of Turku, Department of Teacher Education, Finland, Sofia Vanhatalo, University of Turku / Faculty of Education, Finland, Koen Veermans, University of Turku / Faculty of Education, Finland, Steven Bruneel, University of Helsinki, Finland, Jake McMullen, University of Turku, Finland

Adaptive rational number knowledge is an essential outcome of mathematical learning but remains underassessed during the learning process. Game-based number line estimation environments, such as the Number Trace game, offer stealth assessment opportunities through automatically recorded log data, yet whether log-based indicators can validly capture ARNK as learners engage with tasks remains unexamined. Without validated in-process measures of ARNK, it remains unclear how to design inquiry-based environments that provide meaningful ARNK learning opportunities during gameplay. This study investigates the diagnostic potential and limitations of log data captured in number line estimation tasks, using think-aloud data as a complementary validity lens. Thirty-six undergraduate students completed the tasks while verbalizing their reasoning. Log data analysis results reveal items with ARNK measurement and discriminative potential. Preliminary think-aloud analysis showed that ARNK items trigger greater variation in reasoning strategies, and identified potential scaffolding moments for supporting adaptive reasoning.

These findings will advance understanding of accurate diagnosis as a foundation for adaptive scaffolding in game-based learning environments.

Research of fractions, decimals and percentages in Finnish mathematics textbooks

Saku Määttä , University of Turku, Finland, Minna Hannula-Sormunen, University of Turku, Finland, Erno Lehtinen, University of Turku, Finland

A decline in students' mathematics proficiency has been observed in international (PISA) and national studies in Finland. Transition from natural numbers to rational numbers is challenging for many students during primary school. Natural number bias is seen as one of the reasons why rational numbers are found difficult to learn. Overcoming natural number bias is suggested to require conceptual change. Consequently, students may benefit from mathematics instruction that would highlight the differences between rational and natural numbers.

We present results on rational number instruction in three Finnish mathematics textbook series. We report on results of examining the proportion of fraction, decimal, and percentage tasks (and tasks that require multiple representations). The present study searches explicit references in mathematics textbooks and teacher manuals that highlight explicit differences between whole- and rational numbers (similarly as Van Dooren et al., 2019). Categories examined are rational number size, operations, density, and representations. Additionally, we will examine the textbooks on task level regarding rational number instruction (e.g., amount of number line estimation based tasks).

Does inquiry-based learning increase students' interest in mathematics lessons?

Tomi Jaakkola , Tampere University, Finland, Mikko Kesonen, Tampere University, Finland, Mika Koponen, Tampereen yliopisto, Finland

Background: The decline in students' proficiency and interest in STEM subjects is a global concern. While inquiry-based learning (IBL) has well-documented positive effects on learning, its impact on students' interest—particularly in mathematics—remains underexplored. Aims: This study investigates whether IBL increases students' situational interest in mathematics lessons compared to traditional textbook/teacher-led instruction, and examines the role of individual interest, gender, and grade level. Methods: Participants were 250 primary school students (grades 3–6) at a university teacher training school. A crossover design was employed, with each student experiencing both lesson types (regular and IBL). Situational interest was measured after each lesson using ten 7-point items assessing affective (feeling) and value dimensions. Individual interest in mathematics was measured with ten 4-point items. Data were analyzed using linear mixed models. Results: Individual interest in mathematics declined across grade levels and was higher among boys. Individual interest significantly predicted situational interest. Situational interest (feeling) was higher in IBL lessons than in regular lessons, with the effect driven by sixth graders. No lesson type effect was found for the value dimension. A gender × grade level interaction indicated girls' perceived value declined more steeply than boys'. Conclusion: IBL shows promise for enhancing situational interest in mathematics, particularly among older students. Longer-term interventions with more experienced teachers are needed.

Designing a workshop for conceptual change in students' understanding of equality

Emilia Aaltonen , University of Helsinki, Finland, Dimitri Tuomela, University of Helsinki, Finland

The transition from elementary to middle school involves significant curricular discontinuities in mathematics, one being students' limited understanding of equality. Research shows that many students entering middle school interpret the equal sign operationally — as "the answer is" — rather than relationally as "the same as," and that this misconception persists across grade levels and impedes algebraic reasoning. Another discontinuity concerns the shift in emphasis from answer-getting to mathematical reasoning and justification. To address these challenges, we are designing a 45-minute classroom workshop through design research, targeting both conceptual change in students' understanding of equality and their ability to use equality to justify and communicate solution methods. The workshop is developed iteratively: the first version was implemented in two classrooms, observed by two researchers, and revised based on field notes and teacher reflections. Preliminary findings from the first design cycle indicate that task placement, timing, and the deliberate use of cognitive conflict are critical design factors. The presentation will report on completed design cycles and discuss implications for both the design of transition-focused interventions and the broader theoretical understanding of how conceptual change in equality can be facilitated in classroom settings.

Parallel Session 4 B: Conceptual Replacement and Inquiry

Chair: Marvin Fendt

Room: Educarium 3

Distinguishing Theories, Knowledge Assemblies, and Cultural Models When Modeling Conceptual Change

Tamer Amin , American University of Beirut, Lebanon

This paper assumes a multilevel theoretical perspective on conceptual change in science learning that integrates theory change, knowledge-in-pieces, and situated/embodied/distributed perspectives. I assume that viewing conceptual change at the functional, representational, and implementational levels offers a rich modeling toolkit that allows us to see the complementarity between different theoretical perspectives. This modeling toolkit will need further refinement, and many details need to be unpacked. In this paper, I focus on refining the constructs we need to characterize learners' pre-instruction conceptual understanding. While using the notion "theory" is empirically adequate in some cases, it is less so in others. Specifically, I argue that we need to distinguish "theories," "knowledge assemblies," and "cultural models" to capture important distinctions between different forms of pre-instruction understanding that emerge from underlying representational resources. I also argue that recognizing these different forms of pre-instruction conceptual understanding has implications for instruction. I make the case for this three-way distinction based on three case studies of pre-instruction conceptual understanding (focusing on the concepts of matter, force, and energy) and what research tells us about instructional strategies that can successfully guide science concept learning.

From Conceptual Replacement to Meaning Expansion: Rethinking Conceptual Change in the Social Field

Aster Van Mieghem , University of Antwerp, Belgium, Eef Rombaut, University of Ghent, Belgium

Research on conceptual change has predominantly conceptualised learning as a process of epistemic correction and convergence towards stable disciplinary knowledge (Chi, 2008; Vosniadou, 2013). While productive in domains characterised by relatively stable concepts, such models become problematic when applied to the social field, where many concepts are interpretative, normatively contested, and closely connected to learners' experiences and social positioning (Gallie, 1956; Berenskötter & Guzzini, 2024). This paper reconsiders how conceptual change can be understood in relation to social concepts such as identity, inequality, or justice. Drawing on conceptual change research and social studies education, it argues that conceptual change in the social field is better understood as an open-ended process of meaning expansion rather than as conceptual replacement or epistemic convergence. The paper introduces an analytic framework that articulates four interrelated dimensions shaping conceptual change in the social field: context, conceptual input, affective–cognitive reasoning processes, and conceptual outcomes. By emphasising reasoning, justificatory practices, and epistemic plurality, the framework provides a way of analysing how conceptual change unfolds when learners engage with socially contested concepts. The paper concludes by discussing implications for conceptual change research and for educational practices aimed at supporting learners in developing more informed understandings of complex social phenomena.

Development of scientific explanations through Predict-Observe-Explain peer inquiry.

Niilo Huuhka , University of Jyväskylä, Finland, Anna-Leena Kähkönen, University of Jyväskylä, Finland, Antti Lehtinen, University of Jyvaskyla, Finland, Terhi Mäntylä, University of Tampere, Finland

We explore the effects of a Predict-Observe-Explain based peer-inquiry learning sequence on the conceptual knowledge of pre-service physics teachers. The learning sequence had the participants in pairs working with direct current electric circuit tasks that increase in difficulty as they progress. Each task has the participants first form an individual prediction (Predict), then, forming a collective prediction with their pair, testing the validity of those predictions with real batteries and bulbs (Observe), and finally discussing their findings (Explain). Each task focused on the order of brightness of bulbs in different configurations. The conceptual knowledge of the pre-service physics teachers was operationalized by analysing their explanations given. The focus was on the relations of concepts that relate to brightness. The results show that the learning sequence had positive effects on the conceptual knowledge as it appeared in the explanations. The explanations gained complexity and more concepts as the tasks got more difficult. Finally, we investigated what critical moments preceded the changes in explanations. Such moments included differences in predictions and observations, increase in complexity of tasks and discussions with the instructor. Our findings support the benefits of inquiry-based learning in teacher education and offer insights into the relatively unmapped territory of critical moments in Predict-Observe-Explain learning sequences.

An ecological lens for tracing the emergence of a shared inquiry focus in momentary interactions

Simona Pesaresi , KU LEUVEN, Belgium, Jianwei Jianwei Zhang, University at Albany, State University of New York, United States

In collaborative open-ended inquiry, students investigate ever-deepening problems of understanding through paths not known in advance. A research challenge lies in understanding how students sustain and deepen a shared inquiry focus without relying on pre-scripted procedures or extensive teacher direction. This study applies an ecological lens to examine how a shared focus on light refraction emerges and evolves in the moment-to-moment interactions among Grade 4 students engaged in an inquiry into light. Using interpretive thick description and interactional analysis, the study traces the dynamic interplay of three dimensions of the ecological lens: expressions of conceptual unknowns, material objects, and

knowledge wantings. Findings illustrates how the dynamic relationships between these three dimensions propel inquiry into expansive ways of knowing. The ecological lens may guide designs of learning analytics that map material objects to conceptual ideas enhancing teacher's attention to turning points in the deepening of the inquiry.

Parallel Session 4 C:
Physics Simulations & Inclusive STEM

Chair: Tomi Jaakkola

Room: Publicum 5

Using Physics Simulations with Interactive Equations to Facilitate Mathematical Inquiry (ONLINE)

Jared Arnell , Utah State University, United States, Hillary Swanson, Utah State University, United States, John Edwards, Utah State University, United States

Simulations have long been a highly successful educational tool in physics for improving conceptual understanding. However, very few simulations incorporate explicit mathematical elements—in particular, equations. This imbalance is disconcerting, especially in light of the oft-found result across physics education research that physics students routinely struggle to connect mathematical and conceptual ideas. In this work, we share case studies of intermediate physics students interacting with a suite of simulations called PhysMath, which expand on the traditional template of physics simulations by including a second copy of the phenomenon governed by equations provided by the user. We observed that the PhysMath simulations were capable of facilitating the students' conceptual inquiry in identical fashion to traditional simulations. Moreover, the mathematical elements of the PhysMath simulations allowed students to investigate and test numerous mathematical ideas as well. These results validate the inclusion of interactive mathematical elements in physics simulations to expand their instructional capabilities.

Conceptual Change in Inclusive STEM Classrooms: The Role of Self-Regulated Learning

Daniela Nussbaumer , Université du Québec à Montréal (UQAM), Canada

Conceptual change and inquiry-based learning are widely regarded as key approaches for fostering deep understanding in STEM education. Both require learners to actively construct knowledge, confront prior conceptions, and engage in processes of reflection and restructuring. However, these processes place high demands on learners' ability to regulate cognition, motivation, and emotion. This is particularly challenging in inclusive classrooms, where students with special educational needs, especially in the domain of emotional and behavioral difficulties, often show limited or unstable self-regulatory capacities. This theoretical paper argues that self-regulated learning (SRL) constitutes a critical, yet often underexplored, prerequisite for successful conceptual change in inquiry-based learning environments. Without sufficient self-regulation, learners may fail to engage productively with cognitive conflict, leading to avoidance, superficial processing, or persistence of misconceptions. Drawing on research on SRL, conceptual change, and special education, the paper proposes a three-stage didactic model describing a developmental progression from guided to increasingly self-regulated inquiry. The model emphasizes co-regulation, scaffolding, and diagnostically informed transitions as key mechanisms. By reframing inquiry as the outcome of a developmental process rather than its starting point, the paper contributes to a more inclusive understanding of conceptual change in STEM education.

Transforming Student Teachers' Sustainability Conceptions Through EE Instruction

Otto Rydman, University of Turku, Finland; Ilona Södervik , University of Helsinki, Finland, Neea Heinonen, University of Eastern Finland, Finland, Eila Matikainen, University of Turku, Finland

Sustainability is a complex, multidimensional concept that future teachers must understand deeply in order to integrate it meaningfully and holistically into their pedagogical practices. Yet, typically sustainability has been approached through narrow or fragmented perspectives, suggesting that student teachers' existing conceptions may not align with current scientific and interdisciplinary understandings. This study examined the sustainability conceptions of 48 student teachers before and after a university Environmental Education (EE) course. Qualitative analysis revealed substantial variation in participants' initial understandings, ranging from limited, single-dimension interpretations to comprehensive, systemic views. Although a subset of students demonstrated clear conceptual development, the majority exhibited only minor shifts. These findings highlight the particular challenge of transforming value-laden concepts such as sustainability, which are closely tied to personal worldviews and moral frameworks. The study underscores the importance of explicitly supporting deep, holistic conceptual development in teacher education to enable future teachers to foster robust sustainability learning in schools.

Predicting university students' understanding of biology concepts: a person-oriented approach

Ilona Södervik , University of Helsinki, Finland, Vesta Vančugovienė, Vytautas Magnus University, Lithuania, Erno Lehtinen, University of Turku, Finland

This study examines how university biology students understand the core concepts of photosynthesis and respiration and how their high school biology achievement and epistemic cognition relate to this understanding. Prior research shows that many students, including those in higher education, struggle with scientifically accurate conceptual understanding on these processes. Research on domain-specific epistemic cognition suggests that students with more sophisticated beliefs about the justification of scientific knowledge are more likely to achieve conceptual change. A total of 224 students from biology and closely related university programmes participated in the study in 2025. Conceptual understanding and students' epistemic cognition were measured using validated questionnaires. Latent profile analysis revealed four distinct student profiles based on high school biology grades, epistemic cognition, and conceptual change. Only 17.9% of students demonstrated full understanding of the critical aspects of photosynthesis and respiration. The profiles showed varied relationships between prior achievement and conceptual understanding: some high-achieving high school students continued to excel conceptually, while others with low high school grades demonstrated strong conceptual understanding at the university level. Across profiles, more sophisticated epistemic cognition was strongly associated with higher conceptual change. These findings highlight the importance of epistemic cognition in supporting conceptual understanding in biology and demonstrate substantial heterogeneity in students' learning trajectories.

Symposium 3 A:
Different routes to diagnosing learners` conceptions and misconceptions in physics and astrophysics

Chair: Peter Edelsbrunner , LMU Munich, Germany

Discussant: Lennart Schalk , PH Schwyz, Switzerland

Room: Educarium 2

Abstract:

A growing body of research emphasizes that knowledge often consists of multiple distinct elements that do not necessarily correlate strongly, posing challenges for traditional psychometric approaches presuming the measurement of a coherent construct (Edelsbrunner et al., 2025; Stadler et al., 2021). These issues are particularly relevant in physics and astrophysics education, where learners frequently hold simultaneously persistent misconceptions and scientifically correct conceptions that are difficult to diagnose using traditional assessments (Sadler et al., 2010; Sands et al., 2018; Schneider & Hardy, 2013). This symposium aims to present and compare the development and empirical results of several concept inventories designed for physics and astrophysics education that acknowledge this perspective but use different operationalizations to diagnose learners' knowledge. Study 1 introduces a concept test on Newton's First Law that systematically varies stationary and moving contexts as well as reproduction and transfer tasks based on a clear theoretical model. Study 2 presents the development and validation of a questionnaire assessing conceptual understanding during gameplay in a serious game on quantum sensor technology. Study 3 presents a different approach with a concept inventory on the topic of the reasons for seasons for seventh-grade students, in which correct conceptions and common naïve ideas are systematically integrated to diagnose students' conceptual understanding. The contributions use different approaches for similar aims on topics from related domains, providing ground for integrated discussion on the relative strengths and disadvantages of the variations in assessment methodologies regarding their potential to diagnose multidimensional or incoherent knowledge structures in learners.

Capturing Context-Sensitive Concept Understanding in Mechanics with a Visual-Textual Concept Test

Ipek Paksoy , ETH Zurich, Switzerland, Salome Flegr, Dresden University of Technology, Germany, Martina Rau, ETH Zurich, Switzerland

Accurate assessment of students' conceptual understanding is essential for identifying prior knowledge and alternative conceptions. This is especially important in physics, where everyday experiences and pre-conceptions often conflict with scientific conceptions. Existing mechanics concept tests are often text-heavy, lack systematic item-to-concept mappings, and provide limited diagnostic resolution at the subtopic level. To address these limitations, we developed and validated a concept test targeting Newton's First Law. The instrument systematically varies stationary/moving contexts and reproduction/transfer tasks, while integrating visual representations into every item to balance factors known to affect conceptual understanding. We developed items based on documented alternative conceptions in mechanics. Then we refined these items through expert reviews and results of pilot-testing to strengthen content validity and ensure suitability across a wide range of prior knowledge levels. We then administered the 28-item multiple-choice test to 112 Swiss university students from non-physics-focused backgrounds. The test showed strong internal reliability ($\alpha = .87$, $\omega = .88$). Exploratory and confirmatory factor analyses indicated a dominant general factor. A two-factor model separating stationary and moving contexts showed acceptable

fit and moderate latent correlation, while models separating reproduction and transfer showed weaker fit with high correlations. We also observed context-sensitive clustering for friction-based equilibrium items. Overall, findings support the structural validity of the instrument and suggest it can serve as a reliable tool for diagnosing students' initial conceptions and tracking conceptual change in mechanics instruction.

Measuring Understanding of Quantum Sensor Technologies in Nonformal Settings

Caroline Wermann , Université du Québec à Montréal (UQAM), Canada, Stefan Küchemann, Ludwig-Maximilians-Universität (LMU), Germany, Jochen Kuhn, Ludwig-Maximilians-Universität (LMU), German

Quantum technologies are increasingly becoming the subject of public discourse, media coverage, and political strategies. Consequently, tools are required to diagnose learners` knowledge about this topic to be able to gauge and support their understanding. We investigated the psychometric properties of a self-developed test assessing learners' prior knowledge of eight concepts related to quantum sensor technology before engaging with a serious game. Unlike most existing instruments, the questionnaire does not measure learning in a school or university context, but during a voluntary leisure activity, targeting interested individuals without prior mathematical or physical knowledge. Existing measuring instruments proved unsuitable for this audience that typically lacks mathematical or physical knowledge, as they often use formalized representations. The objective of the game was to enable learners to perform a measurement sequence with an NV diamond. This objective encompasses eight concepts: qubits, the Bloch sphere, measuring a quantum state, applications of quantum sensors, the structure of NV diamonds, their initialization, manipulation, and the measurement routine. The study was conducted with visitors at the Deutsches Museum in Munich. A confirmatory factor analysis revealed inadequate model fit (CFI = 0.62, RMSEA = 0.057, SRMR = 0.07). Many factor loadings were low, and several items showed cross-loadings on multiple factors. Contextualized, application-oriented items can capture authentic understanding but are often associated with reduced psychometric reliability in measuring the understanding of individual concepts. At the same time, the complex factor structure could indicate that learners' prior knowledge of quantum sensor technologies is fragmented and loosely connected.

Measuring conceptual understanding of seasons: Development and validation of a concept inventory

Aishwarya Girdhar , LMU, Germany, Zoya Kozlova, Ludwig-Maximilians-Universität (LMU), Croatia, Christoph Hoyer, Ludwig-Maximilians-Universität (LMU), Germany, Jörg-Henrik Heine, Universität der Bundeswehr München, Germany, Jochen Kuhn, Ludwig-Maximilians-Universität (LMU), Germany, Sarah Hofer, Ludwig-Maximilians-Universität (LMU), Germany

Astronomy gauges strong student interest but also involves abstract and often inaccessible phenomena that hinder conceptual understanding. Assessing such understanding is equally complex, making validated concept inventories valuable tools for measuring learning gains. In this study, we present the development and initial psychometric validation of a concept inventory targeting students' conceptual understanding of the causes of seasons. Understanding the occurrence of seasons requires integrating multiple scientific concepts and their interplay. Accordingly, the instrument was designed to assess the understanding of individual sub-concepts, and overall conceptual understanding while accounting for prevalent misconceptions. The validation process employed a comprehensive set of quantitative methods, including classical test theory, item response theory, model-based reliability estimation, and structural analysis. The instrument was administered to a sample of N=171 seventh-grade students, following an immersive learning instruction conducted for different groups with virtual reality, 360° learning environment, and desktop conditions. The students' scores from the pre- and post-test are used to conduct an initial

validation of the concept inventory's reliability in evaluating understanding of seasons. This resulting concept inventory enables detailed insights into students' understanding at multiple levels: individual concepts, their integration, and persistent misconceptions. Ongoing data collection will further enable iterative testing of the validated version to obtain a robust instrument for evaluating learning gains particularly in context of instructional interventions on reasons for seasons.

Symposium 3 B: Coexisting conceptual resources and contextual triggers: rethinking mobilisation of learned concepts

Chair: Patrice Potvin , Université du Québec à Montréal, Canada

Discussant: Patrice Potvin , Université du Québec à Montréal, Canada

Room: Educarium 3

Abstract:

Students' persistent difficulties in applying scientifically accepted concepts are often interpreted as evidence of incomplete or flawed conceptual change. However, recent findings across science and math education suggest a more nuanced picture: intuitive and scientific conceptions may coexist, with their activation depending on contextual cues, task characteristics, and regulatory processes. This symposium explores how inhibition, metacognitive interventions, and task framing influence which conceptions are expressed in specified contexts or settings. The first presentation examines physical and biological misconceptions across educational levels, with a focus on those that appear to increase in prevalence as students progress through the education system. Through cross-sectional measures of response accuracy and latency, it investigates whether these trends can be associated with specific instructional milestones, suggesting a curricular or instructional origin. The second presentation explores the impact of prompting participants to rate their surprise and confidence after each incorrect response as a metacognitive intervention. This resulted in significantly higher accuracy, particularly on incongruent trials known to elicit persistent errors, compared to a control group. In the third presentation, a (different) metacognitive prompt was used to encourage physics students to reconsider their initial answers to the Force Concept Inventory. The findings indicate that while the prompt supported the inhibition of initial answers, it did not facilitate a shift toward correct ones. Finally, the last presentation introduces a theoretical description of the mechanism of physics tasks' completion. The role of inhibition and the idea of a physics-specific testing instrument to measure this inhibition is presented as a prospective aspect of this model.

Instruction-Driven Misconceptions: Cross-Sectional Evidence from Biology and Physics Education

François Thibault , Université du Québec à Montréal (UQAM), Canada, Patrice Potvin, Université du Québec à Montréal, Canada, Steve Masson, Université du Québec à Montréal, Canada

Misconceptions in science education are commonly attributed to students' intuitive reasoning or sociocultural influences. However, this study examines whether formal instruction may contribute to the emergence of misconceptions. Using a cross-sectional design, 720 students from primary school to university in Québec completed three diagnostic tasks targeting misconceptions related to plant respiration and projectile motion. Both response accuracy and response latency were analyzed to assess not only the

prevalence of these misconceptions among the student population, but also the cognitive effort required to overcome them. Results revealed significant decreases in accuracy and corresponding increases in latency following specific curricular milestones, particularly after instruction on photosynthesis and classical mechanics. These findings support the hypothesis that curricular and/or instructional sequencing may inadvertently lead to the emergence of misconceptions despite otherwise scientifically accurate teaching, highlighting the importance of examining not only what is taught, but also when and how related concepts are introduced.

Impact of metacognitive prompts on learner's transition from intuitive to scientific reasoning

Genevieve Allaire-Duquette , Université de Montréal, Canada, Reuven Babai, Tel Aviv University, Israel

One widely adopted approach to encourage transition from intuitive to scientific reasoning is cognitive conflict. In this approach, learners are proven wrong causing them to experience a disequilibrium, and they are expected to try to resolve such conflict by revising their intuitions. Indeed, incorrect predictions have been shown to induce surprise that is believed to facilitate knowledge revision. However, the elicitation of surprise does not appear to be consistently beneficial. Metacognitive prompts could help increase attention allocation to errors and encourage post-error adjustments, i.e. the revision of intuitions. In this study, we use the comparison of perimeters task a as model system for the tension between intuition and scientific reasoning. We randomly assigned 76 adult participants to a practice-based group that received only basic feedback (correct or incorrect) and a metacognitive group in which each error was followed by two metacognitive prompts: How surprised are you that your response is incorrect (1-not at all to 5-Very surprise)? How confident are you to get a correct response in the next trial (1-not confident to 5-Very confident)? Participants in the metacognitive group obtained significantly higher accuracy scores. Next steps should involve exploring the impact of the metacognitive prompts in school settings. In addition, from a theoretical standpoint, future work could distinguish to what extent the effect of metacognitive prompting is driven by increasing awareness to errors (surprise), encouraging post-error adjustment (explanation) or an interaction between the two

The impact of metacognitive prompting on solving the Force Concept Inventory (FCI)

Yannik Ott , RPTU University Kaiserslautern Landau, Germany, Eva Cauet, RPTU University Kaiserslautern-Landau, Germany, Alexander Kauertz, RPTU University Kaiserslautern-Landau, Germany

Applying Dual Process Theory (DPT), we investigated whether metacognitive prompting could initiate analytical reasoning and cognitive reflection to improve performance on the Force Concept Inventory (FCI). Prior work suggests that students fail to inhibit wrong intuitive answers and shift to a correct answer. This ability to inhibit and shift, is called cognitive reflection and is often measured with the Cognitive Reflection Test (CRT). Correlations between CRT scores and students' performance on the FCI suggest that cognitive reflection skills might influence students' approach the FCI. In a within-person design, N=183 students in introductory mechanics completed a split FCI twice: first without prompts, then with a metacognitive prompt asking students to identify the most common incorrect intuitive option before selecting their final answer. CRT scores were relatively high and moderate positive correlations with FCI scores emerged. However, paired comparisons showed no significant change in FCI performance with prompting. We argue that there are two possible reasons for this. First, the prompting was introduced too late, and the students had already developed a certain mindset through their initial work on the tasks, which we could no longer influence sufficiently. Second, the high CRT scores indicate that the prompting was generally unnecessary for most students. Nevertheless, the confirmed correlations between the FCI and CRT suggest that inhibition and shifting (i.e. cognitive reflection) are important for task performance. We will present analyses of response distributions and changes to clarify the null effect and implications on the validity of the CRT.

The mechanism behind the completion of physics tasks – A theoretical description

Alexander Kauertz , RPTU University Kaiserslautern-Landau, Germany, Yannik Ott, RPTU University Kaiserslautern Landau, Germany, Eva Cauet, RPTU University Kaiserslautern-Landau, Germany

Physics educators on all levels experience that students' fail on tasks even if they have learned the relevant content and are prompted during task's completion. We present a theoretical approach grounded in dual-process-theory, executive functions, and structural features of the physics content and task to describe the phenomena. Based on this theoretical understanding we might be able to decide on helpful scaffolds for students or develop supportive learning paths. The basic mechanism of task completion is commonly described in three steps: Identifying the relevant information, processing the information (making and evaluating inferences) according to the expected outcome, and communicating a solution. In all three steps decisions are made what to consider and how to proceed. Those decisions can be ordered on two dimensions: consciously/unconsciously made (analytically/intuitive), biased/unbiased according to the logic of the underlying task. In dual process theories, biases are commonly discussed with respect to intuitive processes, however, pre- and misconception are an example outcome of an analytical but biased decision-making in physics. In the presentation we argue how cognitive reflection based on executive functions such as inhibition and shifting, as well as biases and schema from physics learning are intervened during task completion in physics. We suggest a research agenda to investigate the validity of these theoretical assumptions in empirical research studies.

Parallel Session 5 A:
Pre-service Teachers Conceptual Learning

Chair: Salome Flegr

Room: Educarium 2

Preservice teachers' rational number knowledge before and after mathematics didactics course

Pauliina Salonen , University of Turku, Department of Teacher Education, Finland, Jake McMullen, University of Turku, Finland, Juulia Lahdenperä, University of Turku, Finland

Preservice teachers need both mathematical and pedagogical knowledge, yet rational numbers remain a challenging content area, making it essential to understand how their knowledge varies and develops during teacher education. This study examined how preservice teachers differed in their rational number knowledge at the start of their first mathematics didactics course and how their knowledge developed during the course. A total of 102 preservice teachers completed assessments measuring six aspects of rational number knowledge at pretest and four aspects at post-test. Cluster analysis based on pretest performance identified distinct knowledge profiles, and one-way and repeated-measures ANOVAs were used to analyse differences between clusters and their development over time. Three clusters — low, medium, and high — emerged at the beginning of the course, with differences across measured aspects. All groups showed improvement during the course, but the extent and pattern of development varied: the low group improved in all aspects, the medium group improved in most, and the high group showed only limited gains. Despite overall growth, some group differences remained also in post-test. These results indicate that preservice teachers enter didactics courses with considerable variation in rational number knowledge and develop unevenly during pedagogically focused instruction. The findings highlight the need for teacher education programs to support mathematical content knowledge alongside pedagogical development.

Preservice teachers’ learning of biodiversity loss in an inquiry-based self-study setting

Henna Vilppu , University of Turku, Finland, Mirva Heikkilä, University of Jyväskylä, Finland, Anni Vidbäck, University of Turku, Finland, Mirjamaija Mikkila-Erdmann, University of Turku, Finland

In today’s information-rich online environment, accurate scientific knowledge competes with misleading and inaccurate content, making learning from the internet challenging. Moreover, prior knowledge and beliefs may hinder learning when new information conflicts with existing conceptions. This study explored how an inquiry-based digital self-study environment comprising multiple texts supported preservice teachers (N = 73) in developing conceptual understanding of biodiversity loss. Additionally, we examined preservice teachers’ prior knowledge in relation to their learning of biodiversity loss. The self-study environment included ten texts, some of which were relevant, some irrelevant, and some based on fake content. The study utilised three datasets: a pretest questionnaire of prior knowledge, written syntheses based on multiple texts, and a posttest questionnaire with an open-ended reflection on self-perceived change of knowledge. Preliminary findings show certain misconceptions in prior knowledge, for example, a third of the participants believed that biodiversity loss can even boost economic growth. In their syntheses, preservice teachers scored highest on definition of biodiversity loss and its causes and implications, whereas integrating different perspectives and writing a coherent synthesis based on the relevant source

texts proved more difficult. Most of the participants reported that their knowledge of biodiversity loss had deepened or widened, whereas 4% experienced no change. 12% mentioned concrete ideas in terms of which their knowledge of biodiversity loss had changed. Analyses examining the associations between prior knowledge, synthesis performance, and perceived conceptual learning are ongoing and will be presented at the conference.

Parallel Session 5 B:
Critical Information Skills & Cognitive Reflection

Chair: Yoana Omarchevska

Room: Educarium 3

Refute, Research, Reflect: A Short Curriculum to Foster Critical Information Skills

Marvin Fendt , Ludwig-Maximilians-Universität Munich, Germany, Fabian Reinwarth, Technical University Munich, Germany, Daniil Serko, Technical University Munich, Germany, Anastasia Kozyreva, Max-Planck-Institute for Human Development, Germany, Peter Edelsbrunner, Ludwig-Maximilian-University Munich, Germany

Misinformation poses a substantial challenge, yet individual interventions targeting its context, content, or source often yield short-lived effects. We designed a comprehensive curriculum integrating these pillars via pedagogical principles to build a holistic misinformation toolbox. We investigate the extent to which this curriculum increases credibility discernment, sharing discernment, analytic processing, and intellectual humility. In a registered report, we conducted a randomized controlled study with a pilot (N = 276) and a main study (N = 900) in German secondary schools. The intervention group received three one-hour modules. The context module uses active practice to teach inoculation against manipulation strategies. The source module teaches lateral reading based on Cognitive Apprenticeship principles. The content module discusses AI-generated videos to foster intellectual humility and plausibility reappraisal. Bayesian linear mixed models demonstrated the curriculum's effectiveness. The context intervention improved credibility discernment, sharing discernment, and analytic thinking (β=0.52–0.69). The source intervention improved these metrics for news articles (β=0.63–0.87). The content intervention increased intellectual humility (β=0.21) and reduced the third-person effect (β=-0.58). This approach offers a scalable framework against misinformation for formal education. Our presentation will detail the main study findings, evaluate covariates (e.g., conspiracy thinking), explore potential synergies between inoculation and lateral reading, and assess effect longevity via a delayed posttest and a refresher intervention

Theoretical Concepts in Instruction: Opening a Dialogue Between Developmental Education and CC

Anna Broman , Stockholm University, Sweden, Mimmi Waermö, Stockholm University, Sweden

Attempts to explore how Developmental Education (DE) and Conceptual Change (CC) traditions relate have been made recently, and a dialogue between these traditions has been requested. DE approaches students' formation of theoretical concepts as the central task of formal instruction. In this paper, we present an analysis of an instructional sequence designed within the framework of DE and thus aim to contribute to the conversation between the two traditions. The instructional sequence was designed to facilitate students' formation of the biological concept of the life cycle as a theoretical concept. From DE perspective, forming a theoretical concept of the life cycle requires identifying the essence of the phenomenon. The essence of the life cycle lies in the role each stage plays in reproduction, transformation, and the transmission of genetic information. We analyse how a model that captures the essence of the life cycle emerges through collaboration between the students and the teacher. Students first read a text about a mayfly's life. The teacher asks students to draw a diagram of the mayfly's developmental stages that

shows both the transitions between stages and how it remains the same organism throughout. Students depict in diagrams their answers. Through joint reading and discussion of the diagrams, students stepwise adjust the diagrams, moving in their thinking from the specific case of a mayfly's life cycle towards an initial abstraction – the essence of the life cycle – captured in a model. How might the process of modelling described in our analysis be interpreted in CC terms?

Children's cognitive reflection skills predict their conceptual learning

Elfriede Holstein , DIPF Frankfurt, Germany, Lucas Lörch, DIPF Frankfurt, Germany, Garvin Brod, DIPF | Leibniz Institute for Research and Information in Education, Germany

Cognitive reflection, the ability to override immediate reactions for more considered responses, is measured using the Cognitive Reflection Test (CRT). The original CRT's mathematical content limits its applicability for children, leading to the development of the child-friendly version, the Developmental Cognitive Reflection Test (CRT-D). The CRT-D measures children's ability to override immediate reactions for more considered responses, a skill crucial for learning non-intuitive concepts, particularly in science. However, the predictive validity of the CRT-D for inquiry-based learning has not been established. This study validates a German version of the CRT-D aged 5 to 10 (N = 255) and investigates its role as a predictor of conceptual change in children (N = 116). The CRT-D demonstrated acceptable internal consistency (McDonald's ω = .69), and its factor structure and developmental trends were consistent with other populations. Children's CRT-D scores significantly predicted their conceptual learning, suggesting that cognitive reflection is essential for successful science learning.

Effects of Preparation for Future Learning and Argument Tasks on Evidence Evaluation

Hiroki Oura , Tokyo University of Science, Japan, Clark Chinn, Rutgers University, United States, Etsuji Yamaguchi, Kobe University, Japan, Toshio Mochizuki, Waseda University, Japan

Citizens frequently encounter scientific claims on social media that rely on limited evidence rather than larger bodies of evidence. To address the need for instruction that promotes evidence evaluation, this study examined the additive effects of a Preparation for Future Learning (PFL) task (Schwartz & Bransford, 1998) prior to instruction and a post-instruction argument task within text-based instruction. A total of 155 undergraduates at a Japanese public university participated in a 2 × 2 randomized factorial experiment. In the PFL conditions, students generated criteria for strong evidence and ranked conflicting documents before instruction, whereas comparison participants generated summary criteria. The argument task required students to compose an evidence-based argument after instruction. In a post-assessment, students read three documents presenting conflicting claims about a fictitious cognitive-enhancement supplement, with one document supported by a meta-analysis and two by single studies. Outcomes included agreement judgments, perceived evidence strength, and credibility ratings. Multivariate analysis of covariance (MANCOVA), controlling for pre-reading agreement, tested the effects of both instructional factors. Results showed no significant main effects but a significant interaction. The argument task increased students' agreement with the position supported by stronger evidence (pro-position) only when the PFL task was absent. Follow-up analyses indicated that this effect was driven by changes in an agreement with the pro-position. Likewise, the PFL task increased students' pro-position when the argument task was absent, whereas no single variable drove the changes by follow-up analyses. These findings suggest that post-instruction argumentative writing may contribute more to evidence-based judgments than preparative activities.

Parallel Session 5 C: Metacognition, Emotions & Math

Chair: Sofia Ikonen

Room: Publicum 5

Exploring the Link Between Metacognitive Strategies, Emotions, and Math Performance: CB-SEM

Robiatul Adawiya , Szeged University, Hungary

Educational achievement outcomes in mathematics show persistent gaps in Indonesia. This study investigates the association between metacognitive strategies, emotional variables, and mathematics performance using Covariance-Based Structural Equation Modelling (CB-SEM). This research focuses on the interaction between metacognitive strategies such as planning, monitoring, evaluation, and mathematics problem-solving ability, and how emotional influences such as math anxiety and enjoyment contribute to academic performance. The sample population consisted of 1,084 students in the 11th grade from urban, semi-urban, and rural areas of North Sumatra and Central Java, Indonesia. The novelty of this study lies in the combination of components: the integration of metacognitive strategies along with emotional regulation within a single structural model, a comprehensive framework that explains more clearly the relations of these factors with student performance. The study highlights the importance of fostering both cognitive and emotional skills to support math performance. It suggests that targeted educational interventions should be implemented to cultivate metacognitive strategies and emotional resilience in diverse educational contexts.

Photovoice as a Mediating Structure for Conceptual Reorganization During Inquiry

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Climate change poses a challenge for inquiry learning because it is scientifically complex, emotionally charged, and often perceived as psychologically distant. This paper examines photovoice as a visualization-mediated inquiry routine that supports conceptual reorganization by grounding climate reasoning in lived experience. Across three coordinated studies (an elementary classroom intervention, a longitudinal wetlands inquiry, and an ongoing international mixed-methods project), we investigate how learner-generated photographs serve as mediational tools that integrate perception, emotion, and scientific explanation. Findings show that photovoice reduces psychological distance, strengthens links between emotional articulation and causal reasoning, and supports iterative restructuring of students' interpretive frameworks. Conceptual change becomes visible as students shift from treating climate change as a distant phenomenon to understanding it as a systemic process unfolding within their own communities. The work contributes to scholarship bridging conceptual change and inquiry by demonstrating how visualization practices can mediate meaningful learning in consequential scientific domains.

The Three-Year Development of Beginning Undergraduate's Epistemological Beliefs Across Four Domains

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Epistemological beliefs (EB) are considered important prerequisites for scientific thinking and may develop differently across academic domains depending on domain-specific knowledge characteristics. This longitudinal panel study investigated the development of six EB dimensions — Personal Justification, Justification by Authority, Justification by Multiple Sources, Justification by the Scientific Community, Certainty of Knowledge, and Reflexive Nature of Knowledge — across economics, sociology, medicine, and physics over three years. A total of 171 students from various German universities participated in three measurement occasions from 2023 to 2025. The results indicate differential developmental trajectories across domains. In economics, Personal Justification declined slightly, while Reflexive Nature of Knowledge showed a temporary increase. In sociology, Certainty of Knowledge increased overall, and Reflexive Nature of Knowledge also tended to rise. No significant changes were found in medicine. In physics, Justification by Multiple Sources and the Reflexive Nature of Knowledge declined. Limitations include small subsamples and partly low internal consistencies. Overall, the findings support the assumption that EB development differs across domains and may reflect the distinct characteristics of disciplinary knowledge.

Conference Venue

The Main Conference will take place on the Lower Campus of the University of Turku, primarily in the Educarium building (Assistentinkatu 5, 20500 Turku).

Lunch will be served in the Educarium restaurant Piccu Maccia.

Coffee breaks, the welcome reception, and poster session will be held in the hallways of Educarium on the 2nd and 3rd floors.

Paper sessions, Symposia, and Keynotes will be held in the Educarium, Calonia, and Publicum. Please follow signs to the different venues or ask conference staff for help.

Campus map and more information can be found at: https://www.utu.fi/en/university/turku-campus

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