

EARLI SIG 27 Conference 2024 (Online Measures of Learning Processes)



**Educational design and research using responsible
online process measures**

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Book of Abstracts

Keynotes

Tamara van Gog

The biopsychosocial model of challenge and threat in research on learning and instruction

According to the biopsychosocial model of challenge and threat (Blascovich, 2008), challenge and threat motivational states result from a person's (un)conscious evaluation of the demands of a situation in relation to their resources to deal with it. When the individual feels their available resources (e.g., available skills/cognitive capacity) exceed the task demands (e.g., required skills/effort), this results in a challenge state; when the demands outweigh the available resources, this results in a threat state. Challenge and threat can be measured via self-reports or cardiovascular measures, and higher levels of challenge (/ lower levels of threat) have been associated with higher performance on a variety of tasks. In this keynote, I will discuss results from recent studies in which we investigate the relation between challenge/threat and learners' responses to feedback, effort investment, performance, and (self-regulated) learning outcomes in educational research.

Olga Viberg

Cultivating Trust and Values in the Era of AI-Powered Education

As adoption of AI in education has rapidly increased, the promise of transforming teaching and learning practices emerges. AI-powered technology offers opportunities to improve student learning outcomes, foster critical thinking, and refine problem-solving skills through features like personalized learning paths and immediate feedback. Similarly, educators stand to benefit from streamlined planning and assessment practices. However, alongside technological advancements, it is our responsibility to foster trust as well as to consider and sustain different values in the adoption and utilization of AI-powered technologies for broaden inclusion and equity among stakeholders in education. This keynote focuses on the intersection of AI in education, exploring the significance of trust and values, including educational, human and cultural values, in the adoption and utilization of AI technologies for learning and teaching in educational settings. Drawing upon interdisciplinary research and practical case studies, strategies for nurturing trust and upholding values amidst the advent of AI-powered education will be discussed.

Michail Giannakos

Multimodal AI for hybrid human learning

The intersection of multimodal human activity data and advanced computational analyses can improve our understanding of how humans learn and provide novel affordances that augment learning, such as embodied learning, and multimodal interaction. Multimodal data coming from learners' interaction with technology and the learning context not only offer new ways to detect human learning experiences but also enable powerful learning technologies and interfaces (via AI and ML algorithms). In this talk, I will present indicative results on how human activity data and AI

contribute to intelligent learning systems, and how those systems intertwine with humans in hybrid intelligence settings. Moreover, I will discuss distinct ways in which humans and AI can ethically and synergistically combine their strengths.

Papers

Exploration of behavior sequences for successful complex problem solving using n-grams

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Jörn Sparfeldt, Saarland University, Germany

In typical complex problem solving (CPS) environments, learners are required to explore an unknown problem space (knowledge acquisition) and to subsequently reach target values within a given number of steps (knowledge application). Even though learners are provided with a correct model of the problem space at the start of the knowledge application phase, many fail the task. In the present study, we explored which behavior sequences are typical for successful and unsuccessful problem-solvers during knowledge application.

We classified the knowledge application behaviors of N=495 high-school students into four categories: correct and incorrect monotelic behaviors (varying only one input variable in correct or incorrect directions) as well as correct and incorrect polytelic behaviors (varying several input variables simultaneously, in correct or incorrect directions). Sequences of those behaviors we analyzed using n-grams (n=4).

Results show that successful problem-solvers mainly applied sequences of entirely correct polytelic behaviors, or a combination of entirely correct polytelic and monotelic behaviors. A small number of students showed sequences with incorrect polytelic behaviors at the beginning, but managed to reach the targeted values by correct monotelic behaviors at the end of the sequence. Unsuccessful problem solvers showed sequences of entirely incorrect polytelic behaviors, or a combination of entirely incorrect polytelic and monotelic behaviors. Some showed sequences with correct polytelic or monotelic behaviors at the beginning, but failed to solve the problem because of incorrect behaviors at the end of the sequence. The study sheds light on the typical mistakes that lead to unsuccessful knowledge application in complex problem-solving environments. Synchrony between multiple affect signals and game-based learning outcomes

Synchrony between multiple affect signals and game-based learning outcomes

Elizabeth Cloude, Tampere University, Finland

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Game-based learning (GBL) environments are designed to foster emotions conducive to learning; however, there are mixed findings regarding GBL effectiveness. The unclear findings may stem from methodological and analytical challenges associated with studying emotions as multi-componential constructs. Traditional approaches often use one data channel and inferential statistics, which limit our understanding of the multiple components that underlie emotions during

GBL. Non-linear dynamical systems (NLDS) methods offer a means to assess emotions as a multi-componential system during GBL. In this study, we merged NLDS theory with the component process model of emotion to examine the degree of synchrony between two emotion components during GBL--specifically, facial expressions and heart rate variability (HRV)--to assess its relation to knowledge and learning. Data were collected from 58 learners (n=58) during GBL, and the results showed a significant improvement in knowledge after GBL. A NLDS technique called cross-wavelet transformation showed there were varying degrees of synchrony between facial expressions and HRV. Neutral facial expressions showed the highest degree of synchrony with HRV, followed closely by happiness, anger, and HRV, while fearful expressions and HRV showed the lowest rate of synchrony. However, there were no relationships between synchrony of facial expressions and HRV with prior knowledge, post-test scores, and learning gain. This research contributes to the field by demonstrating how multiple emotion signals synchronize during GBL and its relation to learning and knowledge. Implications of this work offer opportunities to leverage NLDS tools to study emotions as a multi-componential phenomenon.

Using eye tracking to support professional learning: A case of aviation pilots

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Bram De Wever, Ghent University, Belgium

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In an authentic flight simulator, the instructor is traditionally located behind the learner and is thus unable to observe the pilot's visual attention (i.e. gaze behaviour). The focus of this article is visual attention in relation to pilots' professional learning in an Airbus A320 Full Flight Simulator. For this purpose, we measured and analysed pilots' visual scanning behaviour during flight simulation-based training. Eye-tracking data were collected from the participants (N=15 pilots in training) to objectively and non-intrusively study their visual attention behaviour. First, we derived and compared the visual scanning patterns. The descriptive statistics revealed the pilots' visual scanning paths and whether they followed the expected flight protocol. Second, we developed a procedure to automate the analysis. Specifically, a hidden Markov model (HMM) was used to automatically capture the actual phases of pilots' visual scanning. The advantage of this technique is that it is not bound to manual assessment based on graphs or descriptive data. In addition, different scanning patterns can be revealed in authentic learning situations where gaze behaviour is not known in advance. Our results illustrate that HMM can provide a complementary approach to descriptive statistics. Implications for future research are discussed, including how artificial intelligence in education could benefit from the HMM approach.

Yarbus Revisited: The Webcam Edition

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This study explores the viability of webcam-based eye-tracking as an alternative or adjunct to traditional eye-tracking methods in educational research. Replicating Yarbus's seminal study, participants viewed a painting under varied instructions while their gaze patterns were recorded with their webcams using the iMotions platform. Out of 53 participants, 26 yielded usable data. We compared eye-tracking metrics for two different instructions: (1) estimate ages and (2) remember positions of people and objects. The painting was divided into four AOIs of equal size. For each AOI, fixation count and fixation duration were calculated. In addition, the GINI coefficient (GC) was calculated per instruction which is a measure of inequality of gaze distribution. Results from mixed effects models revealed significant differences in fixation counts and durations for some AOIs between the two instructions. In addition, the GC showed a significantly higher inequality in gaze distribution for age estimation compared to recall of positions of people and objects. Findings are in line with results from traditional lab studies. The findings support the utility of webcam-based eye-tracking in replicating established links between gaze and task demands, offering potential for wider application in online experimentation within educational sciences.

Designing a feedback dashboard for primary and secondary education via educational design research

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From 2023-2024 onwards, standardised tests for Dutch and mathematics are introduced in primary and secondary education in Flanders (Belgium). The main purpose of these tests is to foster school development and improve educational quality. An inter-university consortium designs the tests, coordinates the implementation, administration and analysis of the results, and provides digital feedback to the school principals, teachers, pupils and parents. As part of the consortium, our aim is to develop a high-quality, relevant, accessible and user-friendly feedback dashboard to disclose the results of the Flemish tests to the different user groups, paying attention to the feedback dashboard's content and design. In order to address this goal, a mixed-methods approach was set up in line with Educational Design Research (Phillips & Dolle, 2006).

During the first project year, a design framework was synthesised through desk research, expert interviews, and focus groups with principals and teachers. During the second project year, the design cycle continued to arrive at a first design prototype of the feedback dashboard. In the third project year, a selection of schools participated in a study to calibrate the tests and received their

results through the dashboard. A large-scale user research, including online surveys, focus groups, and think-aloud sessions, informed improvements to the feedback dashboard and adjustments to the design framework.

During this presentation, we will present the results of our large-scale user research, how they informed adaptations to our design framework, and the theoretical and practical insights gained.

Holistic models of image perception: Can they be used to analyze eye movements during code reviews?

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Despite being a well-structured discipline, software engineering is currently missing domain-specific models and theories when it comes to eye tracking research. Therefore, it is advisable to use suitable approaches from other domains (such as psychology and medicine), which are more experienced in this field of research. In the case of this study, holistic models of image perception were used to analyse and interpret eye movements during a code review.

23 participants (15 novices and 8 experts) took part in this study. The participants' task was to review 6 short code examples written in C programming language and to identify possible errors. During the experiment, their eye movements were recorded with an SMI 250 REDmobile. Additional data was collected through questionnaires and retrospective interviews.

The analysis was focused on whether the holistic models of image perception were suitable for code reviews and whether the relevant eye tracking metrics showed similar results as in radiology or psychology. In addition, it was surveyed if certain eye movement patterns can be found in the data and which purpose they fulfil.

The results showed that holistic models of image perception provide a suitable theoretical background for the analysis and interpretation of eye movements during code reviews. The assumptions of these models were particularly evident for expert programmers: their approach is divided into different phases with characteristic eye movement pattern. It is best described as switching between scans of the code example (global viewing) and the detailed examination of errors (focal viewing).

Eye movement modeling examples in software engineering - The expert's view

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This study investigates the impact of eye movement modeling examples in software engineering education. Software engineering is a highly visual domain. The daily tasks of a software engineer (e.g., formulating requirements, creating UML diagrams, or conducting a code review) require in many cases the use of certain visual strategies. Although these strategies can be found for experts, it has been observed in different eye tracking studies that students have difficulties in learning and applying them. To familiarize students with these visual strategies and to provide them with a better understanding for the cognitive processes involved, a total of seven eye movement modeling examples was created. The seven eye movement modeling examples cover relevant parts of an introductory software engineering lecture; they are focused on typical situations in which visual strategies are applied. The results of a questionnaire-based evaluation show that students consider the eye movement modeling examples as useful, feel supported in their learning process, and would like to see more use of them in the software engineering lecture. Furthermore, the students suggested that eye movement modeling examples should also be used in other lectures.

How do trait and state mathematics anxiety affect performance? An analysis with EDA and eye-tracking

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Mathematics anxiety (MA) is subdivided into trait and state MA. While it is well known that MA and mathematics performance are related, but it is not clear to what extent trait and state MA are differentially related to mathematics performance in specific learning situations. This study investigates the relationship between trait and state mathematics anxiety (MA) and processing efficiency on item level, using a combination of self-reports and two real-time measures. Participants completed addition problems while their EDA and eye movements were monitored. Linear mixed models were used to predict processing efficiency, revealing that trait MA significantly predicted processing, but only if state MA was not included as predictor. When entering state MA, trait MA was not significantly related to processing efficiency. These findings suggest that trait MA may be associated with general performance measures, while state MA could relate to more specific performance indicators like eye movements. Combining different real time measures offers insights into the differential effects of trait and state MA on performance in specific situations. The study emphasizes the importance of considering both components of MA and employing multiple measures for a comprehensive understanding of its relation to performance.

Students' situational motivational beliefs and physiological arousal in collaborative learning

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Current academic motivation research emphasizes the situational, contextual, and process-sensitive nature of motivation. However, evidence on changes in students' motivational beliefs during learning situations, particularly in the context of collaborative learning, is lacking. Capturing these dynamic changes requires novel methods that can indicate students' motivation unobtrusively throughout the learning process. This study aims to investigate how students' situational beliefs of expectancy for success, task value, and emotional costs are reflected in their physiological arousal during collaborative learning. The participants were 95 secondary school students who performed a science task in 31 small groups. The students' situational motivational beliefs were collected with a repeated self-report before, three times during, and after the task. Electrodermal activity was recorded to indicate the students' physiological arousal during the task. The results revealed that the students' situational beliefs of attainment value, expectancy for success, and emotional costs were significant predictors of physiological arousal: attainment value and expectancy for success positively predicted arousal, while emotional costs negatively predicted arousal. A negative interaction effect was found between attainment value and expectancy for success: when the students had lower expectations of their group's success, the effect of attainment value on arousal increased. The results provide novel evidence on the role of students' situation-specific motivational beliefs in their physiological responses during learning. Moreover, the study showcases the potential of physiological measures as an additional modality for helping to understand situational motivation, which is still relatively hard to capture unobtrusively during learning, contributing to methodological advancements in academic motivation research.

Co-design of online teacher professional development courses – Findings of a development project

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Over the last ten years, there has been a growing interest in online teacher professional development (oTPD). Although many oTPD courses have been launched in recent years, there is still little known about best practice in the design, implementation, perception and learning outcomes of oTPD models. In general, the central prerequisite for the sustainable effectiveness of professional development programmes is to link scientific content with practical classroom examples and thus to contribute to linking theory and practice. Co-constructive collaboration

between experts from academia and the school sector in the design and implementation of professional development programmes is therefore desirable.

Against this background, online courses for teachers were designed, produced, and comprehensively evaluated in the context of the project at hand. The courses were developed by a total of 29 tandems, each consisting of a lecturer from the Universities of Teacher Education involved in the project and a mentor teacher. After creating their course, the lecturers and mentor teachers were asked in guided interviews about their cooperative work and how they and their course benefitted from their cooperation. The interviews were recorded, transcribed, and analysed by means of qualitative content analysis. The results show that the cooperative work is rated very positively. Moreover, the lecturers and mentor teachers not only benefit, among others, professionally and due to their cooperation, but also consider their course to profit considerably due to the theory-practice link.

The presentation will outline findings from the evaluation and discuss ideas for the co-design and implementation of oTPD courses.

Exploring the Use of Complexity Science for Revealing Emergent Learning Processes via Trace Data

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Learning is a complex process that is often difficult to measure, track, and analyze as it dynamically changes over time. Trace data can afford researchers the opportunity to capture the learning process as it occurs in real time, collecting data across several time scales. However, theoretically situating and analytically approaching learning and trace data through traditional methodologies is challenging as most learning theories and statistical analyses do not account for the dynamical shifts in processes and behaviors that may occur over time where a simple perturbation ripples throughout subsequent learning. Complex Systems Theory (CST) provides a promising solution for capturing, analyzing, and interpreting these fluctuations captured within trace data across learning contexts. CST allows researchers to quantify the functionality of a system according to the degree of repetition of learning processes over time where there is a balance between novel and repetitive learning behaviors. However, little is known about how to identify when a learner transitions in and out of functional system behaviors. This paper examines the affordances of CST as we utilize trace data to identify the fluctuation of functional and dysfunctional behaviors and provides implications for when to intervene when dysfunctional behaviors persist.

Between Pixels and Paper

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Aims: This study maps differences in note-quality, cognitive levels of processing and learning outcomes between different types of note-taking when learning from interactive videos

Methods: 15 Higher education students participated in our study in a within-participant design. Participants watched three videos under three different note-taking conditions (order was counterbalanced): No note-taking, longhand note-taking, PC note-taking.

Results: Results suggest differences regarding the quality of notes between paper and PC note-taking. Regarding cognitive processing, no differences were found regarding the type of information participants focus on, but participants process content deeper when taking notes on paper. Taking notes on paper also led to increased recall quantity and quality, and both PC and paper note-taking led to increased outcomes on open questions compared to not taking notes.

Conclusions: Our study suggests that the merits of note-taking and differences in note-taking mediums (pen vs PC) might depend on contextual factors and the pace of lectures.

Physiological Traces of Learners' Help-Seeking and Tutor Support in Immersive VR Environments

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This study explores the physiological traces (electrodermal activity, heart-rate) before help-seeking occurs as participants are learning in an immersive virtual reality simulation. Simulations are an important tool for healthcare education, as they allow learners to practice critical skills in a safe environment without real-life consequences of their actions. However, when learning in virtual reality, learners are fully immersed in the learning environment, which separates them from their tutor, who is outside of this virtual environment. As learners progress through the simulation, they can face trigger moments, which require them to activate SRL processes, such as metacognitive monitoring and control in order to progress. This can happen, for example, by employing help-seeking strategy. In real-life situations, this help-seeking still involves a human tutor, as intelligent agents in virtual reality simulation are not (yet) widely available. Multimodal data was collected from 20 participants: think aloud data, heart rate data and electrodermal activity measures. Results showed that in the 5 s window before help seeking, learners experienced a higher electrodermal activity than outside these windows. This study contributes to the multimodal evidence that identifies trigger moments for regulation of learning.

What helps you? Individual differences in which learning behaviors are relevant for achievement

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This study investigates whether students differ in the learning behaviors that help them learn better (e.g., some students may benefit from regular learning, others from duration) and how these differences relate to students' prior knowledge, personality traits, and motivation. Utilizing an intelligent tutoring system for English as a foreign language, we collected and analyzed behavioral trace data from 507 German 7th-grade students during the school year 2021/22. We trained several state-of-the-art machine learning models to predict English performance based on learning behavior. The best-performing machine learning model, XGBoost, explained 41% of the variance in English performance. To understand the relevance of each learning behavior variable for the model's prediction, we generated explanations with the explainable AI method SHAP. Based on these explanations, we identified three student clusters for whom various learning behavior indicators were equally relevant for predicting later performance. Subsequent analyses revealed that students from the three clusters differed substantially in their prior knowledge and motivation with a high prior knowledge, average motivation cluster, a low prior knowledge, average motivation cluster, and a low prior knowledge, low motivation cluster. Overall, we found that different learning behaviors are of varying importance for learning gains and that this different importance is related to students' prior knowledge, motivation, and personality traits. The results stress the need for tailoring learning systems to individual students to better allow for and support personal learning experiences.

Emotional cohesion and collaborative problem-solving between competitive and non-competitive teams

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Collaborative problem-solving (CPS) is an epicenter of emotional activity; yet, the role of these processes within CPS contexts is poorly understood. There is limited knowledge on how competitive and collaborative dynamics within teams influence emotional processes during CPS and its impact on CPS outcomes. Thus, the objective of this research is to understand the role of emotional processes at the individual- and team-level on CPS outcomes between competitive and non-competitive teams with a multi-player, CPS game. One hundred and fifty-two ($n=152$; 52 teams) high-school students' facial expressions of anger, disgust, happiness, sadness, fear, and surprise were captured using videos during CPS with a multiplayer game. Participants were randomly assigned to a team of three in one of two conditions: within-team competition (WTC) or no within-team competition (NWTC). The NWTC group had higher CPS outcomes than the WTC group. The WTC group expressed more consistent fear at the team-level and a higher percentage of shared sadness than the NWTC group. Regardless of the condition, team-level outcomes were

associated with anger differently depending on its level (individual or team), whereas only team-level happiness, sadness, and fear were associated with team-level outcomes. The implications of this work suggest that socio-emotional cohesion within teams is influenced by competitive and collaborative dynamics, which had a differential impact on CPS team outcomes.

Reading strategies in poor decoders: a webcam-based eye-tracking study

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An important aspect of reading comprehension is using reading strategies. A distinction can be made between selective reading and intensive reading. In previous research, poor decoders reported using fewer reading strategies. However objective differences in reading strategies are not evidenced yet. This can be done using eye-tracking. To understand which reading strategies children used, whether they differed between poor, average, and good decoders, and how they related to reading scores, we measured 273 5th and 6th grader's eye movements during reading assignments that elicited either intensive or selective reading. Children's attention allocation within the text was indicative of their reading strategy. We used webcams to measure eye-movements, to increase ecological validity. Results showed that, across both types of assignments, children usually showed an intensive reading strategy. The relation between reading strategies and scores seemed to differ between poor, average, and good decoders. Poor decoders who read more selectively in the selective assignments scored lower, raising the question whether they focused on the correct paragraph. Average decoders benefitted from reading the whole text for the intensive assignments suggesting active building a mental model of the text. The fact that mostly intensive reading strategies were used suggests that children may not yet have sufficient knowledge or self-regulatory skills to implement a different strategy. However, differences between various levels of reading comprehension suggest otherwise. This study showed the usability of webcams to measure reading strategies, even in children, and provides the next step in disclosing children's reading strategies in realistic educational contexts.

Intraindividual dynamics of students' executive functioning: accuracy and response-time

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Following a meta-cognitive perspective on executive functioning (EF), we go beyond cross-sectional studies to investigate intraindividual dynamics of accuracy and response-times. Forty-three 8-11 year-old children (MAge = 9:11 years, 48.8% boys) completed the Hearts and Flowers task on

tablets twice per school-day during two weeks ($n = 651$). The Mixed block taps into working memory, inhibition and switching elements of common EF. Specifying Dynamic Structural Equation Models (DSEM), by adjusting time-lags, specifying individual differences in residuals, and random state-accuracy-on-response-time-slope, using semi-informative priors, novel findings emerged. State-accuracy and state-response-time were relatively stable over time. There were individual differences in state-accuracy-on-response-time-slopes, indicating that children with a relatively lower trait-accuracy performed more accurately when they slowed down. In contrast, children with a relatively higher trait-accuracy performed at the same level of accuracy regardless whether they accelerated or decelerated. An intraindividual approach to EF provides an important window into cognition in a naturalistic school context.

Is Big Brother watching or helping me? Students' thoughts about eye tracking to support learning

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Ellen Kok, Utrecht University, Netherlands

Eye-tracking data holds the potential to inform teachers about students' learning and could be more widely applied to improve higher education. However, ethical concerns arise, especially with webcam-based eye-tracking data collected in students' homes. This paper investigates students' perceptions of the ethical implications of being eye-tracked and having their data used for learning analytics. Using Tzimas and Demetriadis' (2021) six ethical dimensions for learning analytics—Privacy, Transparency, Labelling, Data Ownership, Algorithmic fairness and accuracy, and the Obligation to Act—we explore under what circumstances students would consent to their eye-tracking data being used to improve education. We conducted interviews with 13 higher education students, sampling for diversity in study background, university, and experience with eye-tracking. Students were provided with information about webcam-based eye-tracking and a topic guide covering the six ethical dimensions. Interviews were recorded and transcribed using Amberscript software, with analysis conducted using NVivo software. Preliminary analyses indicate that Transparency and Privacy are the most commonly mentioned dimensions. Regarding Algorithmic fairness and accuracy, students express concerns about whether data accurately represents the learning of all learners. Furthermore, students are apprehensive of negative side effects, such as a loss of autonomy, less personal interaction in their education, or skewed power dynamics between students and teachers. This project aims to understand students' perspectives on the responsible use of webcam-based eye-tracking data, addressing crucial ethical considerations in education.

Toward emotion-adaptive support in Adaptive Learning Technologies for early mathematics education

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Adaptive Learning Technologies (ALTs) are widely used in early mathematics education, offering real-time assessment of learners' performance and immediate feedback to learners. Yet these technologies often ignore that feedback can evoke emotional responses in learners. Understanding these emotional responses is crucial as they can both enhance and impede learning and this can vary between students. This study therefore investigated young learners' emotional responses to immediate feedback during mathematics tasks in an ALT. With a multimodal approach, we captured students' physiological arousal (electrodermal activity), experiential responses (self-reported valence), and behavioural responses (observed emotion type). Results indicated that feedback triggers peaks in physiological arousal at an above-chance level. Regarding experiential responses, more positive than negative valence was detected after both feedback on success (FOS) and feedback on failure (FOF). Regarding behavioural responses, more negative than positive emotion types were observed after FOF, but for FOS there were no differences. Latent profile analysis revealed four distinct profiles for FOF and three for FOS, indicating that most students showed minimal emotional response to FOF and moderate arousal and positive valence after FOS.

Metacognitive AI Agent in Collaborative Groups – Recognition of Triggers for Regulation

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Learners' metacognitive abilities play a pivotal role in solving wicked problems in groups. In successful collaboration, learners engage in socially shared regulation of learning (SSRL) by monitoring and enacting regulatory strategies in response to cognitive or emotional obstacles. Despite knowing the importance of SSRL in collaborative learning, when obstacles emerge during tasks, the ability to identify and strategically optimise learning is hard; learners should be made aware of and supported in these situations. In this study, an SSRL theory guided metacognitive artificial intelligence agent (MAI) was used to detect cognitive and emotional obstacles, called regulatory trigger events, and prompt learners during these moments to invite for SSRL in groups. Video and audio data from pre-service teachers (N=52) was used to study the reciprocity between MAI prompts, the situated nature of trigger events, and participants' regulatory responses to those prompts. In particular, metacognitive monitoring and regulation emerging on a group level was studied by coding regulatory initiation and possible adaptation visible among the participants. The qualitative analysis revealed that while many triggers began as socio-cognitive (task or content related challenges), they led to socio-emotional triggers (such as frustration). Students recognised a regulatory trigger and responded with regulatory acts after half of the prompting situations, but these led to SSRL in only seven cases out of the fifty-eight MAI prompts. The findings suggest that SSRL necessitates shared monitoring from learners in response to MAI prompts. The study sheds light on the role of human-AI interaction in supporting strategic and adaptive collaboration.

Eye read you! How gaze displays of reading strategies can inform teachers' reading instruction

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Reading is a covert process, hence, it is difficult for teachers to monitor their students' progress or strategy use. Gaze displays can visualize learners' reading strategies to support teachers' instruction. We investigated whether and why teachers use gaze displays in addition to reading comprehension scores to inform their instructional decisions.

We surveyed 107 teachers from primary (n=72) and secondary (n=35) schools. They reviewed 16 vignettes that included reading comprehension scores and/or gaze displays showing reading strategies. The vignettes varied by assignment type (summarize/search), reading strategy (intensive/selective/not provided), and reading score (pass/fail/not provided). Teachers identified the reading strategy, decided whether to provide instruction, and explained their rationale. Their attitudes towards gaze displays were also surveyed.

Teachers completed 1342 vignettes, with 134 trials excluded because of incorrect strategy identification. Instruction was provided almost always when learners failed the assignment. For summary assignments, instruction was more likely with a mismatch (OR=4.18) and a match (OR=2.20) strategy than with no gaze display when students passed. For search assignments, instruction was more likely with a mismatch (OR=6.55) than without gaze display. Teachers' decisions were primarily influenced by scores but also by strategy information. Most teachers (72.9%) found gaze displays helpful, despite some practical concerns.

The study showed that teachers primarily used scores to decide on giving instruction, but gaze display information also played a crucial role, especially for mismatching strategies.

Misinterpretation of gaze displays highlighted the need for better training. The findings underscore the potential of gaze displays in reading education.

Physiological Synchrony in Interpersonal Agency: Case Study of Collaborative Problem Solving

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Purposeful behaviours of student agency are essential in collaborative learning. As agentic behaviour is based on psychological mechanisms, it is also reflected in a person's inner, psychophysiological arousal. As agency is a relational process, physiological synchrony (mutual shifts in physiology) may provide unique insights into the role of agency in collaborative learning. This research uses two approaches to understand the continuous connection between physiological synchrony and agency behaviours. We use skin conductivity to measure physiological arousal both in reaction to context (phasic) and the level of intensity (tonic). As a novel parallel measure, we use coding of agency behaviours as a quantitative measurement to understand collaborative group work of four students during one lesson. Signal similarity analysis of a maximum time lag series (MTLC) by dynamic time warping (DTW) revealed moments of intense collaboration. The results indicate that students' agency is reflected in physiological synchrony. During collaborative group work, the students displayed high physiological synchrony, with students' tonic electrodermal activity (EDA) correlated with agency behaviours. The benefits of analysing skin conductivity and video analysis of agency behaviour together further the interpretation of physiological synchrony during social processes. Both physiological reactions and contemporary interpersonal analyses display a symbiotic relationship worthy of further investigation.

The temporality of epistemic, procedural, and social dynamics in collaborative problem-solving

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Collaborative problem-solving (CPS) in higher education is complex and multifaceted. Despite substantial research on students' CPS processes (e.g., epistemic, social, and procedural), these dimensions are often studied in isolation using unimodal datasets, ignoring their intertwined and temporal nature. This paper argues for multichannel data (e.g., survey, audio and video recordings) and a combined analytical approach to capture the complexity of CPS processes more richly and to allow for a nuanced analysis of high-level collaborative patterns. The empirical context is a semester-long master's-level legal technology course conducted online (via Microsoft Teams) and face-to-face (through boot camps and physical lectures). The dataset comprises approximately 25 hours of video data from 12 groups across three cohorts (2022, 2023, and 2024). Preliminary results based on Epistemic network analysis (ENA) and data from one group showed that individual students' CPS processes varied across the meetings and the various CPS processes. The study provides insights into the temporality and sequence of CPS processes as they unfold and relate to one another over time and during specific collaborative moments. These insights can be used to create indicators of successful teamwork and CPS, which can be modelled to compute multimodal teamwork analytics to support students through timely and strategic reflections. Methodologically, the study demonstrates how multichannel data sources and analytical methods at different levels of granularity enhance the understanding of epistemic, procedural, and social CPS processes, offering a holistic view of CPS in higher education.

Using physiological online measures to examine measurement reactivity to experience sampling

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Measurement reactivity occurs when the act of measuring influences the participant, a concern particularly noted with the Experience Sampling Method (ESM) due to its frequent assessments that might alter behavior, thoughts, or feelings. The regular interruption by ESM could also potentially invoke stress responses among participants, evidenced by changes in heart rate (HR) and heart rate variability (HRV), which reflect physiological arousal and autonomous nervous system activity. In a study involving 136 high school students aged 17-18, we explored the physiological measurement effect of ESM by continuously monitoring participants' HR, HRV, and metabolic equivalent (MET) through biometric sensors over three days. During these days, participants completed ESM questionnaires six times a day, detailing their current activities and emotional states. Data analysis was conducted using linear mixed models focusing on HR and HRV, examining responses with 5-minute intervals before, during, and after ESM prompts, while controlling for physical movement and study contexts. The results indicated no clear effects on HR; however, significant findings were observed in HRV indices. Very Low Frequency (VLF) and Low Frequency (LF) HRV decreased following ESM prompts, indicating less parasympathetic activity (i.e., less relaxation), with small indices that the drop in VLF might be higher in study moments. These findings point to some physiological measurement effect with indication that the ESM measurement during studying could have a slightly more pronounced effect. Thus, repeated interruptions may cause stress to students, especially if they are concentrating on studying at the time of the ESM beep.

Higher Education Students' Value Tensions and Alignments with Learning Analytics Dashboard

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Sophisticated data and algorithm-based technologies can not only support but also contradict human values. Previous research indicated that learning analytic dashboards design can be misaligned with individual and cultural values and that students' value investigation is necessary for supportive LA. So far little is known about values embedded in learning analytics systems in higher education (HE) and how these values align or contradict the values of their stakeholders. We

investigate students' (N = 12) value alignment and tension experiences in connection to LAD use in HE institution. Results from qualitative content analysis and epistemic network analysis indicate that LAD most strongly concern students' values of Self-Direction, Achievement, Security and Stimulation. Significant value tensions as well as alignments experiences emerge in connection to LAD use. Value tensions are distributed differently between students with different educational backgrounds. Educational students experience significantly more tensions with the investigated LAD than did information technology students. We conclude that values of students from educational sciences are not sufficiently accounted for in LAD design, thus causing contradictory experiences.

Examining Groups' Motivation Regulation in Collaborative Learning: A Multi-Method Approach

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Social context and peers significantly impact students' motivation, especially in collaborative learning, where groups share the responsibility of regulating their learning and motivation together. However, evidence on how students influence each other's motivation through socially shared regulation of learning (SSRL) is limited. This study explores secondary school students' (N=95, 31 groups) SSRL during collaborative learning, examining particularly how groups regulate motivation in social interactions, and how students perceive peer influence on their situational motivation and motivation regulation.

Collaboration was videotaped to capture SSRL and repeated self-reports were collected five times during the task to track students' perceptions of peer influence on their motivation. Stimulated recall interview data were collected to identify students' subjective views on motivation regulation. Chi-square test of independence was used to examine the occurrence of regulation in relation to the task progress. Changes in students' perceptions of peer influence on their motivation during the task were analyzed using linear mixed effect models (LMMs). Interviews were analyzed with qualitative content analysis.

Results show that at the beginning of the task, the groups were more likely to activate regulation of cognition and motivation separately, while the simultaneous regulation of both targets increased later. LMMs indicated that peer influence on motivation varied across the task: students perceived higher influence of the peers in the final phase of the task. In the interviews, the students described how their peers motivated them through the establishment and maintenance of motivating, socio-emotionally positive atmosphere, but recognized only few motivation regulation strategies.

The Impact of Decorative Images on Digital Testing

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Digital testing is expanding (e.g., PISA, TIMMS, CITO, etc.) along with the integration of multimedia elements in it (Scherer, Greiff, & Kirschner, 2017). Though knowledge on multimedia test design remains limited (Kirschner et al., 2016) with first empirical findings showing a clear need for its systematic investigation (e.g., Dirkx et al., 2021). Drawing on the coherence principle from the Cognitive Theory of Multimedia Learning (Mayer & Fiorella, 2021), we assume that adding decorative images to test items – a common occurrence in educational practice – disrupts information processing and hampers testing performance – a phenomenon well established in the context of multimedia learning (Fiorella & Mayer, 2021). This study investigated this effect in multimedia testing on students' test performance, cognitive load, visual attention, and interest. In a mixed-design experiment, 51 eighth grade completed a digital math test with half of the items adhering to the coherence principle and the other half not. Participants self-reported their interest and cognitive load (Paas, 1992). Visual information processing was measured using webcam-based eye-tracking technology. Results showed no significant influence of decorative images on test outcomes, interest, or visual attention, but an increase in cognitive load for test items featuring decorative images. Item-level between-subject analyses revealed effects of specific images on both cognitive load and interest, suggesting that different image characteristics may elicit varying effects (Kerckhoffs, Janssen, Pat-tel, & Jarodzka, *subm.*). These findings emphasize the complexity of interactions between decorative images and cognitive processes and underscore the need for further investigation of multimedia principles in digital testing.

Advancing team collaboration and learning research through multichannel work? A roadmap and showcase

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This study aims to systematically elucidate the significance of adopting a multichannel approach in team collaboration and learning research. First, the systematic scoping review comprehensively describes various modalities that generate process measures and have been combined, such as video observation, speech analysis, physiological metrics, and movement data. By integrating these diverse channels, the unique insights gained and their contributions to the team collaboration and learning literature are presented. Second, to further illustrate the review's findings, we present empirical results from a pilot study that implemented a multichannel assessment of team collaboration and learning. This pilot underscores the practical application of our review, showcasing the integration and analysis of multiple data sources. The output of the

review and pilot includes a detailed discussion of the opportunities, challenges, and ethics associated with each phase of adopting a multichannel approach in a team context. This entails a roadmap addressing key decisions and potential pitfalls throughout the research process, including study scope, channel selection, data collection and storage, data analysis, and result interpretation and presentation. In doing so, this paper highlights the advancements and complexities of multichannel methods, offering valuable guidance for researchers aiming to enhance team collaboration and learning studies through responsible and technology-rich process measures.

Posters

How students' self-efficacy and data-literacy relate to perceived support from learning analytics?

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Learning analytics (LA) has the potential to support higher education students on their study paths by aiding study planning. However, most studies have focused on supporting student learning within course level. For LA solutions to support students, the design choices of dashboards should consider students' self-efficacy beliefs and data-literacy skills, and thus varying interpretations of feedback on their performance. The study explored how students with different self-efficacy and data-literacy skills perceive support from digital tools throughout one academic year. To achieve this, we first created student profiles based on their data literacy and self-efficacy skills. Then, we investigated students' perceived support for study planning from a LA dashboard. We also analyzed qualitative questionnaire data to better understand student experiences on aspects that affect the received support. We created two profiles: students with higher self-efficacy and data literacy (PHigh) and those with lower skills (PLow). Students in PHigh reported receiving more support from the LA dashboard compared to peers in PLow. Students raised concerns of potential bias, misinterpretation of visualizations and comparative information affecting one's self-efficacy beliefs negatively. Our results indicate that meaningful use of LA requires skills from students thus running into risk of discriminating those with lower skill levels. Our study raises concerns of ethical development and use of emerging technologies. It emphasizes the technology-related skill-development of higher education students to ensure equality in data-supported learning.

Evaluating the Impact of Authentic Learning on Student Competencies in Public Health

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This study rigorously examines the impact of authentic learning on student competencies within the dynamic field of public health education at Tampere University, Finland. Employing a comprehensive mixed-methods approach, we meticulously compared cohorts of students immersed in authentic learning experiences with those undergoing traditional instructional methods. Encouragingly, our preliminary findings unveil substantial enhancements across key domains including critical thinking, problem-solving, and collaborative skills among students engaged in authentic learning. Additionally, qualitative data underscored a marked increase in confidence levels and a deeper comprehension of real-world public health challenges among participants in authentic learning contexts. These promising results strongly suggest that authentic learning holds immense promise in better equipping students for the multifaceted demands of

professional practice in public health. However, the study advocates for further research endeavors to elucidate the enduring impacts of authentic learning and to identify best practices for its effective implementation. By contributing empirical evidence to the ongoing discourse on fostering authentic learning and community engagement within public health education, this evaluation aims to inform and inspire transformative pedagogical practices in the field.

Does TPACK-oriented teacher training change how teachers use an ITS? Learning Analytics on an RCT

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The digitalization of teaching is often viewed as a promising prospect. Intelligent tutoring systems (ITS), for example, can create great opportunities for individualized learning. However, their use in schools is not trivial to implement, as teachers face the challenge of linking individual learning with the ITS back to joint classroom activities. To do this successfully, teachers need Technological Pedagogical Content Knowledge (TPACK). Despite this, ITS are often introduced into the classroom without teachers receiving appropriate training in TPACK. It is therefore questionable whether ITS can reach their full potential in these classrooms.

We argue that combining the introduction of an ITS with TPACK-oriented teacher training leads to greater success in students' language learning than the ITS alone. To test this hypothesis, we are conducting an RCT to demonstrate the added value of supplementary teacher training. To this end, 47 teachers introduced an ITS in their 7th grade English classes at the beginning of February. They

will integrate the ITS system into their instruction until the end of June. Of these teachers, 24 in parallel are taking part in a TPACK-oriented teacher training, which is spread over 2.5 full days plus two online sessions. Through pre- and post-tests and surveys we will compare the development of motivation and performance between the groups. In addition to comparing these outcomes, we also want to use learning analytics to investigate which behavioral differences could be the cause of the hoped-for treatment effect. In a Roundtable we want to present first analyses of that investigation.

Quantifying the impact of student-active learning through feedback collection

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When active student learning activities are introduced extensively into a course, and qualitative feedback (on what has worked well with the designed and executed learning activities and what could be improved further) is elicited at regular intervals through student response systems (SRS) such as Mentimeter, where students respond synchronously and asynchronously, how can the teacher feedback literacy be better informed? When the course has a diverse composition of students in terms of their technical backgrounds, which presents a huge challenge of having to take into proper account the diversity of student learning processes in the set up of a variety of learning activities, how can it be checked if the learning activities serve all students equally well or if they benefit some students more than others? The objective of this poster session is to discuss these challenges encountered in a STEM course that has an annual enrollment of around 100 students, where extensive activity-based instructional and learning mechanisms (ABILMs) have been recently introduced. The goal is to figure out how SRS-based student feedback be used for a formative assessment of a teacher's success in facilitating student learning? Note that the focus here is on the formative assessment of teacher's demonstrated competence and not the formative assessment of student's assimilation of intended learning outcomes.

Student progress in self-paced mastery learning with transparent tests

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Self-paced mastery-learning can give the students more control of their own learning and allow each to learn in the pace that suits them the most. Some may fear that this causes a loss of control for the teacher, as there is no longer a joint progress plan followed by all students in the class. A potential advantage of mastery learning, however, is that the frequent fine-granular tests give better insight into the progress of the students – first and foremost to the students themselves, but also to the teacher. In this paper we report on the design, delivery, and follow-up research of a mastery learning course at Anonymous University which took testing to an even more fine-granular level than usual by allowing students to do formative practice tests drawing questions from the same banks as the summative module tests. With self-pacing there were no plenary lectures, instead digital learning resources plus a compulsory weekly seminar where students could work together

with others currently at the same level, for instance jointly trying to solve a formative practice test. Our research questions are, (RQ1) to what extent did the testing approach used in this course help students gain insight about where they stood, and (RQ2) what information could the teacher gain about student progress, both pertaining to interventions along the way and improvement of the next offering of the course?

An Educational Perspective on Eye Tracking in Engineering Sciences

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The Eye Tracking in Engineering Sciences (ETES) course at OTH Regensburg integrates eye tracking technology with empirical research methodologies in an innovative educational model. Aimed at Master's students, this course combines theoretical learning with practical applications, allowing students to develop skills in experiment design, data analysis, and scientific writing. The course, delivered in block format, covers 5 ECTS over 150 hours. It challenges students to conduct eye tracking studies, analyze data statistically, and present findings in a scientific paper format. This program notably bridges the gap in traditional engineering training by emphasizing empirical research, often overlooked in technical disciplines. A key feature of the ETES course is the pair-teaching method involving engineers and psychologists, which fosters interdisciplinary learning and enhances student engagement through dialogue-based instruction. This method has proven effective in teaching complex concepts such as statistical analysis and empirical study design, preparing students for advanced research roles in engineering and beyond.

Primary school students' online inquiry behaviour- what does log data indicate?

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This paper addresses primary school students' online inquiry behaviour concerning time allocation and performance indicators like quality of the written synthesis. A closed learning environment captured the log data for the used time indicators for the six online inquiry phases (assignment, search, SERP, select relevant pages, snippets, synthesis) and the three performance indicators. The primary education pupils used over 70% of their process time for two phases, working on the pages and writing the synthesis. Within a quasi-experimental design both the intervention and the control group used less time in the post-test than in the pre-test. Both groups allocated statistically significant more time on the writing synthesis phase in the post-test than in the pre-test. Nevertheless, the intervention group outperformed the control group by allocating time on the synthesis phase. With regard to the performance indicators, the quality of the synthesis, the intervention group outperformed the control group by a statistically significant margin.

Improving Online Learning: Outcomes of a Redesigned Academic Literacy Course for First-Year Student

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This study examines the impact of redesigning a mandatory first-year course at Tokyo Online University to improve student satisfaction and achievement in an online learning environment. Initially, the course followed an omnibus format, where faculty members introduced their fields, which overwhelmed new students. To address this, the course was restructured from "Essence of Academic Research" to "Academic Literacy," focusing on essential university skills such as report writing, presentations, utilizing online systems, and developing lifelong learning skills.

Data were collected from learning logs and student evaluation surveys before and after the redesign, covering the periods 2018-2021 and 2022-2023. Analysis revealed no significant differences in course completion rates between the two groups. However, a notable increase in student satisfaction and perceived achievement was observed post-redesign, as indicated by significant improvements in evaluation survey scores.

These findings suggest that while the redesign did not affect completion rates, it positively impacted student satisfaction and perceived accomplishment. The study underscores the importance of tailored instructional design in online learning environments to enhance student engagement and success. Future research will explore long-term impacts on retention and graduation rates to provide a comprehensive view of student success in online education.

A Process-oriented Approach to Understand Effects of Automated Feedback using Keystroke Logging

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Recently, feedback research has shifted towards a feedback-as-process approach, taking a learner-centered perspective. Considering the role of learners' behavioral engagement in the effectiveness of automated feedback, we conducted an experimental study, comparing two groups of 10th grade English as a foreign language learners (N = 399). The feedback group received LLM-generated feedback for a text revision. The control group received no feedback. To measure behavioral engagement during revision, we used two indicators obtained from keystroke logging. Both the number of keystrokes (normalized against text length) and the active typing time fully mediated the effect of feedback on revision performance, controlling for initial performance and demographic covariates. Learners who received feedback showed higher behavioral engagement during revision than students in the control group and this was positively associated with the quality of text revisions. Our findings contribute to the understanding of effectiveness of (automated) feedback, highlighting the central role of learner engagement in the feedback process.

When interpreting the results, it is important to note that the measures only reflect quantity, but not quality of text revisions. The meaning of investigating the learners' proactive role as a crucial part of the feedback process using different process measures is discussed.

From Surface to Depth: The Impact of Reflective Questions on Student Learning

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This study investigates whether reflective questions in (bi)weekly quizzes can enhance integrative learning among students at Tilburg University. Integrative learning, defined as the ability to connect, apply, and synthesize information across different contexts (Barber, 2012), addresses the common issue of students' superficial engagement with course material and their difficulty in drawing connections between lectures and courses. Utilizing a Switching-Replications design, the research alternates between reflective and multiple-choice quizzes across two groups of students. Group A engages with reflective quizzes in the first half of the course, switching to multiple-choice quizzes in the latter half, while Group B follows the reverse sequence. The primary measure, the Integrative Learning Scale (ILS; Youngerman et al., 2021), will be administered at three points during the course to evaluate changes in students' integrative learning behaviors. This methodology aims to provide insights into the effectiveness of reflective quizzes in promoting deeper learning and making interdisciplinary connections.

Beyond the Post-Survey: A Dynamic Approach to Measure Epistemic Emotions in Reading Refutation Texts

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This study addressed the gap in research on the role of –often overlooked– epistemic emotions in misinformation refutation, predominantly measured in a post-survey. Our study both replicated and expanded previous work by Trevors and Kendeou (2020). First, our study broadened the participant pool beyond well-educated college students and second a novel dynamic emotion measure called "DynamicEmo" was implemented to capture moment-to-moment epistemic emotions experienced while reading various (emotional) refutation texts, allowing analyses at the text, paragraph, and sentence levels. Our results reaffirmed that positive, negative, and standard refutation texts (vs. non-refutation texts) were effective in enhancing knowledge revision. Using DynamicEmo, we analyzed emotion data at the text level, results revealed that negative refutation texts generally evoked more negative emotions, while positive refutation texts elicited more positive emotions. At the paragraph level, paragraphs presenting inconsistent information in refutation texts elicited activating epistemic emotions. At the sentence level, positive and negative emotional language in refutation texts induced more positive and negative emotions, respectively. Notably, in-the-

moment negative emotions triggered by critical correct-outcome sentences were predictive of knowledge revision, highlighting the significance of emotions reported at a critical part in determining knowledge outcomes. Next to novel insights in the epistemic experience of misinformation and knowledge revision, this study contributed to the dynamic measurement of emotions while reading, providing a method in reading research that can be applied online and offer greater ecological validity.

Eye-tracking students' interpretations of statistical graphs with webcams

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Students' have conceptual difficulties with interpreting histograms. For teachers it is difficult to support students in using correct strategies as students' perceptual strategies when interpreting histograms are not visible to teachers. In addition, students' often find it hard to explicate their strategies. Previous research with dedicated gaze-trackers provided insight into students' perceptual strategies but dedicated gaze-tracking equipment is expensive. Webcams can offer a cheap solution. In our project proposal we answer the question: Which of the strategies that students use on histogram tasks can be measured by a webcam? Data will be collected from 80 secondary and 80 senior vocational students. During recall cued with their own gazes, 2x20 students will be asked to explain what they did. We compare the results of measuring students' strategies through webcams with results from a dedicated gaze-tracker. We expect that current webcams are accurate enough so that we can distinguish between the different types of strategies as found in previous research. The results include specification of task-specific strategy measures and the overlap between webcam-based and dedicated gaze-tracking.

Multimodal learning analytics to explore key moments of interdisciplinary knowledge-construction

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Crina Damsa, University of Oslo, Norway

This study explores how multimodal learning analytics can help identify key moments of interdisciplinary knowledge-construction of student groups in health care education. The empirical setting involves students from various health professions working together on a simulated patient case to practice and learn about interdisciplinary learning and collaboration. We argue that recalling and discussing key moments of interdisciplinary knowledge-construction during a debriefing session after the group work can facilitate the students' learning. However, selecting relevant key moments from group work based on memory is a challenging task for teachers and students that is prone to bias and fragmentation. Addressing this challenge, this study uses multimodal learning analytics based on video and audio recordings from five groups to identify verbal and gaze behaviours that indicate interdisciplinary knowledge-construction. Students' utterances are coded based on the TOCK-IP (Tool to Observe the Construction of Knowledge in Interprofessional teams) and further analysed with Epistemic Network Analysis (ENA) to identify patterns of emerging epistemic networks that indicate intensified knowledge construction during group discussions. Additionally, video data is coded for students' gaze direction and resulting gaze

patterns are matched to the emerging epistemic networks. The integrated results are used to identify and create qualitative descriptions of key moments of knowledge-construction that can be used as basis for feedback on interdisciplinary learning during debriefing sessions with the involved students.

Triangulating (un)successful learning at the process level using multimodal data

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Thomas Martens, Medical School Hamburg, Germany

In the field of self-regulated learning it is as of yet unclear which data streams are suitable for making inferences about internal self-regulatory processes. This study investigates the predictive power of different data streams at different temporal granularities and different modalities on (un)successful learning. One hundred participants spent 45 minutes learning about functional neuroanatomy of the human brain. Their knowledge was assessed with the same questions before and after learning. Data was recorded from multiple sources. Using generalized linear mixed-effects models with learning as a dichotomous outcome variable, we compare the predictive power of person-level Achievement Goals, simple behavioral learning analytics metrics, webcam-based EyeTracking, as well as emotions, difficulty and effort estimates at the page-level. We find that only very simple behavioral metrics contribute meaningful explanatory power towards predicting learning outcomes. Our results show that in our study design and using our specific methods of measurement, predictive power to explain learning is underwhelmingly low. We conclude that identifying adequate data streams for drawing inference about processes of self-regulated learning remains a challenge, and that it may not be possible to achieve high explanatory power using peripheral measures.

Using Interactive Documents to Enhance Active Learning for Higher Education Students

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Blended Learning (BL) has gained widespread attention within educational research, particularly during the pandemic due to the emergency remote teaching. The flipped classroom approach, which involves conducting traditional classroom activities at home and traditional home activities in the classroom, is one prominent BL method as it can reduce teachers' workload and improve teaching quality. A new innovation within the flipped classroom approach are interactive documents (ID). These documents, such as the ID application by FeedbackFruits, allow for embedding comments and questions in a shared document and hence, are assumed to foster active learning for the students. However, despite their growing use, the effectiveness of ID in enhancing active learning has not yet been independently verified. This study aims to evaluate ID's impact on active learning in a university setting through a case study analysis. Data from Canvas and FeedbackFruits will be analyzed to assess the perceived benefits for students. Course selection criteria include the teacher's willingness to enable learning analytics, inclusion of ID in the coursework, and a minimum of 30 students for adequate statistical power. The analysis will

combine quantitative Canvas data, tracking student participation, with qualitative FeedbackFruits data, focusing on variables like the skip rate of question cards and social interaction metrics. Given rising concerns about students passively consuming material, it is vital to explore whether new educational innovations enhance active learning in students and how teachers can best utilize them.

Investigating synchrony in collaborative learning through multichannel data analysis

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Daniel Spikol, University of Copenhagen, Denmark

Hanna Jarvenoja, University of Oulu, Finland

Humans often unconsciously mirror each other's behaviors in various aspects during social interaction, including physical movements (like gestures and posture) and linguistic traits (e.g., syntactic structure or vocabulary). This tendency is particularly significant in collaborative learning (CL) environments, where students with different skill and knowledge levels need to negotiate and reach shared understandings for a joint learning outcome. This study investigates how students synchronize during collaborative knowledge construction (CKC) and group-level regulation of cognition and motivation in their speech and physiological activity. Utilizing multimodal data including video observations, audio recordings, and electrodermal activity (EDA), and mixed methods for data analysis, the research focuses on discerning patterns of synchrony in speech and physiological responses among peers in critical moments of collaboration. The primary goal is to identify reliable indicators of how cognitive, socioemotional, and motivational processes manifest in different data modalities. A pipeline was developed to analyze and combine traditional qualitative video coding with advanced speech recognition methods and statistical analyses of physiological data. The poster presents what data channel indicates what processes and the possibilities that multimodal and multichannel data offer for investigating collaborative learning processes in-depth. We will also discuss implications for what data channels are most useful for studying different processes of collaborative learning, which can, in turn, lead to the emergence of novel AI-based methods for live feedback to learners in face-to-face collaborative situations.

Mapping the classroom: Categorizing 'classroom activities' to improve classroom management training

Senne Van Hoecke, Open University of the Netherlands, Netherlands

A classroom is a complex, unpredictable and highly dynamic environment. Learning how to manage one is a key competence for teachers. Proper classroom management does not only create an effective learning environment for pupils, it also reduces the chance a beginning teacher will feel overwhelmed by the reality of teaching. Training classroom management, however, is not a simple task. The teachers ability to notice (i.e., professional vision) and act accordingly plays a crucial role in classroom management. Practice seems to be vital as previous research has already shown differences in eye movements between preservice and experienced teachers. To allow for more authentic practicing opportunities, an increasing number of Virtual Reality (VR) classroom

simulations have already been made and studied. The results seem promising, though they have to be based on research and authentic settings. The number of eye movement studies in authentic classroom settings, however, remains limited.

Van Driel et al. (2023) collected an extensive dataset of authentic classroom settings with teachers wearing eye trackers. While analyzing these data, recurring 'classroom activities' were identified. This began a process of mapping these 'classroom activities' in all recordings to gain valuable insight into how a course is structured and what happens inside a classroom. The analysis of this annotated data can provide support for the development of more accurate and authentic VR classroom situations and give valuable insight into the professional vision of preservice, beginning and experienced teachers in the classroom. The data analysis is currently still in progress.

Identifying Behavioral Patterns of Knowledge Acquisition in Technical Problem Solving

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Jennifer Stemmann, University of Education Freiburg, Germany

Frank Goldhammer, DIPF Frankfurt, Germany

Carolin Hahnel, Ruhr University, Bochum

With the present work, we develop an approach to identify behavioral patterns that adults show in acquiring operational knowledge about unfamiliar home automation and appliances. By doing so, we aim to better understand processes of everyday technical problem solving (TPS). Interindividual differences in TPS behavior might result from individual preferences about how to acquire operational knowledge (i.e., by exploring the device or by using operating manuals) and how systematically individuals approach the task of acquiring knowledge. However, well-investigated behaviors such as VOTAT may not be transferable to TPS contexts. Hence, a new approach is needed which motivates our research questions that focus on identifying different behavioral patterns that reflect 1) preferences for exploration or manual use for purposes of knowledge acquisition (see Kolb, 2015) and 2) different degrees of systematicity in adults' attempts to acquire operational knowledge. We investigate a sample of 213 adult participants who completed a computer-based TPS test and had the opportunity to acquire operational knowledge about several simulated devices in a self-regulated manner by directly interacting with them (exploration) and using operating manuals. Using log data, we define an action library (mapping knowledge acquisition actions with log events) and a process library (combining actions to processes; see Siadaty et al., 2016) that represent different aspects of systematic and unsystematic exploration as well as manual use. We will report results for identified behavioral patterns. In the discussion, we reflect on our definitions of (un)systematic processes of TPS.

Theoretical Expansion for Self-Regulated Learning: Time Frame and Internalization

Thomas Martens, Medical School Hamburg, Germany

Moritz Niemann, MSH Medical School Hamburg, Germany

Learning processes, especially within the framework of self-regulated learning were primarily investigated by questionnaire. New data sources can be triangulated to understand learning processes much better, for example: eye tracking, physiological data or trace data. These advances in empirical data sources should be accompanied by theoretical expansion. So, this theoretical paper will expand self-regulated learning in two directions: (1) extending motivational time frame and (2) complementing engagement processes with internalization processes.

Expanding of the time frame is especially necessary to understand data generated within a micro-level time frame, like physiological data. Capture of internalization is important to connect data sources of different time frames.

For expanding the time frame three different levels can be defined: A micro-level time frame describing direct learning processes that are associated with solving problems and resolution of confusion. These processes may last for seconds or minutes. A meso-level time frame reflecting processes that are described by most theories of self-regulated learning. These processes may last for minutes, hours, even days or weeks. A macro-level time frame comprising processes that develop over months or years usually covered by personality theories.

The internalization processes can be defined as connection from micro-level to meso-level and finally to macro-level. They can be understood as complementary processes to models of self-regulated learning that typically describe engagement processes.

Empirical examples from different studies will illustrate how to connect data from different time frames to better understand motivational internalization over different time frames, e.g., the impostor phenomenon in higher education.

Enhancing writing process insights with feedback based on keystroke logging

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Mariëlle Leijten, Universiteit Antwerpen, Netherlands

Context: Process-oriented feedback has great potential to promote students' learning process in writing. It increases their understanding of personal writing strategies, promotes self-regulation, and can improve writing performance.

Aim: In this study, we report on the design of a feedback workshop that aims to give 60 master students a thorough insight into their writing processes. The study's purpose is to explore students' perceptions on writing process feedback.

Method: Students performed a written task during class. Their writing processes were logged with keystroke logging software Inputlog. During writing, students had access to the course materials (online learning module with theory and exercises) and were allowed to consult online language tools and generative AI tools to support their writing. In addition, students' self-efficacy for writing and self-monitoring were measured via questionnaires. One week later, students participated in the workshop. They received personal feedback based on the questionnaire data and a feedback report with keystroke logging data (Vandermeulen et al., 2020). Students compared visualisations of their

process to model processes and processes of their peers. Via a personalised dynamic source graph, they explored their source use during writing. Process strategies to make effective use of sources and of generative AI were discussed.

Results: The poster presentation will provide insights into the different feedback materials, tools, and activities. We will evaluate this type of writing process feedback based on a questionnaire measuring the participants' evaluation of the feedback and a subsequent focus group conversation.

Conclusion: This study will provide useful insights to further shape writing process feedback based on keystroke logging measures.

Roundtables

Adaptivity for vocabulary learning in immersive virtual reality

Erika Schlatter, Radboud University, Netherlands

Eliane Segers, Radboud University, Netherlands

There is large variation in the amount of vocabulary that kindergartners have when they enter school (Golinkoff et al., 2019). In addition, there is large variation in the amount of experiences they have (cultural capital; Sullivan (2001)). Kindergartners with poor vocabulary and low cultural capital do not benefit as much from storybook reading as their peers with higher vocabulary and cultural capital. Means to address these differences in vocabulary and cultural capital at school are limited. Therefore, an immersive adaptive virtual reality (IVR) using speech technology may be a means to help these kindergartners gain vocabulary and experiences tuned into their specific needs, which in turn would result in higher gains from subsequent storybook reading on a similar topic. We aim to design such an environment and test its effect. The project takes a design-based research approach and is currently in the conceptualization phase, in which we explore the design of such an environment, following the detect-diagnose-act framework (Molenaar, 2022). To this end, teachers are interviewed on their current vocabulary teaching practices and principles, kindergartners' relevant skills are gauged from teacher reports and observations, and several means of detection including speech recognition, gestures and head movements are being tested. In this round table, I would like to discuss the challenges related to adaptivity in IVR for kindergartners.

Multimodal data for evaluating team leaders' emotion regulation during medical emergency simulations

Annamarie Brosnihan, University of Central Florida, United States

Megan Wiedbusch, University of Central Florida, United States

Daryn Dever, University of Central Florida, United States

Roger Azevedo, University of Central Florida, United States

Dynamical team relationships are quintessential within emergency medicine. Given the gravity and acuteness of medical emergencies, it is crucial to understand team leaders' emotions and their impact on team performance, team dynamics, and patient outcomes. The expectation of team leaders to dynamically and accurately monitor and regulate their affective processes highlights the significance of understanding such processes. While there has been a focus on cognitive aspects of team dynamics, emotion regulation (ER) has been neglected, specifically in the effects of team leaders' ER on other team members, overall performance, and patient outcomes. Traditionally, ER is evaluated using self-report measures but this fails to account for the unconscious behavioral, verbal, and physiological responses to selecting and implementing ER strategies in real time. In this roundtable, we propose a study to evaluate the ER of a team leader using multimodal data within a simulated emergency context in caring for pediatric mannequins presenting acute illnesses. As such, we will examine the contagiousness of the team leader's ER on other team members and its effects on team performance and patient outcomes.

Processing Online Feedback Reports: A Mixed Method Study on Self-Efficacy and Attributions

Charlotte Van Tricht, University of Antwerp, Belgium

David Gijbels, University of Antwerp, Belgium

Vincent Donche, University of Antwerp, Belgium

Online self-evaluation instruments with automated, personalized feedback reports are increasingly prevalent in the transition from secondary to higher education. However, the internal processing of this type of feedback remains insufficiently understood, and providing feedback is pointless when it is not used. Recently, several systematic reviews have concluded that empirical knowledge of the internal processing of feedback is very limited, and calls for more empirical research are made. More specifically, there is a lack of knowledge regarding the influence of self-efficacy - students' self-perceptions about their ability to accomplish a task- and its interaction with feedback attributions, which is consequently the focus of this study. Eye-tracking and Galvanic Skin Response (GSR) serve as the basis for cued recalls, accompanied by a small interview and a self-report questionnaire in order to provide an in-depth understanding. Reading times calculated via areas of interest (AOI) are also used. Analysis is ongoing, and some methodological issues will be the basis for discussion.

Enhancing Group Work Understanding in Science Education through MMLA

Zaibei Li, University of Copenhagen, Denmark

With the development of multimodal learning, collecting multimodal data and computationally analyzing the multimodal data delivers a good approach to evaluating and assisting with teaching and learning activities for teachers and students. This research applies Multi-modal Learning Analytics (MMLA) to investigate and enhance group work in educational environments, particularly in science education. By leveraging high-frequency data collection and machine learning analytics, this study aims to discover the patterns of group work dynamics with effective group collaboration and cohesion. We discuss how various MMLA techniques can capture and influence group work dynamics, fostering environments where students actively engage in scientific tasks. This research seeks to understand the factors that promote effective teamwork and collaborative problem-solving, enrich multimodal datasets, and support the validation and evolution of theory in science education. Additionally, the study explores the capacity of MMLA to enhance group cohesion and collaborative engagement, providing educators with actionable insights into optimizing group activities for more productive educational outcomes.

Weighting of Questionnaire Data and Learning Analytics to Generate Learning Paths

Susanne Staufer, OTH Regensburg, Germany

Florian Hauser, OTH Regensburg, Germany

Over the last few years, personalizing the way of learning is becoming increasingly important. More precisely, online learning platforms are confronted with that challenge caused by the Corona pandemic. Individual learning paths are a suitable form of personalization. Therefore, various algorithms are defined to calculate them. Our working environment is Moodle as a learning management system (LMS) with a special plugin (Röhr et al., 2024). The content inside the LMS is classified into ten learning element categories from which AI algorithms calculate learning paths. The goal of our research work is to find a suitable weighting between learning analytics and questionnaire data. Learning analytics refers to learner behavior inside the LMS, while questionnaire data comes from three defined questionnaires. The first questionnaire asked for learning styles after Felder-Silverman (1988), the second one asked for learning strategies (Wild & Schiefele, 1994), the third and last one collects personality traits. The data-based weighting gets its results from Moodle and its events. We do not use plain Moodle, but rather Moodle with a special plugin adaptation that offers learning element categorizations and learning path calculations. These learning path calculations come from two different approaches: a Bayesian network and a Markov model. The dataset consists of learning analytics from 15 undergraduate students in a software engineering course and could give a possible weighting between learning analytics and questionnaire data as a result. Before evaluating the data, we suggest a 3:1 weighting; 75% could come from learning analytics and 25% from questionnaire data.

Validating the interpretation of process indicators of multiple document reading

Carolin Hahnel, Ruhr University Bochum, Germany

Robin Merchel, Ruhr University Bochum, Germany

Lothar Persic-Beck, DIPF | Leibniz Institute for Research and Information in Education, Centre for international Student Assessment (ZIB), Germany

Frank Goldhammer, DIPF | Leibniz Institute for Research and Information in Education, Centre for international Student Assessment (ZIB), Germany

The round table discusses the need for validation and possible validation strategies for investigating the interpretation of process indicators. To this end, we will report on a study that focuses on the interpretability of log data indicators in digital assessments of multiple document reading. Using an experimental design, we aim to elicit processes in students of either information integration (treatment group) or sourcing (control group) that should then result in group-specific differences in student behaviors and, thus, the process indicators. In addition, we use eye-tracking indicators to cross-validate the interpretation of the log data indicators under investigation. We expect that students in the experimental group will show more frequent changes between texts (as indicated by log data) and relevant text passages (as indicated by eye-tracking), while students in the control group should pay more attention to meta-information (only operationalized through eye-tracking). Data collections for a university student sample and a school student sample are still ongoing but will be completed at the time of the conference.

How can log data contribute to measuring skills in the critical use of online information?

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Philine Drake, DIPF | Leibniz-Institut für Bildungsforschung und Bildungsinformation, Germany

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The Internet is one of the most important information sources for students. Their ability to filter, critically question, and construct coherent arguments from online information is known as Critical Online Reasoning (COR). We assessed students' COR skills using extensive process data including mouse positions and keystrokes. While previous research has used process data in performance tests for comparable literacy constructs (e.g. Tenison & Sparks, 2023), our approach differs from these through open-ended questions, free internet access, and the recording of search behaviour, offering high ecological validity. Accordingly, challenges arise in defining and extracting indicators that allow inferring COR from log data. This roundtable examines the use of log data to create process indicators of COR by analysing the content of existing process indicators and developing new ones specifically for two COR facets, Online Information Acquisition and Critical Information Evaluation (Molerov et al., 2020). For this purpose, data from the first of four measurement points of the project are used (N=423 first-year students from four study programs). Scales for the measurement of different COR facets through process indicators will be established and checked for internal consistency. Data analyses will be completed by the time of the conference. The challenges in forming indicators in unstandardized information spaces will be discussed, as well as possibilities for generalizing the procedure itself and applying the COR indicators to other constructs.

The arousal footprint of self-regulated learning: Theoretically underpinning physiological measures

Héctor J. Pijera-Díaz University of Jyväskylä Finland

Self-regulated learning theory was formally developed in the 1980s. Since then, given the importance of students' active participation in their own learning processes, it has been an intense object of study from multiple perspectives. In recent years, the need for data modalities that can capture learning as a process in real time and the increasing availability of wearable sensors has motivated and enabled the use of physiological measures to study SRL. Such measures capture arousal, or in other words, the degree of physiological activation from different bodily systems. However, the integration of SRL and arousal theories is often missing or implicit in empirical studies. This is a situation similar to when the learning analytics field took off driven by the unprecedented amount of data that massive open online courses made available, but without a proper grounding in learning theories. What is the relationship between arousal and SRL? In this

conceptual work, the role of arousal is explicitly mapped into different SRL models by means of factors such as learning challenges (that trigger SRL and increase arousal), performance, arousal-based models of emotions, and extending the traditional understanding of task monitoring in SRL to include monitoring of one's physiological state. This integrated framework can guide experimental designs when planning physiological data collections to study SRL, but also help interpret the results. With this roundtable discussion, it is expected to find common ground on which different labs could build by mapping and designing their research efforts using online physiological measures of learning processes.

Symposia

Hybrid Intelligence: Human-AI Co-evolution and Learning

Andy (Khanh Xuan) Nguyen, University of Oulu, Finland, Organiser

Barbara Wasson, University of Bergen, Norway, Discussant

Sanna Järvelä, University of Oulu, Finland. Organizer

The advancements in artificial intelligence (AI) and its increased integration into educational contexts indeed offer both novel challenges and opportunities. This evolution calls for a thorough examination of the interactive dynamics between human learning and AI capabilities, particularly within the Hybrid Intelligence (HI) framework for learning and teaching. In this context, HI represents a frontier in, signalling a shift towards more symbiotic relationship where human and AI capabilities are intertwined to achieve complex educational goals, surpassing what either could accomplish alone. However, creating effective human-AI partnerships for HI in education is complex and demands concerted, interdisciplinary efforts.

By examining empirical evidence and fostering cross-disciplinary dialogue, this symposium with three empirical studies explores these efforts, aiming to deepen the understanding of how to design, develop, and integrate HI into learning and teaching: Cosentino et al. present a HI system that integrates human teachers with the AI tool MOVES-NL to facilitate student learning. Roger et al. explore the learning outcomes of studying the human circulatory system with MetaTutor. Järvelä et al. share insights and lessons learned from the design of MAI, an AI agent within hybrid systems that promote socially shared regulation in learning.

This symposium as a whole intends to advocate an in-depth discussion across disciplines and bridge the gaps in the field by showcasing endeavours that leverage HI in learning and teaching. The symposium aims to contribute to the theoretical and practical understanding of designing, developing, and integrating HI in education to augment learning theories and practices.

Behind the scenes: Infrastructure, data collection, and services in learning process research

Leen Catrysse, Open Universiteit, Department of Online Learning and Instruction, Belgium, Chair
Halszka Maria Jarodzka, Open Universiteit, Department of Online Learning and Instruction, Netherlands, Organiser

David Gijbels, University of Antwerp, Belgium, Organiser

Sanna Järvelä, University of Oulu, Finland, Organiser

Maaïke Endedijk, University of Twente, Netherlands

This symposium explores the evolution, design, and application of research infrastructures that facilitate innovative research. The presentations delve into distinct aspects of research infrastructure development, highlighting the need for tailored approaches to accommodate diverse research methodologies and settings. The first presentation focuses on the development of lab facilities specifically designed for psychophysiological research. The discussion emphasizes the

unique requirements of conducting both controlled lab studies and extensive physiological tracking in naturalistic environments. Key insights and practical guidelines are shared to enhance the design, efficiency, and robustness of such lab infrastructures. The second presentation addresses the advancements in eye-tracking technology, which now enable research to extend beyond controlled lab settings into authentic educational environments. The presentation explores the technical, logistical, methodological, and ethical challenges of conducting eye-tracking research in real-world settings. Practical knowledge and strategies are provided to help researchers effectively implement eye-tracking experiments in naturalistic learning environments. The third presentation covers the comprehensive research infrastructure, which supports multidisciplinary studies on learning and interaction. Emphasizing the integration of multichannel and multimodal data collection, rigorous research design, and robust data management practices, the presentation shares over a decade of insights and lessons learned. Together, these presentations offer a holistic view of the contemporary challenges and opportunities in designing and utilizing research infrastructures.

Application of online measures to investigate collaborative learning

Muhterem Dindar, Tampere University, Finland, Discussant

Saswati Chaudhuri, University of Jyväskylä, Finland, Chair

Kshitij Sharma, Norwegian University of Science and Technology (NTNU), Norway, Organiser

Steffi Sassenus, University Antwerp, Belgium

The investigation of human behaviour during collaborative learning, problem-solving (CPS), and performance requires using online measures and multimodal approaches. The goal of this symposium is to discuss how online measures are used in different research contexts to investigate collaborative learning and problem-solving. The first paper investigated collaborative problem-solving in terms of de-bugging performance in a pair programming context among university students ($N = 88$) participating in a programming course. The authors employed a multimodal learning analytics approach to explain debugging performance of the students. The second paper examined the associations between joint visual attention, sustained attention, and cognitive and social CPS skill levels of sixth grade students ($N = 24$) working remotely in dyads. Next, they highlighted the CPS processes of two contrasting cases of dyads, characterized by high and low social skills during specific CPS tasks. The authors used a multimodal approach with screen-based eye-tracking technology, neuropsychological test, and log data to analyse students' CPS behaviours in dyads. The third paper investigated the relationship between team stress, adaptive behavior, and performance in a naturalistic team of students involved in a 360° ship simulation. They integrated electrodermal activity, videos, and expert assessments. These three studies will discuss the benefits, pitfalls, and way forward to improve multimodal approaches used to uncover collaborative processes.

Measuring Learning Processes with Trace Data Through a Complexity Science Lens

Daryn Dever, University of Central Florida, United States, Chair

Roger Azevedo, University of Central Florida, United States, Discussant

Elizabeth Cloude, Tampere University, Finland, Organiser
Laura Allen, University of Minnesota, United States, Organiser

Learning for both individuals and teams is a nonlinear process incorporating several components, such as cognition, metacognition, affect, motivation, and social interactions. These components constantly interact with each other to create emergent and dynamic processes of learning evident through online behaviors captured via trace data (e.g., log files, physiological data). Despite vast literature on learning processes, significant limitations exist in how trace data are analyzed to measure learning processes (e.g., profiling learners, linear theories and methodologies), unable to fully capture and interpret trace data related to the complexity of learning processes. The goal of this symposium is to conceptualize and demonstrate how trace data can be captured and analyzed within advanced learning technologies (e.g., MOOCs, simulation-based training environments, online synchronous education environments) to measure the dynamics of learning processes using a complexity science approach. Although complexity science has a well-established history within the naturalistic sciences (e.g., physics, weather), rarely is learning considered a complex system. Our symposium will provide researchers with a theoretical, methodological, and analytical toolkit for measuring individual and team-based learning processes as a complex system leveraging trace data and augmenting advanced learning technologies. Specifically, Paper 1 will provide researchers with a theoretical teamwork competency framework using a complex systems lens and multimodal data. Paper 2 examines some of the methodological challenges of using trace data to measure online social interaction through a systematic review. Finally, Paper 3 reports on an empirical study and analytical approach to quantifying and predicting lesson enjoyment by examining teacher-student physiological dynamics.

JURE invited symposium: Capturing CAMM processes with online measures of learning

Tiina Törmänen, University of Oulu, Finland, Chair
Tiina Törmänen, University of Oulu, Finland, Organiser
Anne Horvers, Radboud University Nijmegen, Netherlands, Discussant

This symposium brings together studies that use various types of online measures to capture cognitive, affective, metacognitive, and motivational (CAMM) learning processes. The first presentation analyzes keystroke data from students' essays to detect different cognitive and metacognitive self-regulated learning (SRL) processes. Additionally, the study aims to use Natural Language Processing (NLP) models to enable real-time identification of SRL processes, tailoring SRL support to individual learners' needs. The second presentation focuses on workplace teams and explores affective states, goal management, and collaboration assessment in relation to adaptation within socially shared regulation of learning (SSRL). This study uses a mixed-methods approach by combining video observations of SSRL with repeated survey data. The third presentation investigates the relationship between physiological measures (electrodermal activity) and self-report measures of achievement emotions using a psychometric network approach. Together, the three presentations demonstrate how different types of online process methods can be utilized and integrated to detect and better understand CAMM processes in both individual and group learning contexts. The presentations and discussion will address the contributions of these

studies to theoretical understanding, methodological development, and practical applications for learning support.

Invited symposium: A micro-ecological, process-oriented, and multimodal approach to studying collaborative learning

Rogers Kaliisa, University of Oslo, Faculty of Education, Norway, Chair

Anni Silvola, University of Oulu, Finland, Chair

Olga Viberg, The Royal Institute of Technology (KTH), Sweden, Discussant

Crina Damsa, University of Oslo, Norway, Organiser

Hanni Muukkonen, University of Oulu, Finland, Organiser

Collaborative learning is crucial for developing teamwork skills but the complexity of simultaneous behaviours during collaboration poses challenges in studying and supporting these processes (Graesser, Greiff, Stadler & Shubeck, 2020). Recent advancements in data-driven methodologies have expanded the scope of collaboration analysis from unimodal to multimodal collaboration analytical (MMCA) approaches, enabling the collection and analysis of otherwise unobservable data, such as video, audio, and physiological sensors (Schneider, Sung, Chng & Yang, 2021). More empirical studies are needed on the effectiveness of MMCA, particularly from an ecological perspective that considers dynamic interactions at multiple levels, from individual to institutional (Jornet & Damşa, 2021). This symposium presents three studies exploring the potential of Multimodal Collaboration Analytics (MMCA) in advancing our understanding of collaborative learning across various settings, including educational and professional environments. The first study by Anni Silvola and colleagues examines the integration of AI agents in collaborative learning, focusing on how students interact with technology for help-seeking in metacognitive and socioemotional challenges. The second study by Daniel Sanchez explores the use of MMCA to provide multimodal feedback in nursing training simulations. This research demonstrates that precise, contextually relevant feedback can enhance skill acquisition by bridging the gap between self-assessment and actual performance. The final study by Marcella Hoogeboom-Hendriksen explores coordination and stress dynamics in police teams using multimodal analysis in virtual reality, revealing that shared stress impacts coordination and communication effectiveness in high-stress situations. Overall, the symposium underscores MMCA's potential in understanding and improving collaborative problem-solving skills.