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18 November 2026 09:30 - 11:00
Sala polivalent 1
Single Paper
Assessment and Evaluation, Cognitive Science, Learning and Instructional Technology

Eye-tracking

Keywords: Argumentation, Automated Scoring, Digital Learning Environments, Digital Literacy and Learning, Electroencephalogram, Engagement, Eye-Tracking, Feedback and Biofeedback, Large Language Models, Longitudinal Analysis, Primary Education, Reading, Scaffolding, Secondary Education
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Bernadette Charlier, University of Fribourg, Switzerland

Feedback Engagement and Nudging: An Eye-Tracking based Cued Retrospective Recall Interview Study
Keywords: Engagement, Eye-Tracking, Feedback and Biofeedback, Secondary Education
Presenting Author: Roselyne Willems, Universiteit Antwerpen - FWO, Belgium; **Co-Author:**Jonas Willems, University of Antwerp, Belgium; **Co-Author:**Stijn Schelfhout, Ghent University, Belgium; **Co-Author:**Vincent Donche, University of Antwerp, Belgium

Students in secondary education increasingly rely on online self-assessment and feedback tools to support their study choice for higher education, yet the effectiveness of these tools depends on how students engage with the feedback. While prior research has conceptualized feedback engagement as cognitive, emotional, and behavioral, empirical evidence on the real-time processes underlying feedback engagement remains limited. Most studies rely on self-report data, leaving the “black box” of feedback processing largely unexplored. Moreover, experimental research on feedback engagement is scarce, although ‘nudging’ has proven effective in influencing behavior. This study aims to explore in depth students’ engagement with feedback and the role of nudging by combining eye-tracking, GSR, and cued recall interviews within an experimental design in which two types of instructional nudges constitute the experimental conditions. We examine how (1) informational and (2) social-comparison video nudges influence students’ cognitive, emotional, and behavioral engagement with online self-assessment feedback from the Columbus platform. In a lab experiment with final-year students, eye-tracking, GSR, and cued retrospective recall data are integrated. We expect nudges to enhance processing and behavioral intentions, with differential effects depending on academic self-efficacy. The study can demonstrate how online measures provide fine-grained insights into feedback engagement, informing the design of more effective self-assessment feedback tools. Findings from the study will be presented at the conference. We aim to empirically contribute to advance the theoretical understanding of process-oriented models of feedback engagement, and to inform practice and policy by offering evidence-based design principles enhancing feedback engagement in self-assessment feedback platforms.

Children’s Navigation Strategies in Multiple Document Reading: A Longitudinal Eye-tracking Study
Keywords: Digital Literacy and Learning, Eye-Tracking, Longitudinal Analysis, Primary Education
Presenting Author: Carolien Knoop-van Campen, Radboud University Nijmegen, Netherlands; **Co-Author:**Aurora Troncoso-Ruiz, Behavioural Science Institute, Radboud University Nijmegen, Netherlands; **Co-Author:**Siena Vergeer, Radboud University Nijmegen, Behavioural Science Institute, Netherlands; **Co-Author:**Marco van de Ven, Radboud University Nijmegen, Behavioural Science Institute, Netherlands; **Co-Author:**Eliane Segers, Radboud University, Netherlands

Reading in digital environments increasingly requires children to navigate and integrate information across multiple documents, yet little is known about how these navigation strategies develop over time. This longitudinal eye-tracking study examines the development of children’s navigation strategies during multiple documents reading and its relation to reading outcomes and individual differences.Primary school children (Grades 3–4 and 5–6) completed a multiple-document reading task in which they read four digital texts, wrote an integrative essay, and answered comprehension questions. Eye movements were recorded, and navigation behavior was modeled using transition network analysis, enabling a fine-grained examination of navigation processes over time. All data has been collected.Preliminary cluster analyses (on Grades 5–6) identified four navigation strategies: Concept Connectors, Linear Navigators, Basic Navigators, and Apathetic Users (see Figure 1). These profiles differed systematically in reading outcomes, with Concept Connectors and Linear Navigators outperforming the other groups on comprehension, and Concept Connectors showing the highest integration score in the essay. Longitudinal analyses revealed shifts toward more strategic, goal-directed navigation over time. Ongoing analyses, including data from Grade 3 and 4, examine how cognitive and linguistic skills (e.g., decoding, working memory, attention) shape these developmental trajectories, also in children with lower reading proficiency.These findings indicate that navigation is a developing, rather than stable, component of reading proficiency. By using longitudinal eye-tracking data, this study provides novel insights into how navigation processes evolve over time. As such, this paper highlights the importance of explicitly supporting navigation as a core component of digital reading literacy.

Digital Reading Intervention Effects on Cognitive Workload and Engagement
Keywords: Digital Learning Environments, Electroencephalogram, Eye-Tracking, Reading
Presenting Author: Mario Romero-Palau, University of Valencia, Spain; **Co-Author:**Clara Soberats, Center for Mind/Brain Sciences, Italy; **Co-Author:**Marta Vergara Martinez, Faculty of Psychology. University of Valencia, Spain; **Co-Author:**Ladislao Salmerón, University of Valencia, Spain

This study examines the effects of a large-scale digital reading intervention on text comprehension, cognitive workload (CWL), and cognitive engagement during the reading of long expository texts. A subsample of 42 secondary-school students (Grades 9–10) from a 16-week nationwide intervention in Spain participated in a study combining electroencephalography (EEG) and eye-tracking. The experimental group consisted of students who had taken part in the intervention, whereas the control group included students of similar age who had not participated in it. Participants read two texts under two conditions: reading with feedback (questions after each paragraph) and traditional reading (questions at the end). Results showed that differences between the experimental and control groups emerged in the traditional reading condition. In this condition, students in the experimental group achieved higher text comprehension, maintained stable frontal theta activity during the reading episode, and showed a less pronounced decrease in their number and duration of fixations as reading progressed. No differences between groups were observed in the reading with feedback condition, except for a positive trend in beta activity across paragraphs in the experimental group. These findings highlight that the effects of the intervention become evident in less supported reading contexts and illustrate the value of combining EEG and eye-tracking measures to capture changes in CWL and cognitive engagement over time.

Beyond Structure: AI Extraction vs. Few-Shot to Assess Civic Argumentation
Keywords: Argumentation, Automated Scoring, Large Language Models, Scaffolding
Presenting Author: Andreas Emter, University of Potsdam, Germany; **Presenting Author:**Christian Mayer, University of Mannheim, Germany; **Co-Author:**Nils-Jonathan Schaller, Leibniz Institute for Science and Mathematics Education at the University of Kiel, Germany; **Co-Author:**Christin Siegfried, University of Potsdam, Germany

Providing formative feedback on socio-economic argumentation requires immediate, in-the-moment evaluation of student discourse. However, manual grading creates an instructional bottleneck, turning feedback into an "offline" measure delivered long after the learning process. To establish a reliable "online" measure for real-time scaffolding, this study compares two AI-based content extraction approaches: traditional Few-Shot (FS) prompting versus LangExtract(LE), a structured, schema-constrained generation approach.Using the German-language DARIUS learner corpus (N=4,570 student statements), we evaluated both systems against human expert annotations across 11 domain-specific criteria (e.g., efficiency, greenhouse gas emissions). While both systems performed adequately on simple criteria, LE outperformed FS on nuanced categories, showing higher F1-scores (e.g., for "Availability" +0.142; "Operation" +0.126) and superior recall (up to +0.249). Furthermore, reliability metrics demonstrated that LE consistently achieved "almost perfect" agreement with human experts (Krippendorff’s Alpha > 0.81 for most categories), whereas FS dropped to moderate agreement on complex ecological factors.Crucially for online deployment, an ANOVA across multiple validation runs (N=100 each) confirmed that LE produced highly stable, reproducible results ($p > 0.20$ across all categories). While FS was generally stable, it exhibited significant variance in specific complex categories (e.g., "Local Emissions", $p=0.036$). By proving that schema-constrained extraction mitigates the occasional fluctuations of standard prompting, this study validates LE as a robust online measure. It empowers educators and digital environments to track domain-specific reasoning as it happens, enabling immediate, targeted interventions exactly when students struggle to weigh financial and ecological trade-offs.

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Symposium
Learning and Instructional Technology

Making Learning Processes Visible at Scale

Keywords: Artificial Intelligence, Clustering, Educational Technology, Engagement, Learning Analytics, Learning Strategies, Log Data, Longitudinal Analysis, Personalized Learning Environments, Trace Data
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Crina Damsa, University of Oslo, Norway
Organiser: Bruno Poellhuber, University of Montreal, Canada
Discussant: Hanni Muukkonen, University of Oulu, Finland

This symposium examines how new analysis techniques can expand learning analytics for studying learning processes at scale as they unfold. Recent reviews and meta-analyses argue that even though learning analytics interventions can be clearly linked to learning outcomes, there is a need for theoretically grounded and methodologically robust approaches (Zheng et al., 2023; Liu et al., 2025; Bergdahl et al., 2024). This symposium provides insight into and discusses advances and challenges related to the development of innovative and scalable methods to capture, classify and interpret learning processes using learning traces available through LMSs or conversations with AI agent logs.The shared agenda will focus on a robust approach for analyzing log data at scale while transforming them to correspond to student engagement (behavioural and cognitive engagement). The proposed papers explore log data transformation and clustering analysis techniques, as well as some AI-assisted analysis techniques. The first paper uses a longitudinal approach and clustering techniques to identify study trajectories across courses and semesters, linking them to performance, study activity and dropout, on a large scale. The second paper analyzes students' interaction logs with an AI biology tutor, using clustering analysis to deepen the analysis of the ICAP engagement levels of each profile with an AI-assisted procedure. The last paper uses AI to model personal learning environments from elicitation interviews. Overall, the symposium will highlight both the potential and the limits of different analysis techniques that can make learning processes more visible at scale.

A Log-Based Analysis of Student Engagement with an Intelligent Biology Tutor
Presenting Author: Bruno Poellhuber, University of Montreal, Canada; **Presenting Author:**Normand Roy, University of Montreal, Canada

Since the emergence of ChatGPT and the possibility of creating personal and adaptative agents with general generative AI tools (e.g., GPTs or GEMs), a wide range of intelligent agents has been developed. As science courses continue to face persistent engagement and retention challenges and as generative AI becomes increasingly embedded in students' academic practices, intelligent tutors emerge as a promising avenue for sustaining motivation, persistence and achievement. In response to this situation, a multidisciplinary team designed Biotutor, an intelligent tutor based on a user-centred development approach, and deployed it in Fall 2025 across 10 college-level cell biology classes. This study investigates how students used the tutor and characterizes these uses in relation to behavioural and cognitive engagement. Based on log analysis classification, the analysis first identified four distinct behavioural profiles that broadly map onto a continuum of behavioural engagement, with the early profiles also corresponding to the initial stages of cognitive engagement in the ICAP framework. An exploratory generative AI-assisted analysis of conversations from the more complex profiles revealed diverse forms of engagement among the two most engaged groups. A closer examination of selected conversations also showed shifts from one stage to another within a single conversation. Clarification seekers appeared to display stronger cognitive engagement than hyperactive polyvalent users, whereas the latter demonstrated higher behavioural engagement. Future research should validate the categories identified through generative AI-assisted analyses against manually coded human analyses and relate these profiles to questionnaire data on perceived value, tutor adoption and learning outcomes

Capturing Learning Processes at Scale: From the MEPA Method to YEPA AI
Presenting Author: Bernadette Charlier, University of Fribourg, Switzerland; **Co-Author:**Joris Felder, Yllyl, Switzerland; **Co-Author:**Leonard Noth, Yllyl, Switzerland; **Co-Author:**Sandy Ingram, HES-SO, Switzerland; **Co-Author:**Morgane Nissille, Yllyl, Switzerland

This paper introduces an original methodological approach to capture learning processes and make learning visible at scale. Rooted in distributed cognition and Personal Learning Environments (PLEs), it presents the evolution of the manual MEPA (Modelling of Personal Learning Environments) method into YEPA AI, an intelligent technological companion. To address the symposium's focus on capturing, describing, and analysing learning processes, this contribution demonstrates how researchers use YEPA to assist the analysis of elicitation interviews, which can be facilitated by a conversational agent. By employing a custom embedding-based neural classifier trained on 17,500 domain-specific samples, YEPA automates the nuanced classification of learning sequences into the MEPA ontology with 94.0% accuracy. This technological augmentation robustly bridges the gap between deep qualitative process measures and large-scale capabilities. We illustrate this workflow using empirical data from a study of nine university students, comparing their PLEs across different instructional designs. The AI-assisted analysis highlights how the tool reliably identifies constructive or destructive frictions and congruences within the learning practices, visualised through the PLEs emerging from learners' interactions with the institutional learning environments. Ultimately, positioning AI as a reflexive research instrument saves substantial time for researchers whilst fostering learner metacognition, offering original methodologies to analyse learning processes and understand lifelong learning dynamics.

Study trajectories in higher education: A longitudinal large-scale learning analytics approach
Presenting Author: Andres Araos, University of Oslo - IPED, Norway; **Co-Author:**Crina Damsa, University of Oslo, Norway; **Co-Author:**Jan Arild Dolonen, university of Oslo, Norway; **Co-Author:**Rachelle Esterhazy, Oslo Metropolitan University, Norway; **Co-Author:**Asmaa Abusamra, Asmaa Abusamra, Norway; **Co-Author:**Anna Mavroudi, University of Oslo, Faculty of Education, Norway; **Co-Author:**Manuel Olivera Toro López, University of Oslo, Norway; **Co-Author:**Stefan Schauber, University of Oslo, Norway

Early dropout in undergraduate education remains a persistent challenge, often measured through aggregate indicators that obscure the complexity of student progression. This study adopts a longitudinal perspective, conceptualizing progression as trajectories unfolding across semesters, courses, and even study programs. The aim is to identify distinct study trajectories at scale and examine how these relate to academic activity, performance, and dropout. The study draws on large-scale learning analytics, combining longitudinal registry data, digital activity data from a learning management system (LMS), and self-reported data from surveys and interviews.Study trajectories were constructed based on semester registration patterns and study point production across the first three semesters. Clustering techniques identified nine distinct trajectory profiles, representing diverse patterns of persistence, progression, and dropout. These were further grouped into three meta-clusters: trajectories with increased dropout probability, trajectories characterized by stable persistence and expected progression, and trajectories showing continued enrollment with reduced study progression.Findings reveal substantial heterogeneity in student trajectories. While 67.8% of students were retained, only 42.1% achieved expected progression, indicating that retention does not imply persistence. Dropout emerges through multiple pathways, including early disengagement and delayed withdrawal. Digital activity data provides complementary insights, identifying varied engagement patterns, though not consistently aligned with performance outcomes.The study demonstrates the value of longitudinal, data-integrated approaches and clustering techniques for uncovering latent progression patterns, as well as methodological challenges related to large scale analytics. It highlights the need for tailored interventions and robust data infrastructures to support data-informed strategies for supporting student progression and persistence

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Single Paper
Higher Education, Learning and Instructional Technology, Motivational, Social and Affective Processes

Collaborative learning and GenAI

Keywords: Artificial Intelligence, Collaborative Learning, Competences, Educational Technology, Electrodermal Activity, GenAI, Heart Rate (Variability), Higher Education, Multimodal Data, Multimodal Learning Analytics, Physiological Synchrony
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Andy (Khanh Xuan) Nguyen, University of Oulu, Finland

Are We in Sync? Exploring Different Physiological Synchrony Measures in a Cooperative Task
Keywords: Collaborative Learning, Electrodermal Activity, Heart Rate (Variability), Physiological Synchrony
Presenting Author: Monika Donker, Utrecht University, Netherlands; **Co-Author:**Timo Kegelaar, Utrecht University, Netherlands; **Co-Author:**Ashley Xia, Utrecht University, Netherlands; **Co-Author:**Casper Sánta, Utrecht University, Netherlands; **Co-Author:**Julia van Nijhuis, Utrecht University, Netherlands; **Co-Author:**Tamara Van Gog, Utrecht University, Netherlands

Cooperation is fundamental to human interaction. Agreeableness has been associated with successful cooperation, yet the mechanisms that underlie this relationship have not yet been explained. Physiological synchrony between dyad partners might be a mechanism explaining the hypothesised link between agreeableness and cooperative success. However, a better understanding of how different measures of synchrony (and settings) affect results is needed when addressing that question. Therefore, we explore two different physiological synchrony measures and different settings in the context of studying the link between agreeableness and cooperative success. Twenty dyads played an adaptation of the Prisoner's Dilemma Game whilst their heart rate (HR) and skin

conductance level (SCL) were measured. Physiological synchrony was calculated separately for HR and SCL using windowed cross-correlations, and different parameters settings and pseudo synchrony analyses were explored. Results of a mediation analysis showed no significant direct effect of agreeableness on cooperative success, nor an indirect effect via physiological synchrony in HR or SCL. We did find, however, that the different physiology measures captured distinct aspects of dyadic physiological dynamics, with HR showing higher levels of synchrony. Mean HR synchrony values differed significantly across configurations, further supporting the notion that HR and SCL capture distinct aspects of physiological dynamics. Furthermore, the pseudo synchrony analyses suggest that the synchrony values mainly reflected the shared task structure or common external influences rather than dyad-specific interaction. These findings underline that researchers interested in physiological synchrony should be aware of the impact of specific physiological measures and settings in data analyses.

Informal Generative AI Practices in Science Education: Patterns, Levels of Use, and Potential Impact
Keywords: Competences, Educational Technology, GenAI, Higher Education
Presenting Author:MEHEDI HASAN ANIK, Chalmers University of Technology, Sweden

The rapid rise of generative AI (GenAI) tools has transformed academic practices, yet their informal and unregulated use raises critical concerns for higher education. In Bangladesh's Science Education context, students are increasingly adopting GenAI without institutional guidance, creating challenges for teaching, learning, and assessment. This study aimed to explore the patterns, levels, and potential impacts of such informal use. A mixed-methods, explanatory sequential design was employed, involving a survey of 83 Science Education students and semi-structured interviews with five faculty members. Quantitative results showed that 96% of students used GenAI for academic purposes, with nearly 69% engaging at advanced creative levels. Qualitative findings revealed inconsistent teaching responses, over-reliance on AI by students, and threats to assessment integrity. The study underscores the need for AI literacy training, clear policies, and AI-inclusive assessment strategies to ensure responsible integration while preserving educational quality.

Investigating emerging agentic behaviors with GenAI: Temporal network analysis
Keywords: Collaborative Learning, GenAI, Higher Education, Multimodal Learning Analytics
Presenting Author: Anni silvola, University of Oulu, Finland; **Co-Author:**Hanni Muukkonen, University of Oulu, Finland; **Co-Author:**Anceli Kaveri, University of Oulu, Finland; **Co-Author:**Tiina Törmänen, University of Oulu, Finland; **Co-Author:**Joonas Merikko, University of Helsinki, Finland

How students work with generative artificial intelligence (GenAI)-based conversational agents (CAs) is a burning topic for higher education. This study focuses on students' AI-mediated interaction practices and postdigital agency in the context of collaborative problem-solving (CPS). Transactivity and post-digital agency offer theoretical grounding to examine the intertwined roles of humans and CA in CPS processes. This study examines how transactive interactions and acts of postdigital agency were temporally connected to CA interactions. The processes of four small-groups of students were studied. Their aim was to resolve three scenarios and to evaluate and experiment with the use of CA. Multichannel data including video recordings and chat-log data from CAs were collected, resulting in 1468 rows of analyzed data. A temporal network analysis was conducted for utterance-level coding of these two constructs. The analysis uncovered patterns that followed the task-design and indicated positive role of CA supporting the quality of student collaboration. The analysis suggests further exploration of temporal dynamics of AI-mediated collaboration to better understand the emerging forms of entangled, agentic practices. The analysis showed a confined contribution from the CA in deepening the conceptual discussion.

Making Sense of Teamwork: Combining MMLA, AI Techniques and Qualitative Interpretation
Keywords: Artificial Intelligence, Collaborative Learning, Multimodal Data, Multimodal Learning Analytics
Presenting Author: Crina Damsa, University of Oslo, Norway; **Co-Author:**Daniel Sanchez, University of Oslo, Norway; **Co-Author:**Mariia Borisova, University of Oslo, Norway; **Co-Author:**Rogers Kaliisa, University of Oslo, Faculty of Education, Norway

Understanding how teams learn together requires moving beyond individual behavior logs toward richer, multi-layered analyses of interaction. This paper argues that the combination of multimodal learning analytics (MmLA), artificial intelligence (AI) techniques, and qualitative interpretive methods offers a uniquely powerful lens for this purpose. Drawing on a case study of a high-fidelity simulation and a post-simulation debriefing in nursing education—where a multimodal dashboard supported collaborative sense-making—we illustrate how quantitative content analysis, AI-assisted coding, and fine-grained multimodal qualitative analysis can be integrated to capture learning processes that no single method alone can reveal. We propose that this methodological convergence enables both the scalability of pattern detection and the interpretive depth needed to understand meaning, context, and pedagogical relevance in collaborative settings.

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Single Paper
Learning and Instructional Technology, Learning and Social Interaction

Video data and multimodal data

Keywords: (Joint) Attention, Emotion and Affect, Heart Rate (Variability), Metacognition, Multimodal Data, Self-regulated Learning, Simulation-based Learning, Socially-Shared Regulation, Video Data
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Charlotte Van Tricht, University of Antwerp, Belgium

Gaze and Proxemics as Signals of Shared Regulation in AI-Supported Collaborative Learning
Keywords: (Joint) Attention, Metacognition, Multimodal Data, Socially-Shared Regulation
Presenting Author: Ridwan Whitehead, University of Oulu, Finland; **Co-Author:**Andy (Khanh Xuan) Nguyen, University of Oulu, Finland; **Co-Author:**Sanna Järvelä, University of Oulu, Finland

Understanding how groups regulate learning together requires attention to the non-verbal cues that shape collaborative activity alongside verbal interaction. This study investigates how gaze and proxemics signal and support socially shared regulation of learning (SSRL) during a classroom-based collaborative inquiry task. Sixty-two secondary school students worked in small groups on a physics task while video and audio were recorded in their natural classroom. Gaze and proxemic behaviors were extracted from standard two-dimensional video using automated computer vision techniques. Challenge and regulation processes were identified using the trigger regulation framework. Transmodal ordered network analysis was used to examined the temporal relationships among gaze and proxemics and verbal regulatory processes across different spatial configurations and AI support conditions. Results show that gaze and proxemics function as online indicators of regulation processes as they unfold. When groups were physically distant, mutual gaze signaled emerging challenges and preceded monitoring. When groups were physically close, joint attention supported transitions from monitoring to selecting and enacting strategies. Adaptive AI support strengthened cycles of shared monitoring, while static support produced more procedural patterns of strategy use. The findings advance understanding of regulation of learning in authentic classrooms and demonstrate a non-intrusive methodological approach for investigating multimodal in-situ collaborative learning processes.

Investigating regulated learning in collaborative workplace teams
Keywords: Emotion and Affect, Metacognition, Socially-Shared Regulation, Video Data
Presenting Author: Niina Palmu, University of Oulu, Finland; **Co-Author:**Hanna Järvenoja, University of Oulu, Finland; **Co-Author:**Piet Van den Bossche, University of Antwerp, Belgium; **Co-Author:**Sanna Järvelä, University of Oulu, Finland

This study explored how team members' emotional dynamics and socially shared regulation of learning (SSRL) support adaptive team learning in workplace meetings. Theory guided framework was applied for analysing emotional dynamics and SSRL processes that enable teams to recognise and manage challenges. The teams were from small- to medium-sized enterprises in the manufacturing, ICT, and service sectors. Data were collected from seven teams (n = 45) through video recordings and surveys. A mixed-methods approach was used, combining both deductive qualitative content analysis of video data with quantitative and inductive qualitative analysis of survey responses.The findings revealed that emotions shifted to positive during the meetings, with consistently high levels of calmness and increasing elation, while negative deactivation such as tiredness declined. Team-oriented reflection related to emotions prior to meetings showed statistical significance and was more likely to occur in mixed-adaptation meetings, which included regulation of learning episodes with and without adaptation. This tendency demonstrates awareness of collective functioning, but this awareness alone was insufficient to ensure consistent adaptation within regulation of learning. Although teams' explicit regulation of emotional conditions was absent, the meetings appeared to function as platform in which teams' regulation of cognitive and behavioural conditions indirectly influenced emotional dynamics. This study offers implications for meeting practices and informal workplace learning by providing insights into team members' emotions and reflection patterns that support adaptive team learning. In doing so, the study integrates individual and team-level perspectives and emphasises how emotions can serve as a beneficial resource that brings valuable information.

Collective Learning Through Sensemaking in Debriefs: A Multimodal Approach

Keywords: Heart Rate (Variability), Multimodal Data, Simulation-based Learning, Video Data
Presenting Author: Amber van Kampen, University of Twente, Netherlands; **Co-Author:**Marcella Hoogeboom, University of Twente, Netherlands; **Co-Author:**Maaike Endedijk, University of Twente, Netherlands

Effective learning processes within teams in high-resilience organisations are crucial for ensuring near-zero failure rates, key in these organisations. These teams, in, for example, the fire, police and medical sectors, are characterised by fast changes and dynamic work environments in which every team member has their own task. Learning from these events collectively is crucial to maintaining high performance. For this purpose, after-action reviews (AARs) or debriefs are often held. During debriefs, individual perspectives will, through sensemaking, be integrated into a collective understanding of the event. This collective understanding can, in turn, lead to the pinpointing of learning points. While the effectiveness of debriefs is a given, how they become successful is largely unknown. Physiological measures, combined with video observations, provide richer insight into sensemaking and other learning processes during debriefs than conventional *post hoc* or linear methods. In this presentation, we discuss how sensemaking unfolds during debriefs and, as a consequence, how learning can occur to maintain high performance in complex contexts. Next to these insights into debriefing processes, it also provides the instructors, guiding the debriefs, with tools to help structure debriefs to the best of their abilities.

Tracing the Complexity of Movement Dynamics in VR Chemistry Lab Skill Learning
Keywords: Multimodal Data, Self-regulated Learning, Simulation-based Learning, Video Data
Presenting Author: Megan Wiedbusch, University of Central Florida, United States; **Co-Author:**Roger Azevedo, University of Central Florida, United States

Immersive virtual reality (IVR) engages learners in embodied simulations to develop practical skills and knowledge. This study applies a Complex Dynamical Systems (CDS) lens to examine how self-efficacy and movement dynamics (quantified via optical flow-derived jerk) co-evolve during IVR chemistry learning. Linear mixed-effects and regression models showed that jerk decreased over time, and self-efficacy change significantly moderated jerk in later gameplay. An interaction between jerk and changes in self-efficacy also predicted learning outcomes, suggesting smoother movement paired with increased confidence supports better performance. By integrating the CDS framework with the CAMIL model, this work reveals how dynamic motivational-affective states manifest behaviorally and influence STEM learning in IVR environments.

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Single Paper
Instructional Design, Learning and Instructional Technology, Motivational, Social and Affective Processes

Electrodermal activity and arousal

Keywords: Arousal, Cognitive Load, Collaborative Learning, Electrodermal Activity, Emotion and Affect, Foreign and Second Language Acquisition, Motivation, Physiological Data, Self-efficacy, Systematic Literature Review
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Christian Mayer, University of Mannheim, Germany

Wordlist Sequencing in Learning Finnish Orthographic Synforms: A Multimodal Study
Keywords: Cognitive Load, Electrodermal Activity, Foreign and Second Language Acquisition, Self-efficacy
Presenting Author:Héctor J. Pijeira-Díaz, University of Jyväskylä, Finland; **Co-Author:**Jobert Ngwenya, University of Jyväskylä, Finland; **Co-Author:**Slawomir Pryc, Åbo Akademi University, Finland; **Co-Author:**Anu Tourunen, University of Jyväskylä, Finland; **Co-Author:**Virpi-Liisa Kykyri, University of Jyväskylä, Finland

Orthographic synforms—words with similar spelling but different meanings—are challenging to learn due to the interference effect and confusion for additional language (L2) learners. An example of synforms in the Finnish language is the words *kappeli* for chapel and *kaapeli* for cable. Currently, there are mixed findings on whether learning synforms together facilitates or hinders learning. Some studies have found a facilitating effect of learning synforms together due to focused attention on key differences, yet other studies have found that this impairs learning due to interference. In this study, we examined how wordlist sequencing influences learning processes and outcomes in L2 (Finnish) vocabulary learning. Using a within-subject design, 101 adults learnt and recalled 30 Finnish synforms under three counterbalanced sequencing conditions: simultaneous, alternating, and spaced pairs. We carried out a multimodal study which measured performance (number of recalled words); word-level cognitive load using the 9-point Paas' scale; self-efficacy using an adaptation of the General Self-Efficacy Scale; and sympathetic arousal through electrodermal activity (EDA), measured via EDAMove4 biosensors. Linear and generalised linear mixed-effects models revealed no significant effects of sequencing condition on recall, cognitive load, self-efficacy, or physiological arousal. However, learner-related factors, especially Finnish proficiency, emerged as strong predictors of performance and perceived cognitive load. Our findings suggest that, in the context of orthographic synforms, word sequencing may be less effective at influencing learning processes. The study suggests that instructional designers should consider adaptive, learner-sensitive approaches rather than uniform instructional designs to support the learning of synforms.

Electrodermal activity in learning and instruction research: A systematic literature review
Keywords: Arousal, Electrodermal Activity, Physiological Data, Systematic Literature Review
Presenting Author:Héctor J. Pijeira-Díaz, University of Jyväskylä, Finland; **Co-Author:**Lina María García Morales, University of Jyväskylä, Finland; **Co-Author:**Faisal Rehman Channa, University of Jyväskylä, Finland

Electrodermal activity (EDA) is a widely used psychophysiological measure given its sensitivity to cognitive and affective processes via sympathetic arousal. The large volume of EDA research in learning and instruction has motivated several systematic reviews, but with limited timespan and number of records ($n \leq 50$ each), and focusing mainly on emotions. Therefore, a comprehensive review is missing. We synthesize empirical educational research leveraging EDA. Our research questions are: 1) Which frameworks and constructs have been used to ground EDA when studying cognitive, affective, motivational, and behavioral aspects of learning? 2) How has EDA data been collected, processed, and analyzed? Seven prominent databases were queried as follows: "(("Electrodermal Activity") OR ("galvanic skin*") OR ("skin conductance") OR ("sympathetic arousal")) AND (education OR pedago* OR teaching OR teacher OR learner OR student)", yielding 1051 records. After checking for duplicates and exclusion criteria, 180 records (20+ countries, years 1960–2024) were included in the analysis, encompassing both higher education (79%) and K–12 (21%). More than 20 theoretical and methodological characteristics of those empirical studies were extracted, providing the most comprehensive systematic review to date on EDA applications to learning and instruction. The primary purposes EDA has been used for so far in learning and instruction research have been to group students into different categories, to find patterns relating to their learning processes, and to study relationships between different constructs more strongly by triangulating different data modalities.

What Happens in CL When Students' Motivation Changes? A Multimodal Analysis of Emotions
Keywords: Collaborative Learning, Electrodermal Activity, Emotion and Affect, Motivation
Presenting Author: Jasmiina Suoraniemi, University of Oulu, Finland; **Co-Author:**Tiina Törmänen, University of Oulu, Finland; **Co-Author:**Hanna Järvenoja, University of Oulu, Finland

Motivational change during collaborative learning is often accompanied by emotional reactions, yet little is known about how students interpret these moments themselves and how such interpretations relate to concurrent physiological activation. Drawing on Control–Value Theory and Situated Expectancy–Value Theory, this study examines motivationally significant situations as they unfold during a collaborative science task, using a multimodal approach that integrates interviews, video-based observation, and electrodermal activity (EDA).Participants were 95 eighth-grade students working in small groups on a 90-minute water purification task. Changes in situational motivation during the task were identified using repeated self-reports and served as anchors for individual stimulated recall interviews. Interview data were analyzed to capture students' interpretations on emotional reactions in different task phases, while emotional reactions during corresponding phases were coded from video and combined with EDA to index physiological activation. Emotional valence profiles (negative, mixed, positive) were constructed at the task phase × student level. Results showed that students most often attributed motivational change to task-related understanding and progress rather than group interactions. Ordinal mixed-effects modeling (CLMM) indicated that interpreted emotional valence was significantly associated with physiological activation, but not with observed valence. This study demonstrates how changes in situational motivation can be used as theory-driven anchors for identifying and examining emotionally significant moments across subjective, expressive, and physiological data streams.

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Sala polivalent 2
No- or not-so-perfect-data presentation (Note: This session also includes a single paper presentation. See details at the end of this document.)

Cognitive Science, Learning and Instructional Technology

Eye-tracking and log data

Keywords: Engagement, Eye-Tracking, Facial Expressions, Feedback and Biofeedback, Game-based Learning, Learning Analytics, Log Data, Multimodal Data, Self-regulated Learning
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Enrique Arturo Vázquez Uscanga, Universidad Alberto Hurtado, Chile

Inside the Black Box of Feedback Engagement: The Role of Video Nudging—An Eye-Tracking and GSR study
Keywords: Engagement, Eye-Tracking, Feedback and Biofeedback, Multimodal Data
Presenting Author: Jonas Willems, University of Antwerp, Belgium; **Co-Author:**Roselyne Willems, Antwerp University, Belgium; **Co-Author:**Stijn Schelfhout, Ghent University, Belgium; **Co-Author:**Vincent Donche, University of Antwerp, Belgium

Students in secondary education increasingly rely on online self-assessment feedback tools to support their study choice for higher education. While such tools provide personalized feedback, their effectiveness depends on students' engagement with that feedback. Although engagement is commonly conceptualized as cognitive, emotional, and behavioral, research still relies largely on self-report measures, offering limited insight into how engagement unfolds during feedback use. Online measures such as eye-tracking and physiological sensors offer opportunities to capture these processes in real time, but their application raises methodological challenges. Translating theoretical constructs of engagement into valid behavioral and physiological indicators remains complex. This study examines students' engagement with online self-assessment feedback using a multimodal experimental design combining eye-tracking, GSR, and cued recall interviews. Final-year secondary students (*N*=72) were randomly assigned to informational, social-comparison, or control video conditions before completing an online feedback module on competences crucial for transition to HE. Feedback-engagement is operationalized through cognitive indicators of attention (e.g., fixation duration, attention distribution across areas of interest) and physiological arousal as a proxy for emotional engagement. Rather than focusing solely on empirical results, this contribution will reflect on methodological challenges encountered in the design, collection and analysis of multimodal data; indicator interpretation, data quality, multimodal data integration, and statistical issues. The potential of complementary qualitative data to support interpretation is considered, but the focus of this contribution lies on the quantitative analyses. By critically examining these challenges, we aim to contribute to a more transparent and theoretically grounded use of online measures in educational research.

Detecting Moments of Curiosity within Game-based Learning Environments using Multimodal Trace Data
Keywords: Eye-Tracking, Facial Expressions, Game-based Learning, Log Data
Presenting Author: Megan Wiedbusch, University of Central Florida, United States; **Co-Author:**Milouni Patel, University of Central Florida, United States; **Co-Author:**Veeraraghava Raju Hasti, University of Central Florida, United States; **Co-Author:**Roger Azevedo, University of Central Florida, United States

Narrative-driven game-based learning environments (GBLEs) provide opportunities to induce and sustain learners' curiosity using interactive game mechanics providing novel approaches to delivery of instructional content as they explore open virtual worlds. We utilize Sinha and colleagues' (2017) curiosity framework to examine individual knowledge identification curiosity to investigate moments of curiosity from undergraduate students (N = 99) acquiring new microbiology knowledge within Crystal Island, a narrative-driven GBLE. Interestingly, our results suggest that learner agency had no significant difference on the frequency of curiosity moments defined using facial expressions, eye-tracking, and log files during learners' first-time interactions with learning materials within the GBLE. Additionally, the frequencies of learners' curiosity moments and the amount of agency afforded to the learner by the environment did not predict their learning outcomes (normalized learning gains and game solved). Through this 'not-so-perfect-data' paper, we invite a dialogue on the analytical approach to the multimodal measurement of curiosity within GBLEs and explore the theoretical implications of future works.

A Case Study of Self-regulating (non) Learning in a Game-based Learning Environment
Keywords: Game-based Learning, Learning Analytics, Log Data, Self-regulated Learning
Presenting Author: Megan Wiedbusch, University of Central Florida, United States; **Presenting Author:**Roger Azevedo, University of Central Florida, United States; **Co-Author:**Cameron Marano, University of Central Florida, United States; **Co-Author:**Veeraraghava Raju Hasti, University of Central Florida, United States; **Co-Author:**Michelle Taub, University of Central Florida, United States

Consistently monitoring and regulating one's cognitive and metacognitive skills throughout learning is difficult for students to execute successfully. As a result, game-based learning environments (GBLEs) have been designed to provide learners with enhanced learning experiences and foster self-regulated learning (SRL) skills within complex environments. Despite extensive research on SRL in GBLEs, large gaps remain in how learners' maladaptive regulation strategies in GBLEs can be indicative of gaming-the-system, a phenomenon widely studied in intelligent tutoring systems (ITS) in which learners manipulate the environment's features to avoid authentic learning. Limited research has examined how and when both gaming-the-system and SRL behaviors unfold during and across a learning session with a GBLE, and how this may affect learning and performance outcomes. This case study, extracted from a larger dataset, examines a cluster of participants (N = 7) previously identified via a sequence analysis and hierarchical clustering approach to identify learners with similar in-game behavioral patterns to inform how the prevalence of both gaming-the-system and SRL behaviors impacts learners' task performance and learning outcomes in a narrative-based GBLE. While their sequences of actions lacked contextual information, we examined the frequency and duration of their behaviors that were excluded in previous analyses. We discuss how the frequencies and durations of behaviors may constitute misdirected regulation, which is imperative to consider in the design of future adaptive scaffolds. Scaffolds should not only mitigate maladaptive behaviors but also consider the temporal and holistic deployment of learners' actions to promote adaptive behaviors that prioritize learning.

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Sala polivalent 1
No- or not-so-perfect-data presentation
Assessment and Evaluation, Higher Education, Learning and Instructional Technology

Artificial intelligence and trace data

Keywords: Adaptive Learning Environments, Artificial Intelligence, Assessment, Collaborative Learning, GenAI, Higher Education, Metacognition, Pedagogical Agents, Scaffolding, Self-efficacy, Trace Data, Writing/Literacy
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Kateryna Horlenko, Vytautas Magnus University, Lithuania

Nudging feedback: attention to self-efficacy (mis)alignment for more behavioral feedback engagement
Keywords: Assessment, Higher Education, Self-efficacy, Trace Data
Presenting Author: Charlotte Van Tricht, University of Antwerp, Belgium; **Co-Author:**David Gijbels, University of Antwerp, Belgium; **Co-Author:**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, most students seem to take little time to read the personalized feedback. Moreover, students process the feedback in a different way, and self-efficacy as an initial state seems to influence internal processing. Therefore, self-efficacy, and self-efficacy alignment with feedback results may play a role in how students read the feedback. The alignment between self-efficacy and feedback results may provoke different internal processing. Raising awareness about students' self-efficacy and alignment with feedback results may consequently act as nudge towards more attentive reading behavior. In this study, 530 students took part in an experiment where one group was nudged towards more attention allocation to the feedback report based on personalized information about their self-efficacy alignment, while a control group was not nudged. Analysis is ongoing, and some methodological issues will be the basis for discussion.

Tracing inferential engagement in AI-mediated digital reading: A process-oriented study
Keywords: Artificial Intelligence, Pedagogical Agents, Scaffolding, Trace Data
Presenting Author: Chiara Magurno, Università Modena e Reggio Emilia, Italy; **Co-Author:**Chiara Bertolini, Università degli studi di Modena e Reggio Emilia - Department of Education adn Human Sciences, Italy

Digital reading environments often foster rapid and surface-oriented engagement, potentially limiting the inferential processes required for deep comprehension. While conversational agents are starting to be proposed as instructional supports, less is known about how structured dialogic scaffolding is associated with learners' cognitive engagement during reading.This study investigates how an adaptive conversational agent is designed to structure opportunities for inferential engagement during digital reading in two fourth-grade primary school classrooms in Northern Italy. The intervention involved a teacher-configurable conversational agent (CLAIRE) designed to guide reading through phase-based dialogic scaffolding, including whole-class modelling sessions and subsequent

individual interactions.Adopting a process-oriented approach, we draw on fine-grained trace data collected during classroom implementation, focusing on students' inferential responses, interaction timing, and scaffolding sequences during stabilized phases of use. The study examines how inferential engagement unfolds across sessions and how students respond to conversational scaffolding, based on indicators such as response quality, suitability, and response time.Data collection has been completed and analyses are currently in progress. A central challenge concerns how to operationalize inferential engagement through these data in authentic classroom settings, particularly in distinguishing inferential from surface-level responses and in interpreting temporal indicators as proxies of cognitive processing.The study aims to contribute to methodological discussions on how process data can capture learning dynamics as they unfold in AI-mediated reading environments, by linking interactional structures to observable indicators of inferential engagement.

Shared Hybrid Intelligent Regulation of Collaborative Learning (SHIRCL) Model
Keywords: Adaptive Learning Environments, Artificial Intelligence, Collaborative Learning, GenAI
Presenting Author: Andy (Khanh Xuan) Nguyen, University of Oulu, Finland; **Co-Author:**Belle Dang, Victorial University of Wellington, New Zealand; **Co-Author:**Thu Duong, University of Oulu, Finland; **Co-Author:**Luna (Thi Thu Nguyet) Huynh, University of Oulu, Finland

This paper proposes the Shared Hybrid Intelligent Regulation of Collaborative Learning (SHIRCL) model to explain how collective hybrid intelligence emerges through interactions among learners and Generative Artificial Intelligence (GenAI) in collaborative learning environments. Building on Socially Shared Regulation of Learning (SSRL) and Human–AI Shared Regulation in Learning (HASRL), SHIRCL conceptualises collaborative learning as a hybrid socio-technical system in which regulation is distributed across both human and AI actors. Rather than functioning as a passive tool, GenAI is positioned as an adaptive participant that contributes to collaborative inquiry through responsive interaction, adaptive prompting, and knowledge synthesis. The framework integrates individual-level human and AI conditions with group-level processes of shared regulation and collective coordination. Human learners contribute contextual understanding, creativity, ethical reasoning, and socio-emotional awareness, whereas AI systems contribute rapid information retrieval, adaptive responsiveness, and support for idea generation. The paper illustrates the framework through a case study involving 132 undergraduate teacher education students working in dyads with GenAI during a collaborative inquiry task on the use of artificial intelligence in primary education. Findings revealed considerable variation in how collective hybrid intelligence emerged. Some groups critically evaluated and negotiated AI-generated contributions, demonstrating deeper shared regulation and metacognitive engagement, whereas others relied passively on AI suggestions. The findings highlight that effective human–AI collaboration depends not only on AI availability, but on learners' capacity to regulate interactions with AI critically and collectively.

Writing Processes and GenAI Feedback in Postsecondary Writing Instruction and Assessment
Keywords: Artificial Intelligence, Higher Education, Metacognition, Writing/Literacy
Presenting Author: John Sabatini, The University of Memphis, United States; **Co-Author:**Katherine Fredlund, The University of Memphis, United States; **Co-Author:**Elliott Casal, The University of Memphis, United States; **Co-Author:**Ben Pierce, The University of Memphis, United States; **Co-Author:**Paul Deane, Independent Researcher, United States

GenAI is increasingly integrated into writing processes in professional, academic, and everyday contexts and offers writing instructors useful, scalable tools for providing personalized, targeted feedback. However, how does pervasive GenAI integration into writing instruction and assessment influence the construct of writing proficiency, particularly the metacognitive skills involved in developing it? In this project, post-secondary instructor-led design teams are working with assessment specialists, learning scientists, instructional designers, and AI/technology developers to build scenario-based learning and assessments (SBLAs), a type of performance assessment that integrates GenAI both in authoring and in students' learning experiences. In this presentation, writing instruction faculty (co-authors) and other project specialists will discuss how we are grappling with understanding and using student process data in postsecondary writing courses.

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Amfiteatre
Symposium
Learning and Instructional Technology

When Sensors and AI Meet Pedagogy: Towards Grounded and Interpretable Multimodal Learning Analytics

Keywords: Artificial Intelligence, Classroom Analytics, Collaborative Learning, Multimodal Data, Multimodal Learning Analytics, Video Data
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Rogers Kaliisa, University of Oslo, Faculty of Education, Norway
Organiser: Crina Damsa, University of Oslo, Norway
Discussant: Margarida Romero, France

Learning is a complex, embodied phenomenon that resists reduction to the digital traces captured by conventional analytics platforms. Multimodal Learning Analytics (MMLA) has expanded the observational horizon by deploying physiological, optical, and auditory sensors to study learning as it unfolds in face-to-face and collaborative settings. Yet the growing sophistication of these sensing and inference pipelines introduces compounding challenges: the interpretive opacity of AI-driven classification systems, unresolved questions about what observational evidence can legitimately stand in for pedagogically meaningful constructs, and ethical constraints imposed by legal frameworks. This symposium and the three individual contributions propose that these challenges, taken together, call for a reorientation of MMLA research around three interconnected commitments. First, following the in-between spaces rationale, MMLA inquiry should be repositioned as laboratory-based research whose findings are designed to inform and enrich real-world classroom practice rather than surveil it. Second, drawing on various theoretical frameworks, AI should function as a bounded computational contributor within architectures that preserve human agency, theoretical grounding, and uncertainty-aware learner representations. Third, building on evidence from collaborative action recognition, human–AI divergence should be treated not as a performance deficit but as an analytic instrument that renders visible the tacit evidentiary standards embedded in coding schemes and annotation protocols. Taken together, these commitments outline a pathway toward MMLA systems that are simultaneously scalable, ethically responsible, pedagogically grounded, and epistemically honest about what automated observation of learning can, and cannot, reveal.

A Framework to Mix Human and Artificial Intelligence to Build Multimodal Learning Analytics Systems
Presenting Author: Xavier Ochoa, New York University, United States; **Co-Author:**Xiaomeng Huang, New York University, United States

Multimodal Learning Analytics (MMLA) seeks to understand learning processes that occur beyond traditional digital environments, including face-to-face interaction and collaborative activity. Recent advances in sensing technologies and artificial intelligence enable increasingly rich analysis of multimodal signals such as speech, gesture, and gaze, but also raise concerns regarding privacy, interpretability, fairness, and educational validity. In this paper, we propose the Theory–Measurement–Evaluation (TME) framework as a human-centered approach for integrating human and artificial intelligence in MMLA systems. Rather than treating AI as an autonomous evaluator, TME positions AI within an evidence-centered process grounded in educational theory and human interpretation. The framework includes three interconnected layers: a Theory Model that defines pedagogically meaningful constructs, a Measurement Model that extracts contextualized multimodal evidence, and an Evaluation Model that generates interpretable and uncertainty-aware learner representations. Using a collaborative interaction study as an illustrative example, we argue that TME provides a pathway toward explainable, pedagogically grounded, and ethically deployable MMLA systems.

Using Multimodal Learning Analytics and AI to foster a Pathway to create Insights in the Classrooms
Presenting Author: Thomas Frøsig, Université Côte d'Azur, France

The field of learning analytics is the study of low-level traces learners generate as they use digital tools in support of their learning process. The availability of such traces depends on the capabilities of the tools, which constrains the scope of analysis to what is captured by the tools rather than what is pedagogically meaningful.. Furthermore, not all learning activities involve digital devices. Some also happen in the classroom, face-to-face or in cooperative learning scenarios. To investigate such contextual learning scenarios, the Multi Modal Learning Analytics (MMLA) approach deploys multiple physiological, optical and auditory sensors to capture and analyse a variety of signals. This process of deploying a potentially invasive set of sensors in a real world classroom setting presents an ethical limitation as defined in both GDPR and the EU AI Act. As a possible solution to this limitation, we propose an in-between space. As an example we present the findings from our MMLA lab study about "Aha!" moments. We then offer some suggestions on how these findings can be operationalised to foster more moments of insight in everyday classroom practices.

When Machines Observe Learning, What Do They Reveal About Us?
Presenting Author: Daniel Spikol, University of Copenhagen, Denmark; **Co-Author:**Morten Misfeldt, University of Copenhagen, Denmark

Automated observation of collaborative learning does not scale human judgment; rather, it inherits its assumptions. When Vision-Language Models classify student actions from video frames, they do not simply replicate what human coders do; they make explicit the tacit inferences that human coders have always made invisibly. This paper argues that human–AI divergence in collaborative action recognition is not a performance gap to be closed but an analytic signal:

where models and humans part ways, hidden evidentiary standards embedded in coding schemes become visible and contestable. Drawing on a multimodal pipeline that integrates gaze detection, hand tracking, and Vision-Language Models to classify STEM collaboration, we show that ground truth is not derived from video data but is constructed through theory-laden interpretive judgments. The practical consequence for MMLA is pointed: AI-supported coding systems are most valuable not when they replace human judgment, but when they force communities of practice to articulate and renegotiate what counts as valid evidence for collaborative learning constructs.

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18 November 2026 16:30 - 18:00
Sala polivalent 1
Poster Presentation
Cognitive Science, Learning and Instructional Technology, Lifelong Learning, Teaching and Teacher Education

Posters A

Keywords: (Joint) Attention, Artificial Intelligence, Classroom Analytics, Cognitive Skills and Processes, Comprehension of Text and Graphics, Computer-assisted Learning, Educational Neuroscience, Eye-Tracking, Facial Expressions, Feedback and Biofeedback, Higher Education, Learning Analytics, Mental Effort, Metacognition, Multimodal Data, Multimodal Learning Analytics, Personalized Learning Environments, Reading, Self-regulated Learning, Teaching Analytics, Think Aloud Data, Video Data
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Francesca Zermiani, University of Valencia, Spain

Forecasting Collaborative Breakdowns: Toward Proactive Dyadic Adaptation in Pair Programming
Keywords: Computer-assisted Learning, Eye-Tracking, Mental Effort, Multimodal Data
Presenting Author:anahita golrang, Norwegian University of Science and Technology (NTNU), Norway; **Co-Author:**Kshitij Sharma, Norwegian University of Science and Technology (NTNU), Norway

Most adaptive learning systems respond to collaboration breakdowns only after they have occurred, limiting their capacity to sustain productive joint activity. This poster presents, a proactive AI-driven adaptive collaborative tutor for pair programming that treats collaboration itself as the object of instruction. The proposed architecture constructs a multimodal dyadic learner model based on Joint Visual Attention (JVA), Joint Mental Effort (JME), and individual mental effort (ME), measured through dual eye-tracking and pupillometry. An XGBoost-based forecasting model predicts sub-optimal collaboration states up to 30 seconds in advance, enabling minimally intrusive, hierarchically ordered adaptive scaffolding that fades during productive collaboration. Preliminary findings from a within-subject study with 26 pair-programming dyads suggest that forecasting dyadic states in real time is both technically feasible and pedagogically promising. We discuss the system design, the forecasting framework, and early indicators of its impact on dyadic regulation processes.

From Eye Movements to Teacher Insights: Designing AI Support for Reading
Keywords: Artificial Intelligence, Eye-Tracking, Learning Analytics, Reading
Presenting Author: Siem Buseyne, Universiteit Antwerpen, Belgium; **Co-Author:**Glen Joris, University of Antwerp, Belgium; **Co-Author:**Konstantinos Tsiakis, Open Universiteit, Netherlands; **Co-Author:**Tine van Daal, University of Antwerp, Belgium; **Co-Author:**Vincent Donche, University of Antwerp, Belgium; **Co-Author:**Sven De Maeyer, Antwerp University, Belgium; **Co-Author:**Leen Catrysse, Open Universiteit Nederland, Netherlands; **Co-Author:**Halszka Maria Jarodzka, Open Universiteit, Department of Online Learning and Instruction, Netherlands; **Co-Author:**David Gijbels, University of Antwerp, Belgium

Many important reading processes during task performance are difficult for teachers to observe. Eye-tracking offers a measure of these processes as learning happens, but the resulting gaze data are too complex and exhaustive to be readily interpreted in classroom practice. This poster presents first results from two connected qualitative studies that explored how such process data might be translated into meaningful teacher support through AI-assisted design. In the first study, semi-structured vignette interviews with 20 primary and secondary teachers examined perceptions of AI-supported eye-tracking for reading comprehension across different levels of human–AI collaboration. Teachers saw clear potential in making otherwise invisible reading processes visible, especially for differentiation and targeted support, but emphasized the importance of teacher autonomy, transparency, usability, and trust. Lower to moderate automation was generally preferred over highly autonomous configurations. The second study focused on the co-design phase of a prototype dashboard that transformed simulated eye-tracking outputs into AI-generated visualizations, alerts, and recommendations. Think-aloud sessions with 10 teachers yielded seven preliminary design needs: actionable narratives, surface control, teacher support, deep agency, on-demand explainability, pedagogical integration, and teacher-envisioned functionalities. Together, the studies show how online measures of reading can inform the human-centred design of AI systems that support teachers during reading tasks.

Classroom eye-tracking study on teacher professional vision for self-regulated learning
Keywords: (Joint) Attention, Eye-Tracking, Self-regulated Learning, Think Aloud Data
Presenting Author: Kateryna Horlenko, Vytautas Magnus University, Lithuania; **Co-Author:**Lina Kaminskienė, Vytautas Magnus University, Lithuania; **Co-Author:**Erno Lehtinen, University of Turku, Finland

Student self-regulated learning (SRL) is a key lifelong learning skill that can be supported by teachers. Previous research focused on teacher assessment, knowledge, and teaching methods for SRL separately. Yet, to understand how teachers can support student SRL adaptively, a holistic approach is needed. This study adopted the concept of teacher professional vision as a conceptual lens for investigating teacher practice in the classroom. This study followed a mixed methods research design, with 10 teachers and their secondary school students (N=157) as participants, teacher mobile eye tracking in the classroom and retrospective think-aloud report. The eye movement analyses showed that teachers visually focused more on students whom they perceived as tending to ask questions or seek information in the lesson. The qualitative analyses of teacher think-alouds revealed that teachers noticed both student behavioural and cognitive cues, to a smaller degree metacognitive cues, as well as student characteristics not diagnostic of SRL. In terms of SRL support, teachers emphasised implicit approaches of strategy modelling and prompting student thinking and independent performance. This shows that teachers do consider student characteristics and processes important for supporting student SRL when teaching a specific lesson; however, teachers' noticing of student SRL cues and reasoning about student learning is not fully conductive of SRL support. This implies including and studying promotion of student SRL as a teaching competence, especially with a focus on the diagnostic cues of student SRL.

Towards a cost-efficient open-source infrastructure for physiological multimodal learning analytics
Keywords: Educational Neuroscience, Eye-Tracking, Facial Expressions, Multimodal Learning Analytics
Presenting Author: Thomas Frøsig, Université Côte d'Azur, France; **Co-Author:**Margarida Romero, Université Côte d'Azur, Nice, France

Sudden moments of insights have shown to be associated with a steeper trajectory towards solution attainment compared to an incremental progress. One possible explanation is that solutions may emerge from unconscious processing and enter conscious awareness in a relatively integrated form. This makes it challenging to explore and study these "Aha!" moments, as insights are commonly referred to. One possible way of exploring them is to collect data from multiple signals in order to both study behaviour as well as context. Such multimodal data collection can quickly become expensive, which is why this study took a two fold approach to the problem. The first was the study of "Aha!" moments during a creative problem solving task. And the second was to explore if a cost-efficient and open-source infrastructure could be developed to collect the needed data. After developing and testing the infrastructure we identified moments of insight to not only be a single cognitive state, but rather three three different cognitive states, expressing inherently different neural patterns.

Research Plans for Online Motivation-Tailored Support in Higher Education
Keywords: Eye-Tracking, Feedback and Biofeedback, Higher Education, Personalized Learning Environments
Presenting Author: Bo Matton, University of Antwerp, Belgium; **Co-Author:**David Gijbels, University of Antwerp, Belgium

Many first-year students encounter difficulties in academic and social integration. Initiatives using online self-assessments with personalized feedback aim to support this transition by stimulating reflection and encouraging students to think about actions to enhance their performance. However, feedback is only effective when students engage with it. Currently, little is known about why students choose to use feedback or not, and the role of motivation in how they process, interpret, make decisions, and act upon feedback remains unclear. Therefore, this project investigates the role of motivation in the internal feedback process and examines the differential effectiveness of an online, motivation-targeted support intervention aligned with students' basic psychological needs. Using a mixed-methods design, this project combines a lab study (eye-tracking, stimulated recall interviews), a longitudinal study (online diaries), an intervention study (online diaries, learning analytics), and an experimental study (pre–post surveys) to generate fundamental insights into feedback processing and provide empirical evidence on how motivation-targeted support can enhance feedback engagement and support first-year students' academic and social integration in higher education.

Tracking the emergence of purposeful reading in children: an eye-tracking study in primary school.

Keywords: Cognitive Skills and Processes, Comprehension of Text and Graphics, Eye-Tracking, Metacognition
Presenting Author: Anaïs Deleuze, Université Grenoble Alpes, France; **Co-Author:**Mirjana Sestier, Université Grenoble Alpes, France; **Co-Author:**Jean-François Rouet, University of Poitiers - CNRS, France; **Co-Author:**Guillaume De Pereyra, Université de Poitiers, France; **Co-Author:**Anna Potocki, Université Grenoble Alpes, France

Developing readers learn not just to decode and comprehend, but also to select texts and sections within texts as a function of their interests and goals. Access to online measures of text processing is crucial for understanding how these strategic reading skills emerge, and which cognitive and linguistic factors support their development.The present study explores the emergence of selective reading between Grades 3 and 5, a key period during which important changes in strategies are expected but remain insufficiently documented. In addition to examining developmental differences, we investigate the cognitive and linguistic factors supporting the emergence of selective reading. To this end, around 200 students completed a comprehensive assessment including reading comprehension, metatextual knowledge, decoding, vocabulary, working memory, and inhibition. Participants' eye movements were recorded as they answered a series of questions by reading a short informational text structured into six paragraphs with subheadings. The question remained visible during reading. We examined how students navigated the text, revisited the question, and efficiently accessed relevant sections.Analyses focus on time to first fixation on relevant areas, distribution of attention across relevant versus irrelevant zones, and overall reading patterns (linear versus selective reading, evolution of strategies during the task). We further examine differences between Grades 3 and 5 and investigate how cognitive and linguistic skills predict eye-movement patterns associated with selective reading. These results will provide new insights into the development of task-oriented reading strategies in children, with potential implications for instructional practices.

Eye tracking and machine learning: Predicting classroom activity based on teacher gaze
Keywords: Classroom Analytics, Eye-Tracking, Teaching Analytics, Video Data
Presenting Author: Senne Van Hoecke, Open Universiteit, Netherlands; **Co-Author:**Kshitij Sharma, Norwegian University of Science and Technology (NTNU), Norway

To become an expert in a field, an individual needs to acquire more than domain-specific knowledge. It also concerns developing the skills to operate effectively within a professional context. One of these skills is professional vision (Goodwin, 1994), defined as the way individuals see and interpret objects or phenomena within their respective profession. Since its introduction, professional vision has been studied across a range of domains, like chess (Sheridan & Reingold, 2017a), medicine (Jarodzka & Boshuizen, 2017; Sheridan & Reingold, 2017b), air traffic control (Van Meeuwen et al., 2014) and also teaching (Van Es & Sherin, 2021; Seidel & Sturmer, 2014; Jarodzka et al., 2023).
A classroom, however, is a complex, unpredictable and highly dynamic environment, making mobile eye-tracking data complex to analyze. To provide structure to the dynamic environment, Van Hoecke and Halszka (in press) proposed a coding scheme for teaching activities. The present paper wishes to partially validate the coding scheme, exploring whether activities correspond to distinguishable gaze patterns, and explore how machine learning can support the data analysis.
We trained a XGBoost machine learning model on a large authentic mobile eye-tracking dataset to predict teaching activities based on gaze features. The model achieved an accuracy of 92.24% on a real, separate testing dataset. Feature importance analyses revealed that saccade duration, fixation duration and count, and blink counts were important measures to distinguish teaching activities. The findings provide support for the proposed coding scheme and demonstrate the potential of machine learning for scalable analysis of teacher professional vision.

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19 November 2026 09:00 - 10:30
Amfiteatre
No- or not-so-perfect-data presentation
Learning and Instructional Technology

Multimodal data

Keywords: (Joint) Attention, Adaptive Learning Environments, Cognitive Load, Collaborative Learning, Electrodermal Activity, Eye-Tracking, Learning Strategies, Multimodal Data, Multimodal Learning Analytics
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Tobias Deribo, Germany

Exploring teacher orchestration load during collaborative scenarios using multimodal data
Keywords: Cognitive Load, Collaborative Learning, Eye-Tracking, Multimodal Data
Presenting Author: Thy Tran Khanh, KU Leuven, Centre for Instructional Psychology and -Technology (Vesaliusstraat 2, 3000 Leuven), Belgium; **Co-Author:**Annelies Raes, KU Leuven, Belgium; **Co-Author:**Ginette Lafit, KU Leuven, Belgium

Collaborative learning can offer substantial benefits for student engagement and learning outcomes, yet its effective implementation requires active teacher guidance. Among various pedagogical approaches, collaboration scripts are used as one method to help teachers structure learner roles, tasks, and interactions in ways that promote productive social learning processes. However, orchestrating such collaborative learning scenarios places considerable demands on teachers, who must manage multiple, interrelated tasks across individual, group, and classroom levels under real-time constraints. These demands contribute to teacher orchestration load, defined as the cognitive, emotional, and physical effort required to coordinate multi-layered learning activities in dynamic classroom environments.Despite growing interest in teacher orchestration, research has largely overlooked teacher orchestration load as a dynamic, continuously evolving process, particularly in low-technology collaborative learning settings. This limits understanding of how orchestration load unfolds as teachers respond to emerging classroom occurrences. Addressing this gap, the present study investigates the temporal dynamics of teacher orchestration load from an integrative perspective, examining how its cognitive, emotional, and physical components fluctuate, cluster, and peak over time during collaborative learning scenarios. It further explores which contextual, interactional, and orchestration features are associated with these fluctuations. Using a multimodal approach that combines eye-tracking measures, experience sampling methods, classroom observations, and stimulated recall interviews, this study aims to contribute a methodological framework for measuring and analyzing teacher orchestration load in authentic classrooms, and to generate practical insights for reducing orchestration load while supporting effective collaborative learning.

Real-time Finnish compound learning: Effects of wordlist sequencing strategies
Keywords: Cognitive Load, Electrodermal Activity, Learning Strategies, Multimodal Data
Presenting Author: Ishmael Kweku Forson, University of Jyväskylä, Finland; **Co-Author:**Heidi Layne, University of Jyväskylä, Finland; **Co-Author:**Héctor J. Pijeira-Díaz, University of Jyväskylä, Finland

Abstract This study considers how different wordlist sequencing strategies, blocked, consecutive, and simultaneous, affect the learning of Finnish compound words (e.g., *sanakirja*, *palvelupiste*). It adopts a process-oriented approach grounded on information processing, cognitive load, self-efficacy, and arousal to examine how compound words are best learned from cognitive, motivational, and physiological perspectives. A randomized controlled trial with a within-subject design will be conducted with approximately 100 adult foreign nationals. Participants will be required to learn Finnish compound words and complete immediate- and delayed-recall tasks across all three sequencing conditions (10 words per condition). The sequencing conditions will be counterbalanced to minimize order effects. Participants' vocabulary recall accuracy will be the primary outcome measure. The online measures to be assessed include behavioural log data (e.g., response times) and physiological arousal, indexed by electrodermal activity (EDA), which is continuously measured with Movisens EDAMove4 sensors. It is hypothesized that the paired strategy will yield the highest recall, while the blocked strategy may increase cognitive load and arousal to detrimental levels. The alternating strategy is expected to balance effectiveness with lower cognitive demands. This study provides a multimodal account of vocabulary learning by integrating performance data, self-reports, log data, and physiological data. It offers evidence-based insights to optimize instructional design in second-language learning.

Multimodal Collaborative Learning Processes in Mixed Reality
Keywords: (Joint) Attention, Adaptive Learning Environments, Multimodal Data, Multimodal Learning Analytics
Presenting Author: Andy (Khanh Xuan) Nguyen, University of Oulu, Finland; **Co-Author:**Boshra Najari, University of Oulu, Finland; **Co-Author:**Tam Le, University of Oulu, Finland; **Co-Author:**Thu Duong, University of Oulu, Finland; **Co-Author:**Mohammadamin Yamini, University of Oulu, Finland

Mixed reality (MR) technologies have advanced rapidly in recent years, creating new opportunities for collaborative learning that extend beyond what has traditionally been explored in virtual reality environments. By integrating physical and virtual objects within shared spaces, MR enables embodied interaction, spatial coordination, and collaborative manipulation of digital artifacts during learning activities. However, limited research has examined how collaborative learning processes dynamically unfold in such hybrid physical–virtual environments. This study investigates multimodal collaborative learning processes in a shared MR environment through the integration of interactional, embodied, and physiological data. A total of 64 higher education students worked in 25

collaborative groups to complete a collaborative problem-solving activity titled the “Universal Alignment Challenge,” in which learners constructed astronomical configurations using virtual celestial objects in MR. During the activity, synchronized multimodal data were collected, including first- and third-person video recordings, verbal interaction, gestures, spatial navigation, object manipulation, and electrodermal activity (EDA). Post-task interviews and surveys were also conducted to contextualize learners’ experiences. Preliminary observations suggest that collaborative learning in MR environments involves dynamic transitions between verbal negotiation, embodied coordination, and shared manipulation of virtual artifacts. The findings highlight how physical and virtual objects jointly mediate collaborative meaning-making and coordination processes. The study contributes to collaborative learning and multimodal learning analytics research by advancing understanding of how learning processes unfold in immersive hybrid environments and by informing the design of future MR-supported collaborative learning environments in higher education.

Session Thu 19, 09:00 - 10:30 2

19 November 2026 09:00 - 10:30
Sala polivalent 2
No- or not-so-perfect-data presentation
Higher Education, Motivational, Social and Affective Processes

Physiological and multimodal data

Keywords: Artificial Intelligence, Cardiovascular Responses, Critical Thinking, Educational Technology, Emotion and Affect, Higher Education, Instructional Design, Multimodal Data, Online Learning Environments, Physiological Data, Psychophysiology
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Simon Tiffin-Richards, Leibniz Institute for Science and Mathematics Education (IPN), Germany

Do Physiological Challenge/Threat States Affect Learning from Debiasing Instructions in Reasoning?
Keywords: Cardiovascular Responses, Critical Thinking, Emotion and Affect, Instructional Design
Presenting Author: Florence Lucas, Utrecht University, Netherlands; **Co-Author:**Tamara Van Gog, Utrecht University, Netherlands; **Co-Author:**Eva Janssen, Utrecht University, Netherlands

Biased reasoning is a pervasive problem in education and society. It is important that students learn to avoid biases in probabilistic reasoning, for their functioning in many professional contexts (e.g., medicine, law, teaching, economics), as well as in their daily lives (e.g., vaccination decisions). Feedback and instructions have proven effective for debiasing, resulting in considerable improvements in reasoning accuracy at group level; however, it is unclear why some individuals improve (much) more than others. We hypothesize this might be explained by affective-motivational responses (which are rarely investigated in reasoning research), more specifically by learners’ challenge/threat responses to the feedback and instruction. A first study using self-report challenge/threat measures, showed that averaged over the entire sample, instruction led to a large improvement in reasoning. Yet, of the participants who were biased at pretest, just over half improved; the others remained biased after instruction. Those who improved were characterized by higher actively open-minded thinking, lower general overconfidence, and higher cognitive ability. In contrast to our hypothesis, it was not (under)graduate students’ challenge/threat response to the negative feedback (telling them that they were biased), but their threat response to the subsequent instruction that was associated with remaining biased or improving at posttest (i.e., with learning from the instruction). Because those findings are correlational and rely on self-report data, we are currently planning a study (presented in this ‘no-or-not-so-perfect-data’ session) with cardiovascular challenge/threat measures to test the effects of experimentally inducing a challenge or threat state on learning from the debiasing training.

Measuring Challenge/Threat: Validating a New Self-Report Instrument with Cardiovascular Measures
Keywords: Cardiovascular Responses, Emotion and Affect, Physiological Data, Psychophysiology
Presenting Author: Florence Lucas, Utrecht University, Netherlands; **Co-Author:**Eva Janssen, Utrecht University, Netherlands; **Co-Author:**Denise Hom, Utrecht University, Netherlands; **Co-Author:**Tamara Van Gog, Utrecht University, Netherlands

Abstract The Biopsychosocial Model of Challenge and Threat describes how challenge and threat states arise during motivated performance situations, from an individual’s (automatic) evaluation of their available resources in relation to the task demands. Individuals in a challenge state have been consistently found to achieve better performance outcomes than those in a threat state across various domains. As such, the BPSM is a promising framework to use in educational research. Challenge and threat states can be most reliably measured with psychophysiological (i.e., cardiovascular) measures. However, such measures are labor intensive and costly, which (currently) makes it difficult to apply them in classroom settings or in larger-scale studies. These states can also be assessed with the use of self-report measures; yet these do not always seem to correlate with cardiovascular measures. Moreover, it seems that these existing questionnaires can also be improved on a conceptual level, given that they most often focus only on a subset of dimensions that weigh into the resource-demand evaluations that result in challenge or threat states. We therefore aim to develop a new challenge and threat questionnaire based on all the dimensions proposed by Blascovich (2008), and in the present study, seek to validate this instrument with cardiovascular challenge/threat measures.

Reimagining Learning Spaces: Imperfect Process Data on School Leaders in Immersive Classrooms
Keywords: Educational Technology, Higher Education, Multimodal Data, Online Learning Environments
Presenting Author: Marc-André Girard, Université du Québec à Montréal (UQAM), Canada

This proposal outlines a qualitative, multimodal study that will examine how school leaders’ spatial–pedagogical approaches evolve when they engage with immersive virtual representations of classrooms and schools. Drawing on theories of conceptual and ontological change and on research into learning spaces,

the study conceptualizes spatial arrangements as central mediators of participation, collaboration, and what counts as *learning activity*. Immersive virtual reality and spatial computing (e.g., Apple Vision Pro, Thinglink) will be used to situate principals and vice principals inside diverse, carefully designed layouts, allowing them to observe, inhabit, and manipulate space while generating online traces of their exploration and sense-making. The design envisages a multiple case study with 12–15 leaders from Québec schools participating in three to four sessions each. Longitudinal data will include positional tracking, interaction logs, and concurrent verbal commentary, complemented by artefacts such as annotated floor plans and design briefs. The contribution will foreground methodological challenges related to the indirect and fragile mapping between theoretical constructs (e.g., viewing classrooms as networks of activity zones) and available process measures, as well as data loss, device heterogeneity, ethical constraints, and small sample sizes.

Noisy feelings: Multimodal measurement of academic emotions during AI-mediated learning
Keywords: Artificial Intelligence, Emotion and Affect, Multimodal Data, Psychophysiology
Presenting Author: Tuisku Tammi, University of Helsinki, Finland; **Presenting Author:**Elina E. Ketonen, University of Helsinki, Finland

Learning with AI and digital technologies is increasingly common, yet the emotional side of these practices remains difficult to study in authentic learning settings. The AI-EMOTION project addresses this gap by combining event-based self-reports (experience sampling) and wearable psychophysiological measures to examine students’ academic emotions as they unfold in real-life learning situations. However, this ambitious multimodal design also produces methodological challenges. These include uncertainty about whether enough AI-related learning situations will be captured, measurement reactivity caused by repeated smartphone prompts, noisy and artifact-prone biosensor recordings, difficulties synchronising physiological signals with momentary self-reports, and ethical concerns related to intensive monitoring. A central pragmatic issue is identifying a suitable device, software and setup that can support repeated experience sampling, reliable physiological measurement, low participant burden and meaningful data integration. Rather than offering solutions, the presentation invites discussion on how researchers might study fluctuating emotional processes in natural learning environments with incomplete, noisy and temporally fragmented data, thereby contributing to methodological development in the field.

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19 November 2026 09:00 - 10:30
Sala polivalent 1
No- or not-so-perfect-data presentation
Assessment and Evaluation, Cognitive Science, Higher Education

(Multimodal) Learning analytics

Keywords: Assessment, Clustering, Cognitive Skills and Processes, Engagement, Eye-Tracking, Feedback and Biofeedback, Healthcare Education, Higher Education, Learning Analytics, Log Data, Longitudinal Analysis, Multimodal Data
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Saswati Chaudhuri, University of Jyväskylä, Finland

A large scale analytics project exploring first-year undergraduate students' dropout
Keywords: Clustering, Higher Education, Learning Analytics, Longitudinal Analysis
Presenting Author: Crina Damsa, University of Oslo, Norway; **Co-Author:**Jan Arild Dolonen, University of Oslo, Norway; **Co-Author:**Andres Araos, University of Oslo, Faculty of Education, Norway; **Co-Author:**Manuel Olivera Toro López, University of Oslo, Norway; **Co-Author:**Anna Mavroudi, University of Oslo, Faculty of Education, Norway; **Co-Author:**Rachelle Esterhazy, Oslo Metropolitan University, Norway; **Co-Author:**Asmaa Abusamra, Asmaa Abusamra, Norway; **Co-Author:**Stefan Schauber, University of Oslo, Norway

A pilot project at a [anonymized] university explored how learning analytics might illuminate first-year dropout by combining study administrative registry data, Canvas activity data, surveys, and interviews. The project analysed historical datasets of 21,564 students (cohorts 2019–2023) and an active cohort of 4,839 students for 2024. While the project identified meaningful patterns, including differentiated study trajectories and varying engagement profiles, it also revealed the methodological fragility of institutional learning analytics. Study administrative registry data required extensive cleaning and recoding while activity data from the LMS were difficult to interpret across diverse pedagogical contexts. In addition, low survey response rates limited the possibility of triangulation. We argue that the succes of institution wide learning analytics depends not only on access to large datasets, but more importantly on the quality, interoperability, and interpretability of those data, which shape methodological decisions during the research process.

Pediatric Emergency team Leaders' Eye Movements During Simulation Training
Keywords: Cognitive Skills and Processes, Eye-Tracking, Healthcare Education, Multimodal Data
Presenting Author: Roger Azevedo, University of Central Florida, United States; **Co-Author:**Annamarie Brosnihan, University of Central Florida, United States; **Co-Author:**Megan Wiedbusch, University of Central Florida, United States; **Co-Author:**Lindsey Schulz, Nemours Children's Hospital, United States; **Co-Author:**Shiva Kalidindi, Nemours Children's Hospital, United States

Medical emergencies are high-stakes environments requiring the collaboration of clinicians across temporal phases and benefit from simulation-based training. Prior work shows that high-performing leaders in these cases focus their visual attention on team members, resulting in effective team dynamics and patient care. However, these findings are isolated to active medical intervention and ignore the critical planning phase that is =critical for defining team dynamics and promoting team fluidity and positive patient outcomes. During this phase, an appointed team leader defines task goals and assigns individual roles, directing the attention of team members and supporting proper enactment of medical interventions. As such, the current study examined team leader gaze during planning an emergency pediatric medical simulation and their relation to performance metrics. Nineteen (N = 19) medical residents completed an emergency pediatric medical simulation as the team leader, where their visual attention on task-, tool-, and role-related stimuli were analyzed in relation to leadership performance, team performance, and medical care efficiency. Despite previous findings, we found no significant relationships between visual attention and performance outcomes. However, the absence of significance does not imply a lack of cognition but highlights a potential inability to capture cognitive constructs through eye-tracking behaviors when individuals are not visibly attending to stimuli or during more controlled simulation settings. Given that pre-task instructions and a patient brief were administered verbally, broader questions arise regarding the most optimal method for delivering clinical information and the balancing of ecological validity and methodological rigor in high-stakes medical simulations.

Individual Antecedents of Behavioral Online Self-Assessment Feedback Engagement
Keywords: Assessment, Engagement, Feedback and Biofeedback, Log Data
Presenting Author: Moira Decorte, Ghent University, Belgium; **Co-Author:**Wouter Duyck, Ghent University, Belgium; **Co-Author:**Nicolas Dirix, Ghent University, Belgium; **Co-Author:**Stijn Schelfhout, Ghent University, Belgium

Choosing a suitable study program for higher education is found to be challenging for many prospective students. Therefore, the Columbus online self-assessment and feedback tool was developed to support secondary education students in making an informed study choice. Columbus provides feedback on potential study success based on assessments of cognitive abilities, motivation, learning strategies and Holland's RIASEC interest profiles. Despite its widespread use, little is known about which students meaningfully engage with the feedback. Moreover, prior research suggests that the specific dynamics between individual antecedents and feedback engagement remain unclear. To address this gap, the present study examines which individual antecedents are predictive of behavioral engagement with online feedback, using large-scale web-tracking data from the Columbus tool. Measuring behavioral engagement using log data presents several methodological challenges. Time-based metrics such as time-on-page cannot distinguish between active processing and passive behavior (e.g., leaving a page open). Different technical preprocessing steps and operationalization decisions to deal with imperfect log data can meaningfully alter the interpretation of engagement. Preliminary findings suggest that associations between individual antecedents and engagement depend on how engagement is operationalized and at which level it is analyzed (e.g., overall or at page-level). This study highlights the importance of methodological choices when using web-tracking data and contributes to the ongoing discussions on how to operationalize behavioral engagement when using large-scale log data.

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19 November 2026 11:00 - 12:30
Sala polivalent 1
Tutorial
Learning and Instructional Technology

Multimodal process research

Keywords: Cognitive Skills and Processes, Eye-Tracking, Learning Analytics, Multimodal Data
Interest group: SIG 27 - Online Measures of Learning Processes

Combining Eye-Tracking, Video, and Verbal Data in Multimodal Process Research
Keywords: Cognitive Skills and Processes, Eye-Tracking, Learning Analytics, Multimodal Data
Presenting Author:Özün Keskin-Senkal, University of Augsburg, Germany

This tutorial offers a practical introduction to designing and conducting multimodal research that combines eye-tracking, video, and verbal data to investigate online learning processes. As learning unfolds over time, no single measure can fully capture the attentional, behavioral, and interpretive dimensions of learners' activity. Eye-tracking can reveal visual attention and information selection, video can preserve situated action and task context, and verbal data can provide access to participants' interpretations, strategies, or reflections. The methodological challenge lies in aligning these data sources within a coherent research design and integrating them in analytically meaningful ways.The tutorial addresses this challenge by guiding participants through the main stages of multimodal process research: aligning research questions with data sources, planning data collection, preparing and processing multimodal records, selecting appropriate units of analysis, and developing defensible integration strategies. The session combines concise input, worked examples, and hands-on activities in which participants sketch a multimodal design and outline an initial integration plan. The tutorial is intended for researchers who want to expand their methodological repertoire and gain a practical entry point into multimodal research on learning as it happens.

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19 November 2026 11:00 - 12:30
Amfiteatre
Tutorial
Learning and Instructional Technology

Computational thinking

Keywords: Collaborative Learning, Computational Thinking, Computer-assisted Learning, Learning Analytics
Interest group: SIG 07 - Technology-Enhanced Learning And Instruction

Computational Thinking as a Method for Analyzing Collaborative Learning Processes with Python
Keywords: Collaborative Learning, Computational Thinking, Computer-assisted Learning, Learning Analytics
Presenting Author: Enrique Arturo Vázquez Uscanga, Universidad Alberto Hurtado, Chile

Computational Thinking (CT) has gained prominence not only as a learning outcome but as a methodological lens for designing and analyzing learning processes. This tutorial introduces CT as a practical methodological framework for studying collaborative learning and classroom interaction through data-driven approaches. Participants will engage hands-on with a structured workflow that connects CT phases (decomposition, abstraction, pattern recognition, and algorithmic design) to the analysis of interactional and behavioral data using Python.The tutorial focuses on lowering the entry barrier for researchers interested in using computational approaches to analyze learning as it unfolds. Using a shared dataset related to learners' digital activity and productivity, participants will

collaboratively explore how research questions about interaction, engagement, and regulation can be operationalized, translated into analyzable variables, and interpreted meaningfully. Emphasis is placed on the research process, including planning analytic strategies, handling noisy data, and making theoretically grounded interpretations of results.Designed for researchers with limited experience in data science but interest in methodological innovation, the tutorial combines short conceptual inputs, collaborative decision-making tasks, and guided hands-on analysis in a cloud-based Python environment (Google Colab). Participants will leave with a replicable analytic template and a clearer understanding of how CT-informed methods can support the study of collaborative learning processes.

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19 November 2026 11:00 - 12:30
Sala polivalent 2
Tutorial
Learning and Instructional Technology

Transition and pattern analysis

Keywords: Clustering, Cognitive Skills and Processes, Learning Analytics, Trace Data
Interest group: SIG 27 - Online Measures of Learning Processes

Capturing the dynamics of learning processes with transition and pattern analysis
Keywords: Clustering, Cognitive Skills and Processes, Learning Analytics, Trace Data
Presenting Author: Mohammed Saqr, University of Eastern Finland, Finland; **Presenting Author:**Kamila Misiejuk, CATALPA, FernUniversität in Hagen, Germany, Germany; **Presenting Author:**Sonsoles López-Pernas, University of Eastern Finland, Finland

Understanding how learning unfolds over time requires methods that can capture temporal dynamics rather than static snapshots. Transition Network Analysis (TNA) offers such a framework, enabling researchers to model, visualize, and validate transitions between learning states moment by moment. This tutorial introduces TNA and its variations, showing how they can be applied to study individual and collaborative learning across different learning environments and settings. Through a guided hands-on walkthrough using Jamovi, participants will work with a real dataset to construct, visualize, statistically analyze, and interpret temporal networks. No programming background is necessary, as Jamovi provides an accessible no-code environment suitable for all skill levels. The tutorial also covers the broader research workflow, including what data to collect, how to pre-process event-based and discourse data, and how to move from raw data to meaningful interpretations. By the end, participants will be equipped to evaluate whether TNA fits their own research questions and to take their first steps toward applying it independently. Additional resources, including the tna R package and corresponding tutorials, will be shared.

Session Thu 19, 14:45 - 16:15 1

19 November 2026 14:45 - 16:15
Sala polivalent 2
Single Paper
Cognitive Science, Learning and Social Interaction, Motivational, Social and Affective Processes

Self-regulated learning

Keywords: Artificial Intelligence, Cardiovascular Responses, Emotion and Affect, Log Data, Mental Effort, Meta-analysis, Motivation, Reading, Self-efficacy, Self-regulated Learning, Socially-Shared Regulation, Think Aloud Data
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Tam Le Hong, University of Oulu, Finland

Audience Effects on Psychophysiological Challenge/Threat Responses and Performance
Keywords: Cardiovascular Responses, Self-efficacy, Self-regulated Learning, Think Aloud Data
Presenting Author: Denise Hom, Utrecht University, Netherlands; **Co-Author:**Eva Janssen, Utrecht University, Netherlands; **Co-Author:**Florence Lucas, Utrecht University, Netherlands; **Co-Author:**Daan Scheepers, Utrecht University, Netherlands; **Co-Author:**Tamara Van Gog, Utrecht University, Netherlands

The *biopsychosocial model of challenge and threat* (BPSM; Blascovich, 2008) is rarely used in educational research, although the use of cardiovascular measures of challenge/threat motivational states might provide a unique opportunity to explore why interventions like learning-by-teaching improve academic performance and learning for some students, but not for others. In this contribution, we will first review literature on audience effects on cardiovascular challenge/threat states, and then present an empirical study in which we investigated these effects in the context of training students' self-regulated learning skills. Students first received task-selection training and subsequently explained the learned procedure aloud to either a fictitious (audience implied) or actual (audience present) other person. We hypothesized that having an actual audience during learning-by-teaching would benefit students higher in self-efficacy (i.e., higher challenge and better performance) and would be less beneficial for those with lower self-efficacy (i.e, higher threat and lower performance). Although the pattern in the data was in the expected direction for lower self-efficacy students, results from the analyses did not confirm our hypothesis. Exploratory analyses showed that when the vignettes required algorithm adaptation (i.e., transfer), having an actual audience was more threatening, but only for higher self-efficacy students. Results will be discussed in light of research on the BPSM and learning-by-teaching, and our experiences with applying these cardiovascular measures of challenge and threat will be shared with the SIG27 audience.

Motivational characteristics underlying temporal self-regulated learning profiles
Keywords: Emotion and Affect, Log Data, Motivation, Self-regulated Learning
Presenting Author: Tiina Törmänen, University of Oulu, Finland; **Co-Author:**Anja Henke, University of Potsdam, Germany; **Co-Author:**Hanna Järvenoja, University of Oulu, Finland; **Co-Author:**Rebecca Lazarides, University of Potsdam, Germany

Self-regulated learning (SRL) involves learners monitoring their learning and, based on this monitoring, controlling and adapting their cognition, motivation, emotions, and behavior during the learning process. This study examined learners' temporal SRL profiles in a computer-based adaptive learning environment. It also examined how these profiles relate to learners' pre-task motivation and domain knowledge, concurrent emotional valence, and post-task gains in domain knowledge and motivation. A total of 159 learners (M_{age} = 15.30) studied climate change in Betty's Brain environment. Log data were collected and segmented into 10-minute intervals, and learners reported their concurrent activity emotions after each interval. Pre- and post-measures assessed domain knowledge, topic-related task value, and topic-related self-efficacy. Learners' behavior sequences were first clustered using mixture hidden Markov models to identify within-interval SRL behavior states, which were then sequenced across each individual learner's full learning process to form temporal SRL profiles. Three temporal SRL profiles were identified: adaptive-to-trial-and-error, moderate-accuracy, and low-to-inactive SRL. The profiles were related to motivational characteristics, particularly self-efficacy and task value, whereas prior domain knowledge and concurrent emotional valence showed no significant relations to profile membership. Differences between profiles in learning and motivational gain (post–pre) were also examined. The results showed no clear differences in domain knowledge gain, self-efficacy gain, or task value gain between profiles. Overall, the findings suggest that SRL profiles reflect differences in how learners regulate their learning over time and are related to learners' pre-task motivational characteristics. However, these profiles show limited relations to short-term learning and motivational outcomes.

Multiple and Single Digital Document Comprehension: Time on Task as a Process Indicator
Keywords: Log Data, Mental Effort, Meta-analysis, Reading
Presenting Author: Simon Tiffin-Richards, Leibniz Institute for Science and Mathematics Education (IPN), Germany; **Co-Author:**Joyce Gubbels, Dutch Center for Language Education, Netherlands; **Co-Author:**Nicole Swart, Dutch Center for Language Education, Netherlands; **Co-Author:**Johannes Naumann, University of Wuppertal, Germany; **Co-Author:**Eliane Segers, Radboud University, Netherlands

The ability to comprehend information from multiple documents is a key aspect of digital reading proficiency. Theories of multiple-document comprehension suggest that, when faced with information from multiple authors and/or sources, readers require specific, cognitively demanding selection, navigation and integration strategies in order to successfully construct meaning from multiple sources. However, it remains unclear how reading processes involving multiple sources differ from those involving a single source, and whether engagement plays a particularly important role. Using PISA-2018 data from 44 countries (N = 341,591), we tested three assumptions: 1) that multiple-source reading is more cognitively demanding than single-source reading, resulting in lower comprehension accuracy for multiple-document comprehension; 2) that greater engagement (i.e. increased time-on-task) is beneficial for comprehension; and 3) that successful multiple-source comprehension relies more on engagement (i.e. time-on-task) than single-document comprehension. Analyses of over seven million responses were conducted at country level using generalised linear mixed-effects models, which were then incorporated into a random-effects meta-

analysis. The integrated results supported our hypotheses: (1) response accuracy was higher for single-source items than for multiple-source items; (2) time-on-task was positively related to overall response accuracy; and (3) the time-on-task effect was greater for multiple-source comprehension than for single-source comprehension. We conclude that readers generally find it more challenging to derive meaning from multiple sources than from single sources, and that investing more time improves comprehension, particularly when readers are faced with information spread over multiple sources.

Analysing SSRL from Video Data Using a Structured Agent-Based Approach
Keywords: Artificial Intelligence, Emotion and Affect, Self-regulated Learning, Socially-Shared Regulation
Presenting Author: Hanna Järvenoja, University of Oulu, Finland; **Co-Author:**Xiaoyu Yuan, University of Oulu, Finland; **Co-Author:**Niklas Heikkala, University of Oulu, Finland; **Co-Author:**Guoying Zhao, University of Oulu, Finland; **Co-Author:**Haoyu Chen, University of Oulu, Finland

Research on socially shared regulation of learning (SSRL) conceptualises cognitive, motivational, and emotional processes as intertwined aspects of collaborative activity. However, empirical approaches have struggled to capture these dimensions within the same moments of interaction. In particular, methodological tools that allow the joint identification of monitoring and controlling processes, the target of regulation, and the valence of interaction within the same episode remain llimited.This study explores how a structured, agent-based analytical framework can be used to analyse SSRL processes from video data. The analysis focuses on how monitoring and controlling processes, together with the cognitive and emotional targets of regulation, can be examined within the same short video-based SSRL episodes. While SSRL processes are theoretically simultaneous, the agent-based approach structures their interpretation sequentially.The results show that the approach enables the identification of multiple dimensions of SSRL within the same interactional context. At the same time, qualitative case examples demonstrate that the sequential structure of the analysis simplifies the phenomenon and may fail in situations where regulation is ambiguous or tightly intertwined. The study shows that the agent-based approach enables examining monitoring and controlling processes together with their cognitive and emotional targets within the same SSRL episodes. At the same time, it faces challenges in situations where these dimensions are tightly intertwined. This highlights a key methodological issue: the sequential analysis organises how the relationships between these dimensions are described, which may be reflected in the analytical outcomes.

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19 November 2026 14:45 - 16:15
Sala polivalent 1
Single Paper
Learning and Instructional Technology, Learning and Social Interaction, Lifelong Learning

Artificial intelligence

Keywords: Adaptive Learning Environments, Artificial Intelligence, Competences, Critical Thinking, Digital Literacy and Learning, Engagement, Learning Analytics, Learning Strategies, Log Data, Longitudinal Analysis, Social Network Analysis, Text Data
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Anni silvola, University of Oulu, Finland

Capturing Learning Processes at Scale: From the MEPA Method to YEPA AI
Keywords: Artificial Intelligence, Learning Strategies, Longitudinal Analysis, Text Data
Presenting Author: Bernadette Charlier, University of Fribourg, Switzerland; **Co-Author:**Joris Felder, Yllyl, Switzerland; **Co-Author:**Leonard Noth, Yllyl, Switzerland; **Co-Author:**Sandy Ingram, HES-SO, Switzerland; **Co-Author:**Morgane Nissile, Yllyl, Switzerland

This paper introduces an original methodological approach to capture learning processes and make learning visible at scale. Rooted in distributed cognition and Personal Learning Environments (PLEs), it presents the evolution of the manual MEPA (Modelling of Personal Learning Environments) method into YEPA AI, an intelligent technological companion. To address the symposium's focus on online capturing, describing, and analysing learning processes, this contribution demonstrates how researchers use YEPA to assist the analysis of elicitation interviews, which can be facilitated by a conversational agent. By employing a custom embedding-based neural classifier trained on 17,500 domain-specific samples, YEPA automates the nuanced classification of learning sequences into the MEPA ontology with 94.0% accuracy. This technological augmentation robustly bridges the gap between deep qualitative process measures and large-scale capabilities. We illustrate this workflow using empirical data from a study of nine university students, comparing their PLEs across different instructional designs. The AI-assisted analysis highlights how the tool reliably identifies constructive or destructive frictions and congruences within the learning practices, visualised through the PLEs emerging from learners' interactions with the institutional learning environments. Ultimately, positioning AI as a reflexive research instrument saves substantial time for researchers whilst fostering learner metacognition, offering original methodologies to analyse learning processes and understand lifelong learning dynamics.

A Log-Based Analysis of Student Engagement with an Intelligent Biology Tutor
Keywords: Artificial Intelligence, Engagement, Learning Analytics, Log Data
Presenting Author: Bruno Poellhuber, University of Montreal, Canada; **Presenting Author:**Normand Roy, University of Montreal, Canada

Since the emergence of ChatGPT and the possibility of creating personal and adaptative agents with general generative AI tools (e.g., GPTs or GEMs), a wide range of intelligent agents has been developed. As science courses continue to face persistent engagement and retention challenges and as generative AI becomes increasingly embedded in students' academic practices, intelligent tutors emerge as a promising avenue for sustaining motivation, persistence and achievement. In response to this situation, a multidisciplinary team designed Biotutor, an intelligent tutor based on a user-centred development approach, and deployed it in Fall 2025 across 10 college-level cell biology classes. This study investigates how students used the tutor and characterizes these uses in relation to behavioural and cognitive engagement. Based on log analysis classification, the analysis first identified four distinct behavioural profiles that broadly map onto a continuum of behavioural engagement, with the early profiles also corresponding to the initial stages of cognitive engagement in the ICAP framework. An exploratory generative AI-assisted analysis of conversations from the more complex profiles revealed diverse forms of engagement among the two most engaged groups. A closer examination of selected conversations also showed shifts from one stage to another within a single conversation. Clarification seekers appeared to display stronger cognitive engagement than hyperactive polyvalent users, whereas the latter demonstrated higher behavioural engagement. Future research should validate the categories identified through generative AI-assisted analyses against manually coded human analyses and relate these profiles to questionnaire data on perceived value, tutor adoption and learning outcomes.

Understanding High-order Human AI Interaction Processes with Higher-order Networks
Keywords: Artificial Intelligence, Critical Thinking, Learning Analytics, Social Network Analysis
Presenting Author: Mohammed Saqr, University of Eastern Finland, Finland; **Co-Author:**Sonsoles López-Pernas, University of Eastern Finland, Finland; **Co-Author:**Kamila Misiejuk, CATALPA, FernUniversität in Hagen, Germany, Germany

The integration of Large Language Models (LLMs) into learning has transformed Human-AI Interaction (HAII). While traditional network analysis yields valuable insights into these interactions, conventional dyadic models fail to capture the extended temporal dependencies and multi-step trajectories inherent in modern HAII. This study investigates high-order HAII processes by applying a Higher-Order Network (HON) framework, moving beyond pairwise relations to accurately model the sequential, complex and interdependent nature of learner-AI dialogues. We analyzed interaction sequences from a university network analysis course where students collaborated with LLMs to generate complex datasets. Interactions were coded using a mixed inductive-deductive approach. The HON framework was utilized to map higher-order dependencies, and Hypergeometric Path Analysis (HYPA) was applied to detect statistically anomalous multi-step pathways. Additionally, simplicial degrees were computed to measure node participation across various pathway lengths. The analysis reveals that higher-order sequential memory resides almost entirely within demand-issuing moves (Specification and Instruct), while critical-thinking moves (Reasoning, Refine, Critique) operate primarily at a first-order level. Over-represented higher-order motifs are dominated by iterative refinement and specification loops. However, when critical-thinking moves do occur within these higher dimensions, they significantly enrich, diversify, and extend the interaction trajectories.

Privacy Matters: An Adaptive AI Learning Agent for Conscious Data Sharing with AI Tools
Keywords: Adaptive Learning Environments, Artificial Intelligence, Competences, Digital Literacy and Learning
Presenting Author: Ellen De Bruyne, AP University of Applied Sciences and Arts Antwerp, Belgium; **Co-Author:**Wim Casteels, AP University of Applied Sciences and Arts, Belgium

Artificial intelligence (AI) is increasingly embedded in educational, professional, and everyday contexts. As AI tools mediate communication, decision-making, and knowledge production, concerns regarding privacy, data governance, and responsible AI use become more urgent. Despite the widespread adoption of AI systems, many users lack sufficient understanding of what happens to the data they share with AI tools, including issues related to data storage, model training, human oversight, and sensitive information processing.This paper presents the design and early development of an adaptive AI-supported learning environment

aimed at strengthening privacy-conscious AI literacy. Grounded in the OECD AI Literacy Framework (2025), the project specifically focuses on privacy awareness and responsible data-sharing practices. The study also responds to emerging European policy frameworks, including the Ethics Guidelines for Trustworthy AI and the EU AI Act, which emphasize privacy and data governance as essential conditions for trustworthy AI systems.This study adopts Educational Design Research approach (Phillips & Dolle, 2006; McKenney & Reeves, 2012), combining literature review, iterative prototyping, technical development, survey research, and pilot testing. Central to the study is an adaptive AI agent that guides users through scenario-based microlearning modules on safe AI use. The agent personalizes explanations, exercises, and feedback according to learners' profiles and prior knowledge. Data collection consists of a pilot implementation with approximately 50 users and a broader survey study involving a minimum of 100 participants focusing on privacy-conscious and ethical AI practices. Preliminary findings are expected in October 2025.

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19 November 2026 14:45 - 16:15
Amfiteatre
Invited Symposium (SIG 27 Conference 2026)
Instructional Design, Learning and Instructional Technology, Motivational, Social and Affective Processes

SIG 16 Invited Symposium. Exploring Mechanisms of Self-Regulated Learning with Multimodal Data

Keywords: (Joint) Attention, Achievement, Anxiety and Stress, Artificial Intelligence, Assessment, Collaborative Learning, Educational Technology, Eye-Tracking, Instructional Design, Large Language Models, Learning Analytics, Learning Strategies, Log Data, Metacognition, Multimodal Data, Multimodal Learning Analytics, Self-regulated Learning, Socially-Shared Regulation
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Emely Hoch, University of Zurich, Switzerland
Chairperson: Kateryna Zabolotna, University of Oulu, Finland, Finland
Chairperson: Madalin Deliu, University of Salamanca, Spain
Organiser: Emely Hoch, University of Zurich, Switzerland
Organiser: Kateryna Zabolotna, University of Oulu, Finland, Finland
Organiser: Madalin Deliu, University of Salamanca, Spain
Discussant: Tamara Van Gog, Utrecht University, Netherlands

Self-regulated learning (SRL) is a dynamic process involving the monitoring and regulation of cognition, motivation, emotion, and behavior over time. Yet, many studies still rely primarily on retrospective self-report or distal performance outcomes, providing only limited access to the mechanisms through which monitoring and regulation unfolds. This symposium brings together four studies that use complementary process-sensitive methods to examine regulation of learning in different educational and applied contexts. The first study examines how multimedia test-item design shapes cognitive and metacognitive processing, integrating performance and confidence judgments with eye-tracking indicators of visual attention. The second study uses theory-informed learning analytics of behavioral trace data to investigate how students' homework behavior relates to academic performance. The third study explores how phases of self-regulation can be externalized through human–LLM dialogue, using conversational interaction and user evaluations to examine forethought, monitoring, control, and reflection during stress and anxiety self-management. The fourth study combines video-based coding of problem engagement and regulatory strategy use with acoustic-prosodic measures of interpersonal entrainment in a collaborative learning task executed by pre-service teachers. Across the four contributions, process data revealed patterns that would remain partly hidden when relying on outcomes or self-reports alone. At the same time, they raise shared methodological questions about how observable traces should be interpreted as indicators of underlying regulatory processes. The symposium, therefore, aims to advance a discussion on the opportunities and limitations of multimodal and interaction-based approaches for identifying SRL mechanisms across contexts.

Using Eye Tracking to Understand Multimedia Design Effects in Test Items
Presenting Author: Emely Hoch, University of Zurich, Switzerland; **Co-Author:**Salome Flegr, Dresden University of Technology, Germany; **Co-Author:**Katharina Scheiter, University of Potsdam, Germany; **Co-Author:**Jochen Kuhn, Ludwig-Maximilians-Universität München, Germany; **Co-Author:**Jan-Philipp Burde, University of Tübingen, Germany; **Co-Author:**Marlit Annalena Lindner, Leibniz Institute for Science and Mathematics Education, Germany

Adding representational pictures to text-based test items facilitates test performance (i.e., multimedia testing effect) and impact on students' perception of test items. However, little is known about how visualizations in test item stem and response options influence cognitive processing during test solving. From a metacognitive perspective, eye-tracking provides an online process measure that may reveal how students allocate their attention during test item evaluation and completion. This study examined how multimedia design for test item stem and response options affects performance, subjective judgments, and visual attention when solving multiple-choice test items. Participants (N = 80) solved 16 items presented in a 2×2 design, combining text-only or text-picture test item stems with text-only or text-picture item response options. Eye movements were recorded while participants completed the test items. Although multimedia design did not affect performance, adding pictures to item response options reduced perceived difficulty and increased confidence in solving the items. Moreover, eye-tracking data showed that adding pictures systematically guided attention allocation, as evidenced by reduced fixation time on textual information of the item stem or response options. These findings suggest that presentation format alters how students perceive and process test items, even in the absence of performance differences. The results highlight the value of online process measures such as eye-tracking for understanding how test item design shapes cognitive processing during test taking. Further, they suggest that pictures in test item stem and response options may serve different functions and should be considered separately in theories of multimedia testing or metacognition.

Using Theory-Informed Learning Analytics to Understand How Homework Behavior Predicts Achievement
Presenting Author: Hannah Deininger, University of Tübingen, Germany; **Co-Author:**Ines Pieronczyk, Hector Research Institute of Education Sciences and Psychology, Germany; **Co-Author:**Cora Parrisius, Karlsruhe University of Education, Germany; **Co-Author:**Robert Plumley, University of North Carolina at Chapel Hill, United States; **Co-Author:**Detmar Meurers, Leibniz Institute for Knowledge Media, Germany; **Co-Author:**Gjergji Kasneci, Technische Universitaet Muenchen, Germany; **Co-Author:**Benjamin Nagengast, Eberhard Karls Universität Tübingen, Germany; **Co-Author:**Ulrich Trautwein, University of Tübingen, Germany; **Co-Author:**Jeff Greene, University of North Carolina at Chapel Hill, United States; **Co-Author:**Matthew Bernacki, University of North Carolina at Chapel Hill, United States

Whether homework fosters achievement remains debated, partly because homework behavior is typically measured with often-unreliable self-reports. We argue that better estimates of these relationships require (a) changes to the data collected to measure homework behavior and (b) more theory-informed ways to model those data. Pursuing a substantive-methodological synergy, we combined an established theoretical model of homework behavior with theory-informed learning analytics to derive behavioral trace indicators of homework effort and time from log data of 507 German seventh graders using an intelligent tutoring system to practice English as a foreign language. Following an eight-step, theory-guided feature-engineering procedure, we extracted five behavior-based components: compliance and completion, homework time, conscientious working style, persistence, and regularity, which partly mirrored the theorized subcomponents of homework behavior. These trace-based components correlated only modestly with self-reported homework effort but outperformed self-reports in predicting subsequent English proficiency. Specifically, a conscientious working style was related to higher achievement, whereas more homework time was related to lower achievement, whereas self-reported effort was not a statistically significant predictor once prior knowledge was controlled. Path models showed that trace-based indicators partially mediated relations between prior knowledge and achievement. These findings help advance research on the long-standing homework–achievement mystery by showing that theory-aligned behavioral trace data capture unique, achievement-relevant information beyond self-reports, offering researchers a transferable feature-engineering framework and educators a more valid basis for understanding and supporting students' homework behavior.

Tracing Self-Regulation in Human–LLM Interaction: A Process Application of Pintrich's SRL Framework
Presenting Author: Madalin Deliu, University of Salamanca, Spain; **Co-Author:**Felipe Soto-Pérez, University of Salamanca, Spain; **Co-Author:**Miguel Ángel Verdugo, University of Salamanca, Spain; **Co-Author:**Andrea Lettieri, Research and Treatment in Mental Health and Social Services (INTRAS) Foundation, Spain; **Co-Author:**Alba Aza, University of Salamanca, Spain

Self-regulated learning (SRL) is inherently processual, yet its phases are frequently examined through retrospective self-report rather than through observable traces of regulation as it unfolds. Conversational large language models (LLMs) provide a novel interactional context in which regulatory processes can be elicited and partially externalized through dialogue. This research examined how Pintrich's four-phase SRL framework—forethought, monitoring, control, and reflection—could be operationalized within LLM-mediated support for stress and anxiety self-management among people with severe mental disorders. A conversational implementation was configured to provide phase-specific support, including anticipatory planning, identification of emotional and bodily cues, enactment of regulation strategies, and reflection on previous experiences. The implementation was evaluated through structured scenario-based interactions with mental-health professionals (n = 9) and service users (n = 26), combining conversational interaction data with post-interaction evaluations and observations of assistance required during use. Across stakeholder groups, concrete regulatory guidance was generally perceived as useful, while repetitive strategy delivery,

limited contextual exploration, and machine-like responses revealed points at which theoretically appropriate support did not necessarily translate into responsive interaction. Service users additionally varied substantially in the assistance required to engage with the conversational support. The findings illustrate how conversational traces can complement retrospective evaluations by making aspects of regulatory progression visible at the interaction level. More broadly, they highlight the potential of human–AI dialogue as a process-oriented methodological window onto how SRL phases are prompted, enacted, and experienced.

Acoustic-Prosodic Entrainment During Collaborative Problem Engagement and Regulation of Learning
Presenting Author: Martin Greisel, University of Augsburg, Germany; **Co-Author:**Kateryna Zabolotna, University of Oulu, Finland, Finland

Collaborative learning requires learners to coordinate their activities, particularly when problems emerge and require regulation. While collaborative regulation is commonly examined through verbal interaction, acoustic-prosodic entrainment may provide complementary information about interpersonal coordination. This exploratory comparative case study examined speaker-transition structures and acoustic-prosodic entrainment in two contrasting groups of pre-service teachers engaged in the same problem-based collaborative learning task. Video-recorded interactions were coded for problem engagement and the immediacy of regulatory strategy use. Acoustic-prosodic features, i.e., fundamental frequency (F0) level and variability, and loudness level and variability, were extracted from speaker turns using openSMILE and eGeMAPS. Entrainment was examined at the dyadic level through proximity and synchrony across adjacent cross-speaker turns. The groups showed distinct speaker-transition structures, with interaction concentrated around a small number of dyads. Acoustic-prosodic entrainment was feature- and dyad-specific: frequently interacting dyads did not consistently exhibit stronger proximity or synchrony across acoustic dimensions. Descriptive alignment with video-based coding further showed that these dyadic entrainment configurations were situated within both ongoing task-focused interaction and episodes of problem engagement and regulation, including immediate regulatory strategy use. The findings suggest that acoustic-prosodic entrainment should not be treated as a uniform group-level phenomenon or as an inherent indicator of successful collaboration. Instead, combining dyadic acoustic-prosodic measures with process-oriented analyses of interaction offers a promising approach for examining interpersonal coordination during collaborative learning.

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19 November 2026 16:15 - 17:45
Sala polivalent 1
Poster Presentation
Assessment and Evaluation, Learning and Instructional Technology

Posters B

Keywords: Artificial Intelligence, Assessment, Competences, Computational Thinking, Digital Learning Environments, Eye-Tracking, GenAI, Learning Analytics, Learning Strategies, Log Data, Meta-analysis, Problem Solving, Reading, Self-regulated Learning, Simulation-based Learning, Trace Data
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Leonard Tetzlaff, German Institute for International Educational Research (DIPF), Centre for International Student Assessment (ZIB), Germany

Plan or Plunge? Forethought-Performance Profiles in an online computational thinking task
Keywords: Computational Thinking, Log Data, Self-regulated Learning, Trace Data
Presenting Author: Tanya Chichekian, Université de Sherbrooke, Canada; **Co-Author:**Maria Cutumisu, McGill University, Canada; **Co-Author:**Annie Savard, McGill University, Canada; **Co-Author:**Yi-Mei Zhang, McGill University, Canada

Online process measures captured as learning happens offer diagnostic advantages over self-report instruments in computational thinking assessment, yet their predictive value relative to surveys remains underexplored in teacher education. Grounded in self-regulated learning theory, this study examines whether trace data such as task completion time, playground exploration time, and a preparation ratio indexing forethought investment revealed meaningful regulatory profiles in pre- and in-service teachers completing an online computational thinking task (N = 160). A k-means cluster analysis yielded four profiles differing significantly in both trace variables and perceived task difficulty, while self-reported metacognitive planning strategies provided negligible discriminant power (classification accuracy 34% vs. 96% for traces). The preparation ratio calculated as the proportion of session time allocated to forethought-phase exploration predicted scores on the online computational thinking task performance (McFadden R^2 = .350) more accurately than either time variable alone or both combined. Perceived task difficulty, captured as an embedded self-evaluative signal, was significantly negatively associated with the preparation ratio, positioning it as a process-level reflective indicator. Findings establish the diagnostic superiority of online traces over offline surveys for identifying regulatory profiles in computational thinking assessment and suggest that preparation-ratio monitoring could support adaptive feedback in teacher education.

Understanding Reading Comprehension Through Eye Movements and Cross-Linguistic Complexity
Keywords: Assessment, Eye-Tracking, Meta-analysis, Reading
Presenting Author: Francesca Zermiani, University of Valencia, Spain; **Co-Author:**Diane Mézière, University of Turku, Finland; **Co-Author:**Cristina Vargas Pecino, University of Valencia / Interdisciplinary Research Structure for Reading Research (ERI Lectura), Spain; **Co-Author:**Sini Hyvönen, University of Turku, Finland; **Co-Author:**Leen Catrysse, Open Universiteit Nederland, Netherlands; **Co-Author:**Johanna Kaakinen, University of Turku, Finland; **Co-Author:**Ladislao Salmerón, University of Valencia, Spain

Prior research assumes a predictive relationship between eye movements and reading comprehension. However, clear eye-movement indicators of comprehension have yet to be established, as this relationship is shaped by reader, text, and task characteristics. To address this, we conducted a meta-analysis examining the link between eye movements and reading comprehension outcomes. A systematic search identified 15,022 studies, with 135 retained after screening and 104 datasets from 37 studies analyzed. Due to data limitations, analyses focused on adults reading expository texts with multiple-choice comprehension tasks. Random-effects meta-analysis models were conducted separately for L1 and L2 readers. Results indicate that shorter fixations are consistently associated with better comprehension in both groups. For L1 readers, a higher number of fixations also predicted better outcomes, while this was not observed for L2 readers. Findings highlight the complexity of eye-movement indicators and the need to consider the influence of language-level properties when drawing conclusions. A lack of data involving children emerged, along with limited studies incorporating varied text types and comprehension tasks as well as reporting information on internal reliability of the comprehension measures. Ongoing analyses further examine the extent to which language-level characteristics may predict eye movements and modulate the relationship between eye movements and comprehension. These analyses aim to provide a more comprehensive account of how processing demands interact with linguistic structure during reading across different languages.

Time Allocation as an Indicator of Learning and Solution Processes in Problem-Solving
Keywords: Assessment, Digital Learning Environments, Log Data, Problem Solving
Presenting Author: Helena Feldhege, DIPF | Leibniz Institute for Research and Information in Education, Centre for International Student Assessment (ZIB), Germany; **Co-Author:**Leonard Tetzlaff, German Institute for International Educational Research (DIPF), Centre for International Student Assessment (ZIB), Germany; **Co-Author:**Carolin Hahnel, Ruhr University Bochum, DIPF | Leibniz Institute for Research and Information in Education, Germany; **Co-Author:**Ulf Kröhne, DIPF | Leibniz Institute for Research and Information in Education, Germany; **Co-Author:**Frank Goldhammer, DIPF | Leibniz Institute for Research and Information in Education, Centre for International Student Assessment (ZIB), Goethe University Frankfurt / Main, Germany

Problem-solving in interactive learning and assessment environments unfolds dynamically over time and is reflected in how test-takers allocate effort across task phases. Interactive digital environments capture such processes through log data providing temporal indicators of task engagement. However, time-on-task is often treated as a unitary indicator, potentially masking meaningful differences across phases of the problem-solving process. Our study investigates how time allocation across different subcomponents of task completion relates to performance on the task. A total of 737 German students participated in the PISA 2025 add-on study “Learning in the Digital World” (LDW; OECD, 2023). The LDW problem-solving tasks offered learning resources on demand via a help function. Using log data, total time-on-task was decomposed into six components reflecting planning, solution construction, monitoring, help seeking, help implementation, and reflecting. Time investment was conceptualized as a voluntarily allocated behavioral resource rather than as speed. Overall time-on-task positively predicted performance. Component-level analyses showed that only specific time components were related to performance. Time invested in planning, solution construction, monitoring, and reflecting showed positive linear predictions of performance. Quadratic effects indicated diminishing returns for planning and solution construction, whereas time spent on reflecting exhibited increasing benefits at higher levels of investment. In contrast, help-related times did not predict performance. Together, these findings suggest that total time-on-task encompasses qualitatively distinct task phases and may therefore conceal meaningful differences in how time investment relates to performance. Decomposing time-on-task into subcomponents provides a more informative basis for interpreting time investment in interactive assessments.

Assessing Divergent Thinking Through Structural Edit Distance in Creative Problem Solving
Keywords: Assessment, Learning Analytics, Learning Strategies, Problem Solving
Presenting Author: Zhanna Kazakpayeva, Université Côte d'Azur, France; **Co-Author:**Louis Köhler, Université Côte d'Azur, France; **Co-Author:**Patricia Reynaud-Bouret, Université Côte d'Azur, France; **Co-Author:**Margarida Romero, Université Côte d'Azur, France

Assessing Divergent Thinking Through Structural Edit Distance: A Process-Based Computational Approach in Tangible Creative Problem Solving

Divergent thinking (DT), a core component of creativity (Guilford, 1967; Runco, 2022), is traditionally assessed through semantic, language-based tasks (Beaty et al., 2022) that capture outcomes rather than the unfolding cognitive processes underlying creative exploration. Such approaches inadequately reflect the embodied, iterative nature of problem-solving in tangible learning environments (Leroy et al., 2023). This study introduces structural edit distance (SED), a computational adaptation of the Levenshtein metric (1966), as a process measure of DT that quantifies the structural transformations between successive solutions generated by learners. In a hands-on educational robotics task (CreaCube; Romero et al., 2019), 373 participants aged 5 to 25 constructed functional vehicles using modular Cubelets, producing sequences of configurations analyzed through SED. We examined SED at three complementary levels: participant (Mean and Max SED), output (transition-level), and trajectory (Cumulative SED over time). Results reveal significant positive associations between SED and DT components (fluency, flexibility, originality), and trajectory analyses identify alternating phases of exploration and refinement consistent with the Dual Pathway to Creativity Model (Nijstad et al., 2010). Notably, 66.9% of original productions emerged within high-slope phases of cumulative SED. These findings position SED as a multimodal, process-sensitive metric capable of making learners' divergent exploration computationally visible, with implications for learning analytics (Swiecki et al., 2022) and process-based creativity assessment.

Human-AI collaboration in problem-solving: effects of goal orientation on GenAI use in simulations
Keywords: Artificial Intelligence, Competences, GenAI, Problem Solving
Presenting Author: Christian Mayer, University of Mannheim, Germany; **Co-Author:**Josef Guggemos, University of Education Schwäbisch Gmünd, Germany; **Co-Author:**Gabriele Schneider, University of Mannheim, Germany; **Co-Author:**Andreas Rausch, University of Mannheim, Germany; **Co-Author:**Juergen Seifried, University of Mannheim, Germany

Generative artificial intelligence (GenAI) is transforming the way we learn and work. At the same time, there is a significant risk of deskilling in education, i.e. the loss of relevant skills due to overreliance on GenAI. This study examines how students of business education use ChatGPT to solve complex, workplace-related problems, focusing on the role of goal orientations (mastery versus performance) and AI-related skills. Drawing on a randomised laboratory experiment involving 53 undergraduates, the participants were challenged by an authentic supplier-selection task. Participants were assigned to either a mastery or performance goal condition, with goal orientations induced through staged stimuli. The results showed no significant differences in overall problem-solving performance between the two groups. Computational thinking was positively associated with information processing, and knowledge of large language models (LLMs) was found to correlate with higher-quality decision communication. Qualitative analysis of ChatGPT interactions revealed that, regardless of their assigned condition, most students adopted a performance-oriented approach, using structured prompts to efficiently reach solutions. Only a small subset engaged in mastery-oriented behaviours, such as iterative questioning to deepen understanding, while some did not use ChatGPT at all. These findings suggest that induced goal orientation alone does not determine performance in AI-supported problem solving. The study highlights the importance of fostering reflective, critical and skill-oriented use of GenAI in higher education, in order to prevent deskilling and promote meaningful learning.

Navigating Complexity with GenAI: Problem-Solving Under Varying Task Demands in an Office Simulation
Keywords: GenAI, Log Data, Problem Solving, Simulation-based Learning
Presenting Author: Gabriele Schneider, University of Mannheim, Germany; **Co-Author:**Andreas Rausch, University of Mannheim, Germany; **Co-Author:**Juergen Seifried, University of Mannheim, Germany; **Co-Author:**Christian Mayer, University of Mannheim, Germany

Generative artificial intelligence (GenAI) is increasingly used to support problem solving in complex professional contexts, yet little is known about how learners integrate GenAI under varying task demands. This poster presents a planned experimental study examining AI-supported problem-solving strategies in a web-based office simulation under different levels of task complexity and task amount. Business students will assume the role of middle managers and solve business-related problem scenarios in the LUCA simulation while having access to traditional office tools and a GenAI chatbot. The study systematically varies task complexity and task amount in a 2 × 2 between-subjects design to investigate whether GenAI is used differently when learners face interdependent constraints versus large volumes of information. Log data, AI chat protocols, and pre- and post-questionnaire data will be combined to identify strategy profiles, compare strategy use across task-demand conditions, and examine associations with problem-solving performance and domain-specific learning gains. Expected findings will contribute to simulation-based assessment and learning analytics by clarifying when GenAI functions as an information-management tool, a cognitive aid, or a delegation device in workplace-related problem solving.

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20 November 2026 09:00 - 10:30
Sala polivalent 1
Single Paper
Higher Education, Learning and Social Interaction

Learning analytics

Keywords: Clustering, Collaborative Learning, Higher Education, Learning Analytics, Problem Solving, Socially-Shared Regulation, Trace Data, Video Data
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Kateryna Zabolotna, University of Oulu, Finland, Finland

Temporal Dynamics of Regulation Following Trigger Types and Trigger Accumulation
Keywords: Collaborative Learning, Learning Analytics, Socially-Shared Regulation, Video Data
Presenting Author: Mengke Wang, University of Oulu, Finland; **Co-Author:**Márta Sobocinski, University of Oulu, Finland; **Co-Author:**Justin Edwards, University of Oulu, Finland; **Co-Author:**Joni Lämsä, University of Oulu, Finland; **Co-Author:**Anni-Sofia Roberts, University of Oulu, Finland; **Co-Author:**Sanna Järvelä, University of Oulu, Finland

The trigger regulation framework offers a contextual lens for understanding when and why regulation emerges in collaborative learning. Yet quantitative evidence on whether trigger type and unresolved trigger accumulation shape regulatory latency remains limited. This study examined time to regulation in authentic collaborative learning. A total of 139 video-recorded collaborative inquiry from 118 seventh grade students working in 32 small groups were coded for five trigger types (cognitive, metacognitive, socio-emotional, motivational, behavioural) and four categories of regulatory acts. Shared-frailty Cox proportional hazards models were used to estimate time-to-regulation following trigger type and accumulated trigger runs. Metacognitive triggers were followed by the fastest regulatory onset, whereas behavioural triggers showed the slowest responses. Trigger accumulation was not linear: runs of four or more unresolved triggers were associated with an approximately 23% lower hazard of subsequent regulation, whereas shorter runs did not differ reliably from single trigger runs. Most regulatory acts occurred within a time window of 400 seconds. These findings provide a quantitative, time resolved test of the trigger regulation framework's temporal and accumulative pattern and suggest that adaptive support should differentiate trigger types and intervene before persistent trigger sequences delay regulation.

Patterns of digital activity and outcomes across study programs, and time in undergraduate education
Keywords: Clustering, Higher Education, Learning Analytics, Trace Data
Presenting Author: Andres Araos, University of Oslo - IPED, Norway; **Co-Author:**Crina Damsa, University of Oslo, Norway; **Co-Author:**Jan Arild Dolonen, university of Oslo, Norway; **Co-Author:**Manuel Olivera Toro López, University of Oslo, Norway; **Co-Author:**Rachelle Esterhazy, Oslo Metropolitan University, Norway; **Co-Author:**Anna Mavroudi, University of Oslo, Faculty of Education, Norway

Student retention and persistence remain major challenges in higher education. Research in learning analytics (LA) has attempted to address these challenges, yet most LA studies focus on limited academic and temporal contexts, such as single courses or short periods. This study examines how first-year students' LMS-based digital activity, academic outcomes, and dropout form patterns across programs and both across and within semesters. We combined LMS logs and assignment records with registry data on course outcomes and semester registrations for 3,837 students over two consecutive semesters. Using transformed, program- and semester-standardized features of pageviews and assignment submissions, together with academic outcomes, we applied Gaussian Mixture Models to cluster semesters into distinct semester-level patterns. The analysis resulted in eight distinct patterns that recur across academic and temporal contexts despite substantial variation in raw LMS use. Some clusters combined high levels of LMS activity with near-complete study-point production, and low levels of digital activity with low academic outcomes. However, these clusters contrasted with clusters that achieved similar outcomes with minimal levels of LMS use, or with those that exhibit intermediate semester-level patterns with high to moderate levels of digital activity and moderate academic outcomes. Meanwhile, dropout rates also varied markedly both between clusters and across semesters. The results highlight the diversity of students' trajectories, and therefore the need to take context into account for understanding student learning and in LA research. The findings also underscore that dropout is a shifting, context-dependent phenomenon rather than a homogenous phenomenon.

Tracing Temporal Trajectories of Collaborative Problem-Solving Using Ordered Network Analysis
Keywords: Collaborative Learning, Higher Education, Learning Analytics, Problem Solving

Presenting Author: Kamila Misiejuk, CATALPA, FernUniversität in Hagen, Germany, Germany; **Co-Author:**Rogers Kaliisa, University of Oslo, Faculty of Education, Norway; **Co-Author:**Crina Damsa, University of Oslo, Norway

Collaborative problem-solving (CPS) is understood as a temporally unfolding process rather than a fixed sequence of interactional events. However, many studies continue to examine collaborative interaction using static or frequency-based approaches that provide limited insight into how collaboration evolves longitudinally. This study investigates how CPS processes evolved over time within a graduate student group working on an ill-defined collaborative project for over 12 weeks, grounded on Lemke's framework of eco-social systems and micro-ecological perspectives on learning. Using Ordered Network Analysis (ONA) as the analytical approach, the study showed that the group's collaboration did not progress linearly but repeatedly returned to planning, task definition, and monitoring throughout the project. Relational exchanges, particularly humour and off-task talk, became integrated into the collaborative process during demanding phases of work. The study demonstrates the value of ONA for revealing temporal trajectories in CPS and contributes methodological insights into process-oriented approaches for studying collaborative learning over time.

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Amfiteatre
Symposium
Learning and Instructional Technology

Nonlinear Dynamics and Complexity during Learning: Leveraging Online Trace Data

Keywords: Cognitive Skills and Processes, Collaborative Learning, Computational Linguistics, Digital Learning Environments, E-learning/Online learning, Educational Technology, Eye-Tracking, Game-based Learning, Learning Analytics, Log Data, Self-regulated Learning
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Megan Wiedbusch, University of Central Florida, United States
Chairperson: Roger Azevedo, University of Central Florida, United States
Discussant: Mohammed Saqr, University of Eastern Finland, Finland

Learning is not a linear accumulation of domain knowledge but rather a complex dynamical system of processes in which cognitive, affective, and social states continuously interact, self-organize, and transition over time. While substantial progress has been made in capturing learning as it happens through online process measures, theoretical frameworks have often lagged behind methodological innovation. This symposium centers complexity theory as the foundational grounding to provide the dynamical and emergent lens by which we can more accurately interpret what online measures captures and ask what counts as meaningful signal in trace data.Grounded in complex dynamical systems theory, all three papers treat temporal structure, nonlinearity, and multi-level emergence as theoretically meaningful properties of learning processes rather than noise. This shared theoretical lens is applied across three contexts - physiological and eye-tracking signals during programming debugging (Paper 1, Norway), behavioral logs from a game-based learning environment (Paper 2, USA), and speech-based interaction records from synchronous collaborative discussions (Paper 3, Germany). Nonlinear methods (i.e., Recurrence Quantification Analysis, Fast Fourier Transforms, and multi-level network modeling) serve as tools that are theoretically motivated by, and interpretable through, complexity theory.The symposium aims to advance both the theoretical and methodological foundations of process-measure research, making the case that complexity theory offers a coherent framework for providing explanation of online trace data of learning dynamics, with direct implications for the design of adaptive educational technologies.

Modeling Debugging Behavior Using Nonlinear Dynamics of Cognitive Load and Stress
Presenting Author: Kshitij Sharma, Norwegian University of Science and Technology (NTNU), Norway; **Co-Author:**anahita golrang, Norwegian University of Science and Technology (NTNU), Norway

Debugging is a complex and cognitively demanding activity that requires learners to regulate both problem-solving processes and emotional responses. Despite its importance in computer science education, effective instructional strategies remain limited, particularly for novice programmers who often experience high cognitive load and stress. This study investigates the temporal dynamics of cognitive load (CL) and physiological stress during debugging, and examines how these dynamics differ across performance levels and instructional conditions. Using data from two experiments (N = 40 and N = 120), cognitive load was measured via eye-tracking and stress via heart rate variability. We applied non-linear dynamical methods, including Recurrence Quantification Analysis, entropy measures, and change-point detection, to capture patterns of stability and transitions in learners' cognitive-affective states. Results show that high-performing students exhibit higher recurrence and determinism, lower entropy, and more transitions toward stable states compared to low-performing students, indicating more structured and regulated behavior. Similarly, students receiving multimodal feedback demonstrate patterns resembling high performers, suggesting that feedback promotes stable cognitive-affective dynamics. These findings highlight the importance of temporal regulation in debugging and suggest that adaptive, feedback-driven systems can support more effective learning by stabilizing learners' cognitive and emotional processes.

What Recurrence Rate Velocity Reveals about the Temporal Dynamics of SRL during Game-Based Learning
Presenting Author: Megan Wiedbusch, University of Central Florida, United States; **Co-Author:**Cameron Marano, University of Central Florida, United States; **Co-Author:**Roger Azevedo, University of Central Florida, United States

In game-based learning environments (GBLEs), effective Self-regulated learning (SRL) has been linked to improved outcomes, yet many learners struggle to adapt and monitor their strategies dynamically. This study investigates the temporal dynamics of SRL by applying auto-recurrence quantification analysis (aRQA) to log data from 223 high school students engaging with Crystal Island, a microbiology GBLE. We examine recurrence rate (RR) as a measure of repeated behavioral states and introduce the measure RR-velocity, its first derivative, as an indicator of the rate of change in one's behavioral states (i.e., stabilization versus exploration). Using sliding-window aRQA and Fast-Fourier Transformations, we extracted frequency-domain features (i.e., dominant frequency, spectral centroid, spectral entropy, and peak-to-peak range) and tested their predictive value for normalized learning gains (NLG). Results showed that RR features significantly predicted NLG, with spectral centroid and dominant frequency emerging as key predictors, whereas RR-velocity features were not statistically significant. However, observed oscillatory patterns suggest RR-velocity may capture process-level dynamics not fully explained by current models. These findings advance the application of complexity science to SRL by highlighting the importance of temporal patterns in learner behavior. Implications include developing adaptive educational technologies that respond to how learners' regulatory behaviors evolve over time, with future work exploring higher-order derivatives (e.g., RR-acceleration) to better detect transitions and tipping points in learning.

Multi-level network modelling of synchronous learner discussions: From utterances to relations
Presenting Author: Oleksandra Poquet, TUM, Germany

Analysis of interpersonal interactions is central to understanding collaborative learning. Social network analysis (SNA) is commonly applied to learner interactions captured by digital technologies, yet the methods used to construct and analyse these networks face conceptual and methodological challenges. Most approaches compile all interactions into a single network and treat individual positioning in this network as indicative of social relations. Poquet, Trenholm, and Santolini (2024) proposed a complexity-inspired multi-level framework that separates posting activity from communication flow and emergent relational structures, demonstrating it on asynchronous discussion forums. We adapt this framework to synchronous video-based group discussions among learners. Our adaptation addresses two gaps: (1) the framework has not been applied beyond asynchronous forums, and (2) behaviour-based relational indicators have not been triangulated with self-reported relational experience. We define utterance-level ties using temporal proximity and semantic similarity of speech turns, project these to person-to-person communication networks and derive relational structures by identifying reciprocal ties. We use the data from 38 small group engaged in a learning discussion on a video call (3-7 speakers each) and their self-reported measures of relational experience. We show that group-level network structure, captured by mean tie weight and weighted clustering in both communication and relational networks, explains up to 27% of variance in selected group-level measures of relational experience.

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20 November 2026 11:00 - 12:30
Sala polivalent 1
Single Paper
Assessment and Evaluation

Log data and assessment

Keywords: Assessment, Cognitive Skills and Processes, Engagement, Feedback and Biofeedback, Foreign and Second Language Acquisition, Learning Strategies, Log Data, Problem Solving, Reading, Task Difficulty, Writing/Literacy

Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Tiina Törmänen, University of Oulu, Finland

When Feedback Is Not Processed: Rethinking the Validity of Feedback Evaluations
Keywords: Assessment, Engagement, Feedback and Biofeedback, Log Data
Presenting Author: Tobias Deribo, DIPF | Leibniz Institute for Research and Information in Education, Germany; **Co-Author:**Cordula Artelt, Leibniz Institute for Educational Trajectories, Germany; **Co-Author:**Frank Goldhammer, DIPF | Leibniz Institute for Research and Information in Education, Germany; **Co-Author:**Carolin Hahnel, Ruhr University Bochum, Germany; **Co-Author:**Ulf Kroehne, Chemnitz University of Technology, Germany; **Co-Author:**Johannes Naumann, University of Wuppertal, Germany; **Co-Author:**Cornelia Schoor, Leibniz Institute for Educational Trajectories (LIfBi), Germany; **Co-Author:**Theresa Zink, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Germany

Self-reports of feedback perception are often used as indicators of feedback quality and are widely used to evaluate feedback interventions. However, such judgments may reflect not only the quality of the feedback, but also how learners access and interact with its content. Therefore, the present study examines this validity issue by linking self-reported feedback evaluations to behavioral indicators of engagement in a sample of $N = 337$ learners.Survey data on perceived usefulness, specificity, and acceptance were combined with log data capturing navigation behavior within a multi-page digital feedback environment. Engagement was modeled using a finite-state machine approach that distinguished states of initial contact, uptake of feedback content, and iterative interaction. These indicators were incorporated into a joint Bayesian latent variable model with monotonic effects. Additionally, feedback access was analyzed using Bayesian logistic regression.The results indicate that the transition from initial contact to substantive uptake is consistently positively associated with perceived usefulness and specificity. Although the total effect is positive, the incremental contribution of sustained interaction with feedback content remains comparatively small and uncertain. Decomposition of monotonic effects suggests that a substantial proportion of engagement-related differences is attributable to the initial transition. In contrast, perceived acceptance shows little association with engagement, but a clear positive association with learner ability.These findings suggest that self-reported feedback evaluations do not reflect feedback quality alone. Rather, they appear to depend, in part, on whether learners engage with the feedback content, revealing a threshold-like pattern in the relationship between engagement and feedback evaluation.

Using IRTrees to model resource-usage processes and their relation to learning outcome measures
Keywords: Assessment, Learning Strategies, Log Data, Problem Solving
Presenting Author: Leonard Tetzlaff, German Institute for International Educational Research (DIPF), Centre for International Student Assessment (ZIB), Germany; **Co-Author:**Carolin Hahnel, Ruhr-University Bochum, Germany; **Co-Author:**Frank Goldhammer, German Institute for International Educational Research (DIPF), Centre for International Student Assessment (ZIB), Goethe University Frankfurt, Germany

Digital learning and assessment environments increasingly provide optional resources, such as hints. Accessing these resources is often considered an indicator of (meta)cognitive processes involved in strategy use or self-regulation. However, it remains unclear whether resource use reflects a single process or qualitatively different strategies depending on the timing and context. Likewise, it is unclear whether solving tasks with or without these resources reflects the same latent ability.We hypothesized two resource-use strategies: (1) *help-before*, where resources are accessed before task engagement, and (2)*help-after*, where resources are used after an initial solution attempt. Using PISA-LDW process data, we analyzed the timing of the first resource access. A bimodal time distribution provided initial evidence for these strategies.Based on these indicators, we estimated IRTree models, which decompose the response process into subprocesses. We specified up to five different latent variables: three abilities demonstrated without resource use (*solve*|*no-help*), with resource use before (*solve*|*help-before*) or after (*solve*|*help-after*) an initial solution attempt, and two resource-use tendencies (*help-before*, *help-after*). Model comparisons showed the best fit for the model with three latent variables (*ability*, *help-before*, *help-after*) assuming that there is only one ability variable. The correlations between these variables show a strong association between the *help-after* tendency and ability, but not the *help-before* tendency.The findings suggest that early and late resource use reflect distinct processes, emphasizing the need for theory-driven interpretation of learner behavior. The same behavior of resource access could be meaningfully classified as different strategies by contextualizing log events.

Time on task effects on language comprehension in beginning readers vary by modality and process
Keywords: Assessment, Cognitive Skills and Processes, Reading, Task Difficulty
Presenting Author: Johannes Naumann, University of Wuppertal, Institute for Educational Research, Germany; **Co-Author:**Patrick Dahdah, University of Wuppertal, Institute for Educational Research, Germany; **Co-Author:**Julia Schindler, Free University of Berlin, Department of Education and Psychology, Germany; **Co-Author:**Maj-Britt Haffmanns, University of Kassel, Department of Developmental Psychology, Germany; **Co-Author:**Tobias Richter, University of Würzburg, Department of Psychology IV, Germany

Language comprehension, both auditory and written, relies on a mixture of automatic and controlled cognitive processes. Drawing theoretically on the Simple View of Reading, the Verbal Efficiency Theory and the Cumulative Cognitive Complexity approach to the processing of local coherence relations, we contrasted time-on-task (ToT) effects for tasks tapping into a basic and easily automatized reading and listening process, phonological analysis (listening) and phonological recoding (reading), and a more complex and a cognitively demanding process, the processing of local coherence relations, in both modalities. For each process and each modality we estimated ToT effects in primary school children, grades 1-4, N=1367. In accordance with theoretical assumptions, negative fixed ToT effects occurred for both listening tasks, and for the written phonological recoding task, while a positive fixed ToT effect occurred for the most demanding written local coherence task. For all tasks, person intercepts and slopes were negatively correlated, meaning that there were less positive (written local coherence), and more negative (phonological analysis and recoding, auditory local coherence) person-specific ToT effects. Item-specific ToT effects were negative for phonological analysis, mixed for phonological recoding and local coherence (auditory), and positive for local coherence (written). Together these results indicate that while processing phonology at the word level is largely automatic both in reading and listening (supporting the Verbal Efficiency Theory), children have to invest cognitive resources into building local coherence when reading, but less so when listening (in accordance with the Simple View of Reading and the Cumulative Cognitive Complexity Approach).

Matching process-level disfluencies with macro-level fluency differences across writing conditions
Keywords: Cognitive Skills and Processes, Foreign and Second Language Acquisition, Log Data, Writing/Literacy
Presenting Author: Gaëtanelle Gilquin, UCLouvain, Belgium; **Co-Author:**Quentin Feltgen, Université catholique de Louvain (UCL), Belgium; **Co-Author:**Georgeta Cislaru, Université Sorbonne Nouvelle, France

Writing fluency has been empirically characterized as a multi-dimensional complex that projects onto process-related components of writing. The goal of this study is to find out which features of the dynamic writing process best explain fluency at the macro, textual level. We use Inputlog keylogging data from PROCEED and, more precisely, their inter-key interval (IKI) distribution.We relate the parameters of the bimodal Gaussian model to fluency measures at the macro-level to predict the fluency difference occurring at the individual level (i) when switching from L1 (French) to L2 (English) writing; (ii) longitudinally, for two L2 (English) texts written within a six-month interval (EN1 and EN2). Fluency is proxied with the mean value of the IKI distribution, so that the lower the value, the higher the fluency. For each participant, we try to predict the fluency difference between the two texts they authored. When modelling each text separately, the mean difference predicted by the model matches the observed difference precisely (99.5% of variance explained for each set of pairs of texts). In order to pinpoint which parameters are the most responsible for this difference, we start from the model of the most fluent text (L1 or EN2) and update one or several parameter values to that of the model of the least fluent text (L2 or EN1). While updating a single parameter yields poor results (28% and 38% of variance explained), updating both the weight and the second mode mean improves the results considerably (79% and 72% of variance explained).

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Amfiteatre
Invited Symposium (SIG 27 Conference 2026)

JURE Invited Symposium. Uncovering visual strategies in learning and teaching with eye tracking

Keywords: (Joint) Attention, Assessment, Cognitive Skills and Processes, Competences, Digital Learning Environments, Early Childhood Education, Eye-Tracking, Learning Strategies, Mathematics/Numeracy, Reading, Secondary Education
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Kateryna Horlenko, Vytautas Magnus University, Lithuania
Organiser: Kateryna Horlenko, Vytautas Magnus University, Lithuania
Discussant: Saswati Chaudhuri, University of Jyväskylä, Finland

Eye tracking has gradually become a method of choice for capturing learning processes. Although common approaches to analysing eye-tracking data include comparisons of aggregated fixation metrics between groups, the process-based temporal and spatial analyses allow detecting visual patterns. The symposium

aims to introduce novel approaches to eye tracking to reveal how participants' strategies are reflected in their visual behaviours in complex tasks. From learners' perspective, the first paper focused on enumeration strategies of young children in a math game, identifying four strategies and suggesting that children relied on subitizing, counting, and the understanding of numerical structures to enumerate objects. The second paper explored the effect of pre-questions on secondary-school students' reading, showing that pre-questions may lead to skimming strategies in less skilled learners, but lower mind wandering and higher intrinsic motivation while reading for all. From teachers' perspective, the third paper unveils differences in critical incident detection between two groups of teacher trainers. School-based trainers showed fast returns to the whole class observation after identifying the incident, while university-based observers had numerous revisits to problematic areas. Finally, the fourth paper explored pre-service teachers' diagnoses of student misconceptions in math, aiming to confirm previously identified efficient, active, inefficient, or passive diagnostic approaches by clustering the eye-tracking data. Overall, studies in this symposium highlight the affordances of eye tracking to uncover and support learning across contexts. The presentations and discussion will examine how these studies contribute to the theoretical and methodological advancements, as well as educational practice.

Object enumeration from naturalistic photos – An eye tracking study with 5- and 6-year-olds
Presenting Author: Satu Rajalakso, University of Helsinki, Finland; **Co-Author:**Markku Hannula, University of Helsinki, Finland; **Co-Author:**Ilona Södervik, University of Helsinki, Finland; **Co-Author:**Minna Hannula-Sormunen, University of Turku, Finland

Children's enumeration skills before school are crucial for later learning of mathematics. Although enumeration is normally learned via informal practice before school, the existing eye tracking research has focused solely on examining students' enumeration processes with formal mathematical tasks and primary school aged children. The aim of the present study is to address this gap and utilize eye tracking to explore how children under school age enumerate sets of two to four objects in naturalistic photos during Memory card game task. In the task, children looked at photos presented for 5 seconds while their eye movements were tracked, and right after described how many objects they saw in the photo. The participants were 51 5- and 6-year-old children. With qualitative analysis of gaze-overlaid videos, we identified four enumeration strategies: 1. Simultaneous enumeration, 2. Quasi-simultaneous enumeration, 3. Partial counting, and 4. Counting all. The results show that 5- and 6-year-old children used strategies based on subitizing, counting, and the understanding of numerical structures to enumerate small sets of objects presented in naturalistic photos. This research deepens our understanding of young children's enumeration processes.

Conceptual prequestions and reading behavior in secondary school: An eye-tracking study
Presenting Author: Mario Romero-Palau, University of Valencia, Spain; **Co-Author:**Ladislao Salmeron, University of Valencia, Spain

Prequestions are considered a promising instructional strategy because they enhance learning by directing students' attention before studying new material, improving text comprehension. However, evidence for their effects on transfer learning and reading processes in secondary education remains limited. This study examined the effects of conceptual prequestions on text comprehension, mind wandering, intrinsic motivation, and eye movements in secondary-school students. Sixty-six students (Grades 9–10) participated in a 2 × 2 within-subjects design comparing prequestion and control conditions across pretested and new comprehension questions. Students read two expository texts while their eye movements were recorded with an eye tracker. Reading comprehension skills and achievement motivation were included as covariates. Results showed no significant improvement in text comprehension due to prequestions, although exploratory analyses suggested poorer performance on new questions compared to pretested questions within the prequestion condition. Students exposed to prequestions reported lower mind wandering and higher intrinsic motivation while reading. Eye-tracking measures revealed reduced fixation patterns but increased lookbacks in the prequestion condition, suggesting a skimming reading strategy. These effects were especially pronounced among students with average-to-low reading comprehension skills, whereas highly skilled readers showed no differences between conditions. Overall, the findings highlight the limited benefits of conceptual prequestions in secondary school and suggest that their effects on reading behavior may depend on students' reading skills.

Professional vision: Exploratory eye tracking study on the visual strategies of teacher trainers
Presenting Author: Valérie DUVIVIER, Université de Mons, Belgium; **Presenting Author:**CONSTANCE COEN, Université de Mons, Belgium

Professional vision is a key skill in teacher training but analysing it in real time remains difficult. Eye tracking offers an objective method for studying the visual strategies used in teaching situations. While this tool has been used to analyse novice and expert teachers, little research has focused on teacher trainers, particularly in French-speaking Belgium. This exploratory study aims to compare the visual strategies of two groups of trainers: university-based teacher trainers (6 UBTs) and school-based teacher trainers (3 SBTs), in order to better understand their observation practices when faced with an incident in the classroom, using a fixed eye tracking tool (Gaze Point GP3-HD). The analysis focused on three indicators: fixation time, revisits (return visits), and first views. The results show that incident detection is similar between the two groups. However, SBTs redirect their gaze more quickly to the whole class after the incident, while UBTs adopt a strategy characterised by numerous revisits. SBTs favour a more focused and prolonged observation, particularly of highly engaged pupils. These differences appear to be linked to the intervention contexts: video analysis for UBTs and real-time observation for SBTs. The study highlights the value of eye tracking in objectifying professional observation and suggests avenues for trainer development, such as calibration workshops and the use of eye tracking as a reflective tool.

Analyzing pre-service teachers' diagnostic competence in mathematics using eye-tracking
Presenting Author: Shayla Giap, TUM, Germany; **Co-Author:**Yifan Ding, Technische Universität München (TUM), Germany; **Co-Author:**Michael Nickl, Technical University of Munich (TUM), Germany; **Co-Author:**Enkelejda Kasneci, Technical University of Munich, Germany; **Co-Author:**Stefan Küchemann, LMU Munich, Germany; **Co-Author:**Matthias Stadler, LMU Munich, Germany; **Co-Author:**Andreas Obersteiner, Technical University of Munich, Germany

Diagnostic competence is required to perceive, interpret, and respond to student thinking, which is fundamental for mathematics teachers. To measure diagnostic competence, research has not only relied on outcome measures like teachers' judgment accuracy but has recently shifted its focus to the diagnostic process through which teachers arrive at their judgments. One approach to doing is analyzing their diagnostic activities and professional vision in task-based situations. In past studies, distinct diagnostic process profiles have been identified based on participants' log data; for example, diagnostic processes were classified as efficient, active, inefficient, or passive. However, relying solely on log data may reduce the validity of the obtained process profiles. Therefore, in the present study, we combine eye-tracking and log data to investigate whether distinct process profiles can be identified and compared to those reported in previous research. In the study, pre-service teachers diagnosed students' misconceptions about functions and graphs in a digital learning simulation by selecting mathematical tasks and analyzing students' written responses. While completing the simulation, pre-service teachers' gaze was recorded using stationary eye trackers. Based on process indicators derived from both eye-tracking and log data, we examine whether distinct process profiles can be identified and, if so, which. At the symposium, we will report the results of the clustering process based on eye-tracking data and discuss differences between profiles identified using eye-tracking and log data.

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20 November 2026 14:45 - 16:15
Sala polivalent 1
Single Paper
Learning and Instructional Technology, Motivational, Social and Affective Processes

Motivation

Keywords: Audio data, Collaborative Learning, Digital Learning Environments, Emotion and Affect, Longitudinal Analysis, Mathematics/Numeracy, Motivation, Online Learning Environments, Video Data
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Tanya Chichekian, Université de Sherbrooke, Canada

Tracing learners in the Math Marathon: Challenges and solutions in data collection
Keywords: Longitudinal Analysis, Mathematics/Numeracy, Motivation, Online Learning Environments
Presenting Author: Rimantas Vosylis, Kaunas University of Technology, Lithuania; **Co-Author:**Rasa Erentaitė, Kaunas University of Technology, Lithuania; **Co-Author:**Simona Sankalaitė, Kaunas University of Technology, Lithuania; **Co-Author:**Berita Simonaitienė, Kaunas University of Technology, Lithuania

This presentation examines the methodological and practical challenges encountered during data collection in a pre-registered longitudinal, randomized experiment investigating mastery- and performance-oriented instructional approaches within an online learning environment. Conducted as a five-week "Math Marathon" challenge with approximately 600 ninth-grade Lithuanian students across nine schools (with an estimated 60–80% retention rate), the study compares mastery, performance, and control conditions to assess differences in situational goals, behavioral engagement, and mathematical learning outcomes. To capture learning and situational motivation in real time, these processes are measured through continuous behavioral trace data and brief, real-time contextual self-reports. While we will briefly share the study's key findings, this session highlights the "not-so-perfect" realities of measuring learning in authentic settings. Specifically, we explore challenges and solutions related to: (a) coordination between researchers and platform developers; (b) collaboration with teachers overseeing classroom implementation; (c) teachers' tech-anxiety and its' effects on data collection; (d) programming issues in questionnaires for situational motivation; and (e) the issues involved in extracting, managing, and interpreting raw platform log data into meaningful learning behaviors. By

addressing these challenges, we aim to share practical "lessons learned" and recommendations for researchers seeking to implement similar studies.

Exploring prosody as an indicator of motivational monitoring during collaborative learning
Keywords: Audio data, Collaborative Learning, Motivation, Video Data
Presenting Author: Kateryna Zabolotna, University of Oulu, Finland, Finland; **Co-Author:**Tiina Törmänen, University of Oulu, Finland; **Co-Author:**Tanvir Hasan, University of Oulu, Finland; **Co-Author:**Hanna Järvenoja, University of Oulu, Finland

Collaborative learning involves dynamic interactions among cognitive, emotional, and motivational processes, in which fluctuations in motivation can disrupt participation and hinder knowledge construction. Learners address these challenges through socially shared regulation of learning, particularly by monitoring and regulating motivation. However, capturing such processes in real time remains methodologically challenging. Speech offers a promising lens, as prosodic features such as pitch and intensity can reflect affective and motivational states, yet their use in authentic CL contexts remains limited.This study presents a multimodal approach to characterizing motivational speech during regulation episodes in a CL science task. A single case exploratory study was conducted with one group of three secondary school students. Video data were qualitatively coded for motivation regulation strategies and monitoring valence, and audio data were processed using voice activity detection and acoustic-prosodic feature extraction. Segment-level features were standardized relative to speaker-specific baselines and aligned with coded episodes.Descriptive analyses indicated systematic variation in prosodic features across monitoring valence categories. Positive monitoring was associated with lower pitch and intensity, whereas mixed and negative monitoring showed higher and more variable vocal activation. Speaker-level analyses demonstrated that pitch patterns were consistent across participants, while intensity showed greater individual variation.These findings suggest that prosodic features reflect interactional dynamics of motivation regulation in CL. In the presentation, the approach will be further illustrated using a larger dataset to examine associations between prosodic changes and monitoring behavior in greater detail.

Capturing In-Situ Motivation: Validating Situational Expectancy-Value Measures in Digital Context
Keywords: Digital Learning Environments, Emotion and Affect, Longitudinal Analysis, Motivation
Presenting Author: Rimantas Vosylis, Kaunas University of Technology, Lithuania; **Co-Author:**Rasa Erentaitė, Kaunas University of Technology, Lithuania; **Co-Author:**Ida Vainio, Kaunas University of Technology, Lithuania

Rooted in Situated Expectancy-Value Theory (SEVT), this study validates a measure of situational motivation in a digital mathematics learning environment. While traditional research emphasizes broad dispositional beliefs, capturing in-the-moment motivational states—expectancies, values, and costs—is critical for understanding dynamic learning processes, particularly on online platforms that use distinct motivational framings. A five-week, longitudinal randomized experiment was conducted with 568 ninth-grade students using an online math platform. Students were assigned to Mastery, Performance, or Control interface conditions. Situational motivation was repeatedly assessed across sessions and compared with baseline dispositional motivation. Confirmatory factor analyses validated the three-factor situational structure. Longitudinal measurement invariance analyses confirmed that the scale functioned equivalently across timepoints, demonstrating stable internal consistency ($\omega = .71$). Furthermore, a multilevel confirmatory factor analysis established cross-level metric isomorphism, showing that momentary motivational states and stable dispositional traits share the same measurement structure. Finally, theoretically consistent correlations between dispositional and situational appraisals supported convergent validity. This study provides robust empirical evidence bridging the conceptual gap between general motivational beliefs and high-frequency learning experiences. Practically, it equips researchers and instructional designers with a validated tool to assess real-time motivation, paving the way for adaptive educational technologies that dynamically respond to students' immediate needs.

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Amfiteatre
Invited Symposium (SIG 27 Conference 2026)
Learning and Instructional Technology

SIG 7 Invited Symposium. Immersive environments for affective learning processes: Finding our path

Keywords: Digital Learning Environments, Educational Technology, Electrodermal Activity, Emotion and Affect, Interest, Log Data, Multimodal Data, Physiological Data, Simulation-based Learning
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Valdemar Stenberdt, University of Copenhagen, Denmark
Chairperson: Jule Krüger, University of Twente, Netherlands
Organiser: Jule Krüger, University of Twente, Netherlands
Discussant: Yizhen Huang, Hector Research Institute of Education Sciences and Psychology, Germany

Immersive environments do not only present content, but they can trigger affective responses in learners. Presence, threat, compassion and curiosity arise in the moment and shape what learners attend to, how long they stay engaged and what they take away. Affect is one of the central processes of immersive learning, unfolding over an experience rather than settling into a single end state.This symposium brings together three studies in which affect plays a different role. The first study establishes that emotionally valenced 360° videos elicit distinguishable responses while learners are watching, a precondition for vocational training in which learners must recognise and regulate their emotions in demanding professional situations. The second study follows an elicited emotion through to an outcome: embodying a tree fosters nature connectedness through compassion, and a virtual threat to the embodied tree intensifies emotional engagement. The third study moves from feeling to action, tracing how curiosity sustains exploration and information seeking, and how this supports knowledge retention.Across the three contributions, affect appears as an elicited response, as an explanatory mechanism, and as a driver of learning behaviour, covering a variety of affective constructs across vocational education, education for sustainable development and science learning. Capturing it as it unfolds requires process measures, and each study takes a different path. The discussion will address what affect does for learning in immersive environments, when eliciting it helps and when it overwhelms, and which design and ethical decisions follow.

Beyond self-report: measuring affective processes in immersive 360° learning environments
Presenting Author: Veronica Nisticò, Swiss federal university for vocational education and training, Switzerland; **Co-Author:**Francesca Amenduni, Swiss federal university for vocational education and training, Switzerland; **Co-Author:**Laura Fusi, Swiss federal university for vocational education and training, Switzerland; **Co-Author:**Alice Tela, Swiss federal university for vocational education and training, Switzerland; **Co-Author:**Alberto Cattaneo, Swiss federal university for vocational education and training, Switzerland

Understanding affective processes in immersive learning environments requires capturing learners' responses as they unfold, rather than relying exclusively on retrospective self-report data. This study investigated whether continuous psychophysiological measures (1) can discriminate emotional responses while viewing 360° videos presented through head-mounted display (360VR) and (2) can be used to complement subjective reports.Twenty-four adults completed a within-subject experiment involving positive- and negative-valenced 360VR. Facial electromyography (corrugator and zygomaticus major), skin conductance, and cardiovascular activity were continuously recorded. After each 360VR, participants self-reported emotional valence, arousal, and sense of presence.The negative video elicited greater corrugator activation and skin conductance, whereas the positive video elicited greater zygomaticus activation. Cardiovascular measures did not differ between conditions. Self-reported valence differentiated the experiences, while arousal did not. No significant association between psychophysiological and self-report measures remained after multiple-comparison correction. These findings demonstrate the feasibility of continuous psychophysiological measurement in 360VR and show that physiological and retrospective self-report measures provide complementary, rather than interchangeable, information. Our study provides a methodological foundation for investigating affective processes in vocational education and training (VET).The validated setup is currently being transferred to an authentic VET population (healthcare) to investigate how design choices in emotionally demanding 360° scenarios shape learners' affective responses. This approach may help identify which features of immersive experiences are most relevant to learners' emotional engagement and provide an empirical basis for the evidence-based design of emotionally meaningful professional learning experiences.

Embodying nature in iVR: The role of compassion, nature connectedness and electrodermal activity
Presenting Author: Jule Krüger, University of Twente, Netherlands; **Co-Author:**Pia Spangenberger, Universität Potsdam, Germany; **Co-Author:**Sonja Geiger, Eberswalde University of Sustainable Development, Germany; **Co-Author:**Georg Felix Reuth, Hector Research Institute of Education Sciences and Psychology, Germany; **Co-Author:**Lena Baumann, Universität Potsdam, Germany; **Co-Author:**Steve Nebel, Universität Postdam, Germany

Immersive VR (iVR) can create unique experiences of nature and support learning processes in education for sustainable development, but the role of iVR-induced affective processes in this context is not yet fully clear. Prior research shows that disruptive events such as the experience of a climate catastrophe, which also have impact on affect, can lead to an increase in pro-environmental attitudes and behaviour. This study investigates how emotions, compassion and physiological arousal initiated by iVR contribute to changes in nature connectedness following the virtual embodiment of a tree as a representative of nature, manipulating the disruptiveness of the experience. Participants (N = 85) experienced the iVR application Tree and were randomly assigned to either a threatening scenario ending in a forest fire or a non-threatening version without the fire. Self-report measures of emotions, compassion and nature

connectedness were enriched with an exploration of a continuous physiological measure of arousal, specifically through electrodermal activity (EDA). Mediation analyses showed that compassion fully mediated the relationship between embodiment and increases in nature connectedness, whereas anger, anxiety, sadness, and joy did not. Moderation analyses revealed that the threatening ending strengthened the relationship between embodiment and anger, anxiety, and compassion. EDA data indicated heightened physiological arousal during the experience, particularly during the forest-fire phases, with peak responses occurring when the fire reached the embodied tree. The findings highlight compassion as a key mechanism linking virtual embodiment and nature connectedness and support the use of iVR as a tool for promoting sustainability-related attitudes and learning.

Investigating curiosity-driven exploration processes in immersive media
Presenting Author: Valdemar Stenberdt, University of Copenhagen, Denmark; **Co-Author:**Guido Makransky, University of Copenhagen, Denmark

Curiosity is a key driver of exploration and information seeking, yet less is known about how curiosity-driven behavior unfolds over time in immersive learning environments and to what effect. This submission synthesizes two studies examining curiosity-driven exploration using behavioral log data from digital simulations. Study 1 reports a randomized field trial with 217 middle-school students who explored a marine-science simulation in either PC or immersive Virtual Reality (iVR). Curiosity and knowledge increased following the intervention, with no significant differences between media. Logged question-asking mediated the association between initial curiosity and later knowledge retention, highlighting information seeking as a potential mechanism linking curiosity and learning. Study 2 extends this work by examining time-stamped behavioral data from an unmanned iVR museum exhibition about exoplanet habitability. Data from at least 600 visitors will be used to identify typical exploration sequences, examine individual differences in exploration patterns, and test whether the timing of specific behaviors predicts continued engagement. Together, the studies provide a process-oriented account of curiosity in immersive simulations, examining when information seeking emerges, how it is sustained, and how exploratory dynamics vary across individuals and moments.

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20 November 2026 16:15 - 17:45
Sala polivalent 1
Poster Presentation
Higher Education, Learning and Instructional Technology, Learning and Social Interaction, Motivational, Social and Affective Processes

Posters C

Keywords: Artificial Intelligence, Collaborative Learning, Eye-Tracking, GenAI, Higher Education, Interest, Knowledge (Co-)Construction, Metacognition, Multimodal Data, Multimodal Learning Analytics, Problem-based Learning, Self-regulated Learning, Socially-Shared Regulation, Video Data
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Mohammed Saqr, University of Eastern Finland, Finland

Tracing AI-Assisted Social Regulation in Writing for Publication
Keywords: Artificial Intelligence, Knowledge (Co-)Construction, Metacognition, Multimodal Data
Presenting Author: Baraa Khuder, Chalmers Unviersity of Technology, Sweden; **Co-Author:**Raffaella Negretti, Chalmers University of Technology, Sweden

Generative Artificial Intelligence is becoming embedded in writing for publication, yet little is known about how it reshapes the social regulation of academic writing as it unfolds. This poster presents a research plan examining how early career researchers (ECRs) use AI during writing for publication and how such use may affect the diversity of scholarly texts. The study is grounded in Social Cognitive Theory and the framework of social regulation of learning, with attention to self-regulation, co-regulation, and socially shared regulation. The project uses a micro-ethnographic, multimodal design combining keystroke logging, screen capture, stimulated-recall interviews, and evolving text drafts to trace regulation events in real time. Nine ECRs across three disciplinary areas will be followed longitudinally, with particular attention to moments when writers turn to AI, co-authors, or both. Expected contributions include a process-sensitive account of AI-mediated writing regulation and implications for theory, doctoral education, and responsible AI use in scholarly communication.

Examining GenAI Use in Collaborative Learning Through a Trigger Regulation Lens
Keywords: Collaborative Learning, GenAI, Socially-Shared Regulation, Video Data
Presenting Author: Mengke Wang, University of Oulu, Finland; **Co-Author:**Tiina Törmänen, University of Oulu, Finland; **Co-Author:**Niklas Heikkala, University of Oulu, Finland; **Co-Author:**Sanna Järvelä, University of Oulu, Finland

Generative AI (GenAI) is becoming increasingly integrated into computer-supported collaborative learning (CSCL), yet little is known about how student groups mobilize GenAI within moment-to-moment regulatory processes during open-ended inquiry task. Drawing on the Trigger Regulation Framework and perspectives on hybrid human-AI regulation, this study investigates how the use of Copilot is embedded in groups' trigger-regulation processes during a collaborative literature review task. Six groups of undergraduate students participated in a seven-session activity supported by a Copilot agent and reflective scaffolding. Video and audio recordings, together with Copilot interaction logs, were segmented into trigger regulation episodes and coded for trigger type, regulatory response, Copilot role, and regulatory outcome. A process-oriented multimodal analysis combining qualitative coding, temporal mapping, and Lag Sequential Analysis was used to examine when groups engaged Copilot, how they positioned it within their shared regulation, and how AI use shaped subsequent regulatory processes. This study contributes to a more fine-grained understanding of GenAI-supported collaborative learning.

Trust Calibration in AI-Supported Team collaborative learning: A Multimodal Process Study
Keywords: GenAI, Higher Education, Multimodal Data, Socially-Shared Regulation
Presenting Author: Tam Le Hong, University of Oulu, Finland

As Generative AI (GenAI) becomes increasingly accessible and more advanced in its capabilities, students increasingly rely on AI systems during learning and complex problem-solving tasks. This growing reliance calls for higher education institutes to design learning processes that systematically promote students' competency to work effectively and responsibly with GenAI systems. One of the critical aspects is to develop students' *trust calibration* which is aligning reliance on AI with its actual capabilities in the team learning process. However, existing research primarily treats trust as an individual and static construct that overlook how trust dynamically unfolds during interaction. This study investigates trust calibration as a socially shared, temporal phenomenon in student teams working with a GenAI-supported group chat to complete an information-intensive task on starting a business, including taxation and registration procedures. The task requires evaluating AI-generated information, negotiating decisions, and managing uncertainty. Multimodal process data, including chat logs, screen and voice recordings during interactions, surveys before, during, and after tasks on trust level, and after-task interviews, are collected to capture learning as it happens. Using temporal analysis and Epistemic Network Analysis (ENA), the study examines how trust-related behaviors (e.g., accepting, questioning, or rejecting AI outputs) co-occur with collaborative regulation processes. Expected findings will identify distinct trajectories of trust calibration (e.g., over-reliance, under-trust, adaptive calibration) and their relation to collaborative learning processes. This work contributes to learning sciences by advancing process-oriented understanding of trust in human-AI teams in higher education learning contexts, with implications for designing effective AI-supported learning environments and pedagogy.

When Generative AI Enters the Group: How Bring-in and Repair Shape AI-Mediated Interaction
Keywords: Collaborative Learning, GenAI, Higher Education, Multimodal Learning Analytics
Presenting Author: Danyu Yang, Oulu university, Finland; **Co-Author:**Anni silvola, University of Oulu, Finland; **Co-Author:**Hanni Muukkonen, University of Oulu, Finland

The increasing integration of generative AI (GenAI) into higher education is reshaping the dynamics of collaborative learning. While existing research has examined how students use GenAI in collaboration and how it affects collaborative processes and outcomes, detailed process-oriented accounts remain limited regarding how group interaction unfolds around GenAI outputs over time. This study investigates AI-mediated collaborative problem-solving involving GenAI-based conversational agents (CA), focusing on the bring-in and repair practices that emerge when students incorporate CA outputs into AI-mediated group collaboration, and how these practices are associated with immediate interactional responses. Informed by the concept of productive interaction, the study adopts a mixed-methods design combining interaction analysis and sequence analysis. The data come from a scenario-based collaborative task and include six groups selected from a larger dataset of 35 university student groups collected in Finland and the Netherlands. The data include video recordings, utterance-by-utterance transcripts, and chat-log data with the CA. Preliminary analysis suggests that the meaning and role of CA outputs in collaboration are shaped through key interactional moments of bring-in and repair. Students may introduce AI outputs by summarizing, quoting, clarifying prompting trajectories, embedding evaluations, or presenting them performatively. When outputs do not meet task expectations, repair may involve repositioning the AI output, selectively retaining useful parts, checking its validity, or asking the CA for alternatives. These findings suggest that AI outputs are interactionally shaped in ways that may influence subsequent interactional responses, with implications for higher education guidance and the design of AI-mediated collaborative tasks.

The Gaze on a Case: Eye-tracking during discussion of research integrity – Automatic AOI-detection
Keywords: Artificial Intelligence, Collaborative Learning, Eye-Tracking, Problem-based Learning

Presenting Author: Reito Visajaani Salonen, Helsinki Institute for Social Sciences and Humanities, University of Helsinki, Finland; **Co-Author:**Erika Löfström, University of Helsinki, Finland; **Co-Author:**Enrique Garcia Moreno-Esteva, University of Helsinki, Finland; **Co-Author:**Prince Nnaemeka, University of Helsinki, Finland; **Co-Author:**Markku Hannula, University of Helsinki, Finland

This study investigates the efficiency of automated gaze target detection methods in eye-tracking research within an educational setting. Data were collected from 18 doctoral candidates participating in a research ethics course at a Finnish university. Participants completed a structured Debate & Dialogue exercise involving two ethical dilemmas: research misconduct and an unsuccessful grant application. Visual posters with key content and QR-code markers were used to support task performance and enable gaze tracking. Eye movements were recorded using wearable eye-tracking devices equipped with eye and scene cameras.The analysis combined marker-based and feature-based target detection methods, including hybrid approaches. Marker-based detection was effective for identifying predefined areas of interest and producing heatmaps and gaze path visualisations across participants and time frames. Feature-based detection showed potential for classifying previously undefined gaze targets. Automated methods reduced the need for manual coding and enabled preliminary comparisons between different stages of early data analysis. However, accuracy limitations remain, and manual verification is still required. The findings suggest that hybrid approaches combining marker- and feature-based detection improve analytical efficiency while maintaining acceptable accuracy. Although further development is needed, automated gaze target detection provides a feasible approach for reducing workload and supporting scalable eye-tracking data analysis.

Trust Calibration in AI-Supported Team collaborative learning: A Multimodal Process Study
Keywords: Artificial Intelligence, Collaborative Learning, Higher Education, Socially-Shared Regulation
Presenting Author: Tam Le Hong, University of Oulu, Finland; **Co-Author:**Luna (Thi Thu Nguyet) Huynh, University of Oulu, Finland; **Co-Author:**Andy (Khanh Xuan) Nguyen, University of Oulu, Finland

As Generative AI (GenAI) becomes increasingly accessible and more advanced in its capabilities, students increasingly rely on AI systems during learning and complex problem-solving tasks. This growing reliance calls for higher education institutes to design learning processes that systematically promote students' competency to work effectively and responsibly with GenAI systems. One of the critical aspects is to develop students' *trust calibration* which is aligning reliance on AI with its actual capabilities in the team learning process. However, existing research primarily treats trust as an individual and static construct that overlook how trust dynamically unfolds during interaction. This study investigates trust calibration as a socially shared, temporal phenomenon in student teams working with a GenAI-supported group chat to complete an information-intensive task on starting a business, including taxation and registration procedures. The task requires evaluating AI-generated information, negotiating decisions, and managing uncertainty. Multimodal process data, including chat logs, screen and voice recordings during interactions, surveys before, during, and after tasks on trust level, and after-task interviews, are collected to capture learning as it happens. Using temporal analysis and Epistemic Network Analysis (ENA), the study examines how trust-related behaviors (e.g., accepting, questioning, or rejecting AI outputs) co-occur with collaborative regulation processes. Expected findings will identify distinct trajectories of trust calibration (e.g., over-reliance, under-trust, adaptive calibration) and their relation to collaborative learning processes. This work contributes to learning sciences by advancing process-oriented understanding of trust in human-AI teams in higher education learning contexts, with implications for designing effective AI-supported learning environments and pedagogy.

Primary School Students' Regulation of Learning During a STEAM Project
Keywords: Collaborative Learning, Interest, Self-regulated Learning, Socially-Shared Regulation
Presenting Author: Jenni Latva-aho, University of Jyväskylä, Finland; **Co-Author:**Héctor J. Pijeira-Díaz, University of Jyväskylä, Finland; **Co-Author:**Piia Naykki, University of Jyväskylä, Finland

Regulation of learning, the processes through which students manage and control their learning, is crucial for students' academic success. To learn to regulate their learning independently, students need repeated guided practice. Although self-regulated learning (SRL) and socially shared regulation of learning (SSRL) have been examined for decades, research has largely focused on higher education and traditional offline measures, resulting in limited evidence concerning primary school students and online measures. In this study, primary school students (N = 21) participated in a fifteen-week STEAM (Science, Technology, Engineering, Arts, and Mathematics) project. During the project, students' use of SRL and SSRL strategies were supported through group-level digital learning diaries. The aim of the study was to explore the SRL and SSRL strategies used, and students' individual interest in STEAM and the relatedness of these to the groups' emotional dynamics during the project. Students' collaborative work was audio-recorded throughout the project, yielding 120 hours of group discussions. Log data from the digital learning diaries were collected and connected with the audio data. Students' interest in STEAM was measured three times during the project. Data analysis implemented thematic coding, repeated measures ANOVA, and sentiment analysis. Preliminary findings indicate that students used a variety of SRL and SSRL regulation strategies throughout the project, such as planning, help-seeking, and reflection. Interest in STEAM, considered as an individual motivational component within collaborative learning, varied significantly over time. This study provides an in-depth insight into the primary school students' regulation processes in digitally supported collaborative STEAM learning contexts.

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18 November 2026 15:00 - 16:30
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No- or not-so-perfect-data presentation (Note: This session includes the single paper listed below.)

Cognitive Science, Learning and Instructional Technology

Eye-tracking and log data

Keywords: Engagement, Eye-Tracking, Facial Expressions, Feedback and Biofeedback, Game-based Learning, Learning Analytics, Log Data, Multimodal Data, Self-regulated Learning
Interest group: SIG 27 - Online Measures of Learning Processes
Chairperson: Enrique Arturo Vázquez Uscanga, Universidad Alberto Hurtado, Chile

Single Paper: "Learning Under Evaluation: Multimodal Process Measures of Learning Dynamics"
Keywords: Anxiety and Stress, Assessment, Heart Rate (Variability), Multimodal Data
Presenting Author: Victoria Prokofieva Nelson, Université Paris Nanterre, France; **Co-Author:**Fabien Fenouillet, Université Paris Nanterre, France

Learning is commonly studied through outcomes measured before or after instructional activity, whereas many mechanisms shaping performance emerge during task execution itself. Addressing the EARLI SIG27 focus on process measures of learning, this paper proposes a process-oriented framework for investigating learning under evaluative pressure through multimodal real-time indicators.
Drawing on convergent evidence from ecologically valid school-based studies, we show that evaluative situations are associated with measurable changes in physiological regulation, temporal dynamics, and cognitive engagement. Heart rate variability (HRV) data revealed autonomic stress responses during classroom events involving social evaluation, including oral responses, short written tests, and public performance demands. These physiological markers help interpret behavioral changes observed during task execution. Under performance-focused instructions, learners showed longer response times accompanied by lower response accuracy, suggesting that evaluative pressure affects both temporal processing and task performance. In creative problem-solving activities, evaluative framing also influenced fluency, originality, time-on-task, and sustained engagement across repeated trials, indicating modifications in exploratory dynamics under evaluation.
Taken together, these findings suggest that evaluative pressure reshapes how learners allocate time, attention, and effort while performing tasks. This contribution extends processing-efficiency approaches toward a multimodal and ecological understanding of learning under evaluative constraints. The findings also raise important questions for school testing practices, where evaluative pressure and strict time constraints may create contradictory demands on learners' natural regulatory and processing dynamics.