



*Instructional Design and Technology
Enhanced Learning: Current States and
Future Perspectives*

Book of Abstracts

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TÜBINGEN CENTER FOR DIGITAL EDUCATION (TÜCEDE)

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Wednesday 21.08.2024

9:30 – 10:30 - JURE Keynote

Tino Endres

Retrieval Practice has gained significant attention in educational research, particularly through laboratory experiments and meta-analyses that consistently highlight its potential to enhance learning especially in delayed assessment (lasting learning). This evidence has led to widespread recommendations for its integration into teachers' classroom practice. However, field studies reveal a different picture: the effectiveness of Retrieval Practice diminishes with complex knowledge as well as when compared to control groups engaged in meaningful activities. This keynote is challenging the prevailing optimism by addresses a critical question: Has cognitive-science research on Retrieval Practice oversimplified its theoretical and empirical underpinnings, thereby overstating its practical relevance? In this talk, I will present theory driven insights from use-inspired experimental research that explores key factors influencing Retrieval Practice' effectiveness in authentic settings. These factors include learners' motivation to engage in Retrieval Practice, the interaction with learner characteristics such as goal orientations, and the metacognitive effects of Retrieval Practice. My aim is to provide a realistic and nuanced picture of when Retrieval Practice can truly benefit lasting learning.

11:00 - 12:00 - Session A

No or not perfect data - I

ChatGPT and Literary Writing: Transdisciplinary Instructional Design Approach

Jennifer Mueller, Olga Özbek, Birgit Brucker, Peter Gerjets

Every emerging technology raises questions about its risks and potentials for children and the acquisition of important skills. As with every technology before, the answer to the impact of ChatGPT and similar text-generating Large Language Models (LLMs) depends on how they are used. The goal of this transdisciplinary research project is to explore how ChatGPT can be used within the framework of a creative AI-Writing-Tool that supports students' literary writing processes. We combine expertise from Didactics, Psychology, and Computer Science to design writing tasks that introduce students to various aspects of literary writing processes, including declarative knowledge about literature such as formal structures and procedural knowledge such as writing a draft. In addition, we also aim to design a user interface that guides them through their own writing processes and offers support when students need help along the way. Our research will focus on identifying instructional and interface factors that impact students' writing and self-regulations skills. Additionally, we will assess various factors of custom GPTs that influence writing outcomes, specifically evaluating their impact on creativity and aesthetic qualities.

Technology-supported Cooperative Learning: A Way to Boost Learning and Socioemotional Skills

Benedetta Zagni, Sara Scrimin, Mark Van Ryzin, Dario Ianes

Cooperative Learning (CL) is an evidence-based pedagogical methodology that has garnered considerable scientific support, particularly when structured according to its theoretical principles. Designing and implementing CL lessons is a complex endeavor. PeerLearning.net is a Web App developed to facilitate the construction and management of CL lessons that simultaneously works to develop socio-emotional skills. This doctoral project aims to assess the effects of using the WebApp in primary and secondary education. The research involves 40 classes from Northern Italy randomly assigned to either the target group (i.e., undergoing the CL technology-based intervention) or the control group (i.e., no intervention). A total of 575 students, with a mean age of 9.62 years (SD = .81), were involved in the study. Half of them were exposed to a program composed of training in socio-emotional skills and four CL modules integrating text comprehension with social-emotional skill enhancement. All children were assessed through self-report scales, behavioral tasks, and physiological measures. Data collection and analyses are ongoing. Preliminary findings from the pre-intervention assessment (T1) show positive associations between peer relationships and attitudes towards school, as well as improved text-comprehension skills. This first data highlights the importance of working on peer relationships to enhance students' learning and engagement. Post-intervention results (T2) are expected to have substantial theoretical and educational implications, potentially establishing PeerLearning.net as a functional empirically sound tool for cultivating well-rounded, socially adept, and academically successful students in the contemporary digital landscape.

Testing Constructive Retrieval in the Classroom – Findings From Two Field Experiments

Dwayne Lieck, Tino Endres, Alexander Renkl, Andreas Vorholzer, Alexander Eitel, Claudia von Aufschnaiter, Johanna Bohm

If a teacher wants their students to achieve lasting learning of complex materials, they have to ensure that the students remember the content. But they also want their students to understand the content with the ability to transfer what they learned to new content. But how can teachers foster both processes? Generative learning via self-explanation has been shown to aid in the construction of high-quality mental representations and positively increases learners' performance on conceptual knowledge and transfer tasks. Retrieval practice, in contrast, has been shown to enhance the consolidation of mental representations and thus to improve retention of learning materials. Consequently, a learning environment combining both approaches (constructive retrieval) should allow for high retention and comprehension. In two experiments, we test a learning environment that utilizes constructive retrieval in the context of the 11th grade physics curriculum. Preliminary analyses of experiment 1 (N = 120) show that a self-explanation task in a closed-book format improved comprehension in two delayed (one and eight weeks) posttests when compared to a description task, supporting the constructive retrieval hypothesis. Experiment 2 (N = 166) employed the same learning environment whilst also varying retrieval demands. Preliminary analyses show a significant benefit of retrieval practice on learning outcomes but no difference between the self-explanation and description tasks. We discuss potential moderators and theoretical explanations driving the discrepancy in results.

What Works Best? – Supporting Pre-Service Teachers' Critical Reflexive AI Literacy

Jana Kemmler, Iris Backfisch, Salome Wagner, Andreas Lachner

Adopting cutting-edge technologies for teaching, such as artificial intelligence (AI), requires pre-service teachers to systematically integrate profound technical and ethical knowledge to make informed instructional decisions. Knowledge integration, however, puts high demands on novices, such as pre-service teachers. In this study, we explored the efficacy of motivational (utility-value intervention) and cognitive (worked example) instructional support in enhancing knowledge integration among pre-service teachers. We applied a two-factorial design to examine the potential main and interaction effects of the interventions. We are currently conducting a study (N = 96 participants so far, ongoing survey) within a university course in teacher education asking students to read hyper-texts on AI's technological and ethical aspects. Preliminary findings, based on generalized mixed effect models, indicate no significant difference in near-transfer knowledge test scores among conditions. Currently, far transfer tasks are analyzed to examine students' knowledge integration. This ongoing research aims to identify effective strategies for fostering knowledge integration among future teachers, crucial for navigating the complex implications of AI in educational contexts.

Single papers - Cognitive skills & Processes I

From Passive to Metacognitive: The Effect of Mode of Engagement on Chemistry Learning Outcomes

Yoana Omarchevska, Brendan Schuetze, Juliane Richter, Katharina Scheiter

The present study investigated how different levels of cognitive and metacognitive engagement during learning with a digital interactive textbook relate to secondary students' (N = 248) immediate and delayed knowledge in chemistry. Cognitive and metacognitive engagement was inferred from logfiles regarding students' activities during learning and classified according to the ICAP framework. Students' activities were used as indicators of four latent variables measuring cognitive and metacognitive engagement. We did not include interactive engagement since students worked individually with the digital textbook. We created SEM models that included prior knowledge, students' activities and levels of cognitive (passive, active, constructive) and metacognitive engagement as predictors of immediate and delayed knowledge. The results indicated that constructive ($\beta = 0.21, p < .001$) and metacognitive ($\beta = 0.37, p < .001$) engagement significantly predicted immediate knowledge, and metacognitive engagement ($\beta = 0.37, p < .001$) was the only significant predictor of delayed knowledge. Passive and active engagement contributed very little to the prediction of immediate and delayed knowledge. Our findings provide important theoretical implications by testing the theoretical assumptions of the ICAP hypothesis in the same model in relation to immediate and delayed knowledge.

Online Learning on Clearinghouse Websites for Evidence-based Education: A Matter of Experience

Marcel Capparozza, Salome Wagner, Iris Backfisch, Jana Kemmler, Jürgen Schneider, Andreas Lachner

Clearinghouse websites play a crucial role in disseminating evidence-based knowledge in education. However, there is a lack of how clearinghouse websites are used by different target groups (i.e., in teacher education) and how they process the provided information. Thus, we conducted a think-aloud study with 38 participants (25 pre-service teachers and 13 teacher educators) who were using a clearinghouse website. In addition, we collected pre- and post-test data. The participants reported distinct cognitive and behavioral processes during the use of the clearinghouse website. Teacher educators exhibited more frequent elaboration and critical evaluation, while pre-service teachers engaged more in paraphrasing. An Epistemic Network Analysis (ENA) further corroborates these findings, revealing distinct network structures for each group and deeper engagement of teacher educators with the website content. Interestingly, these differences did not impact learning outcomes, though teacher educators showed greater skepticism towards the trustworthiness of the website. Based on the results, we

advocate for tailoring features of clearinghouse websites for different groups of users and the integration of clearinghouse websites into formal educational contexts to ensure deeper learning experiences, particularly for pre-service teachers.

Remembering Knowledge Levels of Different Learning Partners

Oktaý Ülker, Daniel Bodemer

Learners are often required to remember information about their learning partners, such as their knowledge levels regarding several learning topics. Such partner modeling processes help to make informed judgments about whether learning partners can provide help or need explanations. Instructional technologies such as group awareness tools provide learners with such information about their partners, and thus support partner modeling and implicitly guide social learning processes. In a (pseudo-collaborative) experimental study, we examined partner models for a computer-supported collaborative learning context. We used multinomial processing tree models to measure memory processes unconfounded by guessing biases. $N = 168$ participants received information on the knowledge levels (high vs. medium vs. low) of a learning partner (expert vs. intermediate vs. novice) regarding 60 topics. For the expert and intermediate partners, high and low levels were better remembered than medium levels. For the novice partner, however, only low levels were better remembered than medium levels. However, participants' metacognitive assumptions about their own memory processes differed from their actual memory processes. Our findings reveal biases in remembering the knowledge levels of learning partners, which could lead to systematic disadvantages of novices in social learning settings. The discrepancy between actual memory and metacognitive assumptions has implications for the design of instructional tools and pedagogical strategies in collaborative learning contexts, such as using adaptive prompts and instructions based on the learning partner type.

Visual Processing of Computer-Based Feedback: Is Visual Attention Predictive for Learning?

Thérèse Eder, Livia Kuklick, Marlit Annalena Lindner

Computer-based feedback plays a central role in adaptive learning environments, offering personalized and timely guidance to learners. Elaborated feedback (EF), which provides not only correct answers but also additional contextual information, has shown promise in enhancing learning outcomes. However, understanding how learners process such feedback remains underexplored. Building upon previous research, this study investigates the gaze behavior of learners during the processing of EF messages in geometry tasks within a testing context. We recruited 84 students to complete a computer-based test comprising 12 geometry tasks with automated EF. Using eye-tracking technology, we analyzed participants' gaze behavior during feedback processing. Our findings indicate that students spend more time on EF after incorrect responses and focus longer on the solution path, suggesting differential processing based on answer correctness. Furthermore, shorter fixations on specific feedback elements were associated with better performance in transfer tasks, highlighting the predictive value of gaze behavior in learning outcomes. This study sheds light on the visual processing of computer-based feedback and its implications for learning in assessment contexts.

Single papers - Competencies

Academic Self-Concept Determines the Effectiveness of Learning by Explaining

Leonie Sibley, Julie Thommes, Julian Roelle, Kou Murayama, Andreas Lachner

Explaining previously learned contents to a fictitious peer can support students' (meta-)cognitive learning. However, prior research demonstrated only mixed findings regarding the effectiveness of generating explanations, which might be an indicator that explaining is not generally effective but may depend on further boundary conditions. Researchers therefore started to explore the boundary conditions of the explaining effect and revealed, for instance, that explaining may only be beneficial for students with a low academic self-concept. These findings, however, are only of explorative nature. Thus, replications which allow causal interpretations are needed. In this project, we aimed to close this research gap and conducted three experimental online studies ($N = 692$) in which we systematically manipulated students' academic self-concept within a 2×2 design to examine its influence on the explaining effect by using a pre-post-delayed test. Results revealed no difference among conditions when students wrote an explanation (Study 1 and Study 2). However, when students explained orally (Study 3), students with low academic self-concept indeed showed higher learning outcomes than students with high academic self-concept. This is in line with prior research which showed that oral explaining is more beneficial than writing explanations. Our project extends prior research since not only the modality (written versus oral) is crucial for the effectiveness of explaining but also students' academic self-concept.

Promoting the Quality of Feedback of Prospective Teachers in Computing Education

Thomas Schmalfeldt

Feedback is crucial to learning, as it helps link current performance to desired outcomes. This paper reports on a study that investigates how feedback competence could be enhanced during a programming course for prospective primary teachers and its effect on their programming skills. The intervention involved 350 prospective primary school teachers in their final semester who participated during self-organized learning time using a learning management system. The study focused on improving teacher students' feedback skills through assignments related to programming tasks. These tasks required teacher students to critique solutions to programming problems in order to develop their ability to provide constructive feedback. The students were divided into groups, who received different levels and types of feedback from lecturers, including generic and individual evaluations. The intervention also included different theoretical inputs on feedback that aimed to refine teacher students' feedback delivery. Pre- and post-tests assessed changes in programming skills, while the assignments were used to evaluate feedback competence at different stages of the intervention. The preliminary results will be presented in detail at the conference.

Teachers' Self-Reported and Actual TPACK – New Results on Their Relation and Gender Differences

Timo Kosiol, Stefan Ufer

The Technological Pedagogical and Content Knowledge framework (TPACK) is commonly used to describe (technology-related) teacher knowledge. Self-reports are predominant measures for TPACK, while knowledge test instruments are scarce. Self-reports can be interpreted as general measures of performance-related self-beliefs. Still, due to the contextualized nature of TPACK and potential biases, it remains uncertain to which extent they reflect actual knowledge. Self-reports may be especially gender biased, as in STEM subjects women often underestimate their performance. Drawing on a sample of $N = 161$ mathematics in-service and pre-service teachers, we aim to analyze (i) the structure of the self-reported knowledge and (ii) the relationship between self-reported and actual knowledge. Participants' amount of actual knowledge in mathematical CK, PCK, TCK, and TPCK is inferred from their performance over multiple authentic demands, separately for each dimension. To this end, we applied an instrument comprising validated and contextualized demands. The current study shows that the TPACK self-beliefs can be separated and measured reliably. Although all self-beliefs show bivariate relations to their corresponding actual knowledge dimensions, this changes for PCK and TPCK self-beliefs when other actual knowledge dimensions are controlled. While variance in TCK and to a lesser degree CK self-beliefs can be explained primarily based on their corresponding actual knowledge, for PCK and TPCK self-beliefs the non-pedagogy-related dimensions contribute to the variance explanation. Lastly, we do not find gender biases, but a small gender effect with lower actual and self-reported knowledge for female teachers over all dimensions.

13:00 - 14:20/ 14:30 - Session B

Symposium I - Advancing Adaptivity of Support in Digital Learning Environments: Focusing on the Adaptivity Design

Organizers: Michael Nickl, Daniel Sommerhoff
Discussant: Manuel Ninaus

Recognizing that students enter learning environments with heterogeneous prerequisites, providing support where it is most needed is paramount for educational success (Corno, 2008). Herein lies the potential of digital learning environments, which can efficiently adapt support to meet the unique needs of learners (Tetzlaff et al., 2021). Effective adaptive support in digital learning environments requires several well-informed decisions regarding the adaptivity design. However, there is no standard way to reach effective adaptivity designs. This lack of standardization possibly contributes to varying effectiveness of adaptive support as can be seen regarding the adaptivity of scaffolding (Beland et al., 2017). As a first step towards standardization, research has suggested i) choosing an adaptation source (i.e., variables that determine what support to provide) and ii) choosing an adaptation target (i.e., support that is adapted) as two crucial decisions in the design process (Plass & Pawar, 2020). This symposium advances research on the design process by showcasing, comparing, and analyzing four distinct adaptivity designs. All contributions share an empirical approach, with the first focusing on the design process of an adaptivity design, the second and third focusing on evaluating adaptivity designs, and the fourth focusing on a scheme for reflecting on adaptivity designs. All designs use cognitive adaptation sources and employ scaffolding, feedback, or difficulty progression as adaptation targets (see Plass & Pawar, 2020). The adaptivity designs are characterized by a solid theoretical underpinning regarding their choices of adaptation source and target (Gašević et al., 2015; Plass & Pawar, 2020).

Identifying Starting Points for Designing Adaptive Guidance in Productive and Vicarious Failure

Charleen Brand, Christian Hartmann, Katharina Loibl, Nikol Rummel

We investigated the role of learners' characteristics and learning processes in two instructional designs with preparatory activities prior to instruction: Productive Failure (PF) and Vicarious Failure (VF). The aim was to identify starting points for the design of adaptive guidance for PF and VF. Based on an experimental study with 110 secondary school students in mathematics, we examined (1) the effect of learner characteristics in PF (students generating own solution attempts) and VF

(students studying these attempts) and (2) learning processes based on think-aloud data from 15 PF-VF-model-observer-pairs. We analyzed frequencies and sequences of cognitive processes, using the HeuristicsMiner algorithm. Mathematical ability and self-concept affected PF and VF students' learning. VF students exhibited a more analytical approach to the task, in which task orientation and evaluation was central for students' learning. PF students showed a more solution-oriented approach, focusing on solution generation. The findings shed light on learning in PF and VF and lay the foundation for designing adaptive guidance. Metacognitive and motivational prompts could assist students with characteristics and facilitate task orientation and evaluation. Think-aloud data could be used to leverage real-time process data for micro-level adaptivity. By incorporating adaptive guidance, PF and VF can evolve into an adaptive and personalized learning environment

Probability Levels in Adaptive Learning Technologies: What Works for Whom?

Martine Baars, C.A.N. Knoop-van Campen, A. Derksen, Rick Dijkstra, Rianne Kooi, I. Molenaar

Adaptive Learning Technologies can assist students' learning processes. Yet, it is unclear at what probability level of succeeding, students perform most efficiently. Therefore, we investigated i) children's practice behavior, learning gains, and lesson experience across three probability levels in an Adaptive Learning Technology, and examined ii) how this differed between low-ability, average-ability, and high-ability students. Hundred-seventy-five primary school students (grade 5) were randomly assigned to a probability level in which the probability of succeeding was 65%, 75%, or 85%. Results showed that the lower the probability, the fewer assignments students made during the lesson, and the fewer assignments were answered correctly. However, learning gain was similar across probability and ability levels. Students who worked with 65% probability of succeeding did seem to realize that they were presented with difficult assignments they had not (yet) mastered compared to the 75% and 85% probability students, but this did not lead to less enjoyment or more stress. Learning experience measures suggested that, even for the low-ability students, lower levels of probability of succeeding (i.e., 65%) seem suitable. With these insights, future research can investigate how to apply probability levels in Adaptive Learning Technologies, to foster students' learning experiences and outcomes, and be attuned to their needs.

Adaptive Feedback from AI in Simulations for Teacher Education: A Replication in the Field

Elisabeth Bauer, Michael Sailer, Frank Niklas, Samuel Greiff, Sven Sarbu-Rothsching, Jan Zottmann, Jan Kiesewetter, Matthias Stadler, Martin Fischer, Tina Seidel, Detlef Urhahne, Maximilian Sailer, Frank Fischer

Artificial intelligence and natural language processing enable automating a formative assessment of written responses for providing automatic adaptive feedback. A recent laboratory study found positive effects of a digital case-based simulation with adaptive feedback—automated through artificial neural networks—compared to static feedback (an expert solution) on pre-service teachers' diagnostic reasoning skills. The effectiveness under field conditions remained an open question. We tested the generalizability of the findings in an experimental replication under field conditions. During their regular online courses, N = 230 pre-service teachers at five German universities either received static feedback or adaptive feedback when learning with three simulated cases. We analyzed the effect of the two types of feedback on participants' judgment accuracy and justification quality in the learning phase and a simulated posttest case without feedback. Compared to the static feedback, adaptive feedback had a significant positive effect on the justification quality but no significant effect on the judgment accuracy. Our field experiment replicated the results of the previous laboratory study. Adaptive feedback primarily seems to foster learners' justification quality but not learners' judgment accuracy. Under field conditions, learners benefit from adaptive feedback using artificial neural networks for natural language processing when learning with simulations.

Adaptive Real-Time Scaffolding for Pre-Service Teachers in a Video-Based Simulation

Michael Nickl, Daniel Sommerhoff, Anika Radkowitzsch, Sina A. Huber, Elisabeth Bauer, Stefan Ufer, Jan L. Plass, Tina Seidel

Computer-based simulations have evolved as promising learning environments in teacher education to provide scalable, authentic learning opportunities for pre-service teachers, for example, to facilitate teachers' assessment skills. Incorporating scaffolding within these simulations, particularly conceptual prompts, has shown additional promise. Given the heterogeneity of teachers' performance in assessing students' knowledge, adapting scaffolding to their performance seems particularly beneficial for improving assessment skills. To investigate the efficacy of the adaptivity of scaffolding, a pre-post study involving 245 pre-service teachers was conducted. During the pre-test and the post-test, participants engaged in a video-based simulation in which they assessed the mathematical proof skills of students (without scaffolding). During the intervention, participants completed the video-based simulation in one of three conditions: adaptive, non-adaptive, or no scaffolding. Conceptual prompts were used as scaffolding and adapted based on the individual performances in the simulation for participants in the adaptive scaffolding condition. Regarding judgment accuracy as the standard measure for teachers' assessment skills, no significant differences across the conditions were found, neither during nor after the intervention. To understand the lack of significant benefits through adaptivity, a theory-based scheme was developed for a standardized analysis and reflection of the adaptivity design. Applying this scheme highlighted, among others, a non-negligible overlap in provided prompts between adaptive and non-adaptive conditions and that the adaptivity design had the intended effects on

more proximal indicators of assessment skills than judgment accuracy. The study highlighted the challenges in designing effective adaptive support and proposed a scheme for reflecting adaptivity designs.

Symposium II - Synthesizing Instructional Design Principles and Teacher Education

Organizer: Jasmin Lilian Bauersfeld

Discussant: Fritz C. Staub

There is agreement that instructional principles from educational psychology such as signaling (van Gog, 2014), prompting (Nückles et al., 2020), example-based learning (Renkl, 2011), and modeling (Hoogerheide et al., 2016) can support learning. However, these principles rarely have been implemented in fields characterized by high complexity. Specifically, in teacher education research, only recently, studies (Martin et al., 2022; Prilop et al., 2021; Seidel et al., 2013; Nückles & Kleinknecht, 2024) have implemented instructional principles to foster core competencies necessary to master the multi-faceted demands of teaching (Grossman et al., 2009). Hence, it is not fully understood how these principles can support student teachers in developing core competencies. The symposium serves as a starting point for discussions around this research gap. The first paper uses complexity-reduced classroom situations with signaling and prompts and found no effect for these principles on competence development. The second paper showed that combining instructional explanations, modeling, and independent practice fostered enactment of core competencies best. The third paper examined how providing general or expert feedback as modeling examples after video-based analyses helped develop peer-feedback skills. The fourth study showed that providing concepts before video-examples of classroom situations was more effective for university student teachers than pre-service teachers in the induction program. Providing concepts after equally affected student and pre-service teachers. These papers show that investigating the implementation of instructional principles in teacher education is promising but yields somewhat heterogeneous results suggesting that more empirical research and theoretical integration are necessary to support future teachers' competence development.

Preservice Teachers' Analysis of Video: Investigating Professional Vision and Multimedia Design

Meg Farrell, Monika Martin, Ricardo Böheim, Dr. Renkl, Werner Rieß, Tina Seidel

Two studies investigate a video-analysis training intervention for preservice teachers' development of professional vision skills. The training employs a practice-based approach for knowledge-based noticing and reasoning about instruction-relevant events within video scenarios. Tailored for novices, it focuses on a reduced-complexity context: the core practice of small-group tutoring. The Descriptive Study assesses preservice teachers' professional vision performance within their video analyses with Epistemic Network Analysis. Results demonstrate that, as anticipated, most participants noticed general pedagogy rather than content-specific events, highlighting the need for further training and support. However, some demonstrated better-than-expected skills. The Experimental Study builds on this. Informed by The Cognitive Theory of Multimedia Learning, some versions of the training implemented multimedia instructional design techniques hypothesized to offer video processing support: signaling cues and focused self-explanation prompts. This study investigates participants' development of professional vision skills and the supportive impact of these techniques. Regardless of condition, preservice teachers' professional vision skills significantly improved after the video analysis training. Surprisingly, both techniques did not provide additional support overall, but a subgroup with lower situational interest benefited from signaling cues. These findings suggest the effectiveness of the video analysis professional vision training, emphasizing its potential as an economical and flexible model to incorporate into teacher education courses. The research emphasizes the need for ongoing support in content-specific noticing and reasoning and raises questions for further investigation on the use of multimedia design techniques in this context. Additionally, it suggests promise for promoting situational interest in video analysis training.

How Can the Acquisition of Complex Teaching Skills be Optimally Fostered?

Hadmut Hipp, Anna Holstein, Marc Kleinknecht, Matthias Nückles

Bringing teacher education and instructional design together – this ambitious yet captivating goal forms the background of our research program. Considering the lack of consensus on how to design skill acquisition trainings for pre-service teachers, we discuss approaches from practice-based teacher education and cognitive psychology: the Learning Cycle (McDonald et al., 2013) and ACT-R theory (Anderson, 1982). We conclude that to foster the acquisition of teaching skills, trainings should include at least (1) a principle-based explanation, (2) a modelling of the skill, and (3) an opportunity for practice. We report results from a study (N = 123) varying the composition of training sequences centred around the reading strategy training Reciprocal Teaching. RT comprises three teaching skills: Explaining RT, cognitive modelling of reading strategies and scaffolding group work. We measured skill acquisition on four levels, (1) teaching performance, (2) professional vision, (3) self-efficacy and (4) declarative knowledge. We assumed that combining all three training phases would foster teaching performance best, while training sequences lacking one of the phases would be less effective. Our results confirmed this hypothesis and showed that different combinations of training phases fostered different aspects of teaching competence. Professional vision mediated the positive effects of the trainings on performance, confirming Blömeke et al.'s (2015) assumption on the mediating role of professional vision for competent teaching. However, declarative knowledge was the strongest predictor of teaching performance, confirming the ACT-R assumption that a thorough understanding of the

The Effect of Expert Feedback on Pre-Service Teachers' Peer Feedback Quality and Beliefs

Christopher Neil Prilop, Kira Weber

High-quality peer feedback can effectively promote (pre-service) teachers' expertise. To be able to provide high-quality feedback, teachers' need to develop their peer feedback expertise early in their careers. Although feedback training has been shown to foster pre-service teachers' peer feedback expertise, recent research indicates that expert feedback may play an important modelling role in enhancing pre-service teachers' feedback expertise during feedback training. Therefore, we investigate the effects of peer feedback training (enhanced by expert feedback) on pre-service teachers' feedback quality and beliefs. Intervention group 1 (IG1) only analyzed classroom videos before the feedback training, while intervention group 2 (IG2) additionally received expert feedback on their video analyses. IG1 and IG2 were compared to a control group (CG). Results show pre-service teachers in IG1 and IG2 improved their peer feedback quality and beliefs in comparison to the CG. Expert feedback (IG2) led to greater increases of peer feedback quality than without (IG1). This study highlights the role of expert feedback when training peer feedback. Our findings indicate that expert feedback is needed as a modelling example in peer feedback training. Expert feedback can further enhance peer feedback training by improving specific aspects of the quality of pre-service teachers' feedback. Hence, our study presents the characteristics of effective peer feedback training that enables pre-service teachers to use the full potential of peer feedback.

Before or After? Sequencing Concepts and Video-based Analyses for Different Teacher Education Phases

Jasmin Lilian Bauersfeld, Patricia Calies, Heike Hahn, Bernadette Gold

To achieve teaching quality, future teachers need to develop professional vision (PV). PV encompasses noticing and reasoning on events of classroom management and instructional support. Research has shown that introducing teaching quality concepts before or after video-based analyses can both effectively support developing PV, but promote different cognitive processes. Introducing concepts before video-based analyses may foster PV by illustrating teaching quality concepts using classroom videos as examples (concept-example sequence). Introducing concepts after video-based analyses, helps fill examples of classroom videos with teaching quality concepts (example-concept sequence). Student teachers at university typically lack knowledge and could be supported in acquiring knowledge through the concept-example sequence and hence, develop PV. Pre-service teachers could relate teaching experience from the induction program to concepts and may benefit from the example-concept sequence. Therefore, we investigated whether the two sequences would be better for different phases in teacher education. In a two-week video-based course N = 133 student teachers at university and N = 36 pre-service teachers in an induction program analyzed teaching quality (classroom management and instructional support) in classroom videos. They received preparatory texts with teaching quality concepts before or after video-based analyses. Pre-post-tests measured PV of classroom management and instructional support with a video-based test. The results showed that providing concepts before video-based analysis supported student teachers, whilst hampering pre-service teachers' development of PV of classroom management. Hence, the concept-example sequence had an expertise reversal effect on pre-service teachers. Further, results on written analyses, implications, and limitations will be discussed

Single papers - Higher Education

Delving into Data on Students' Instructional Knowledge: A Review of the Empirical Research

Morane Stevens, Jan Elen, Fien Depaep

Students, as self-regulating actors, do not blindly adhere to the expectations and prescriptions imposed on them by learning environments. Rather, they appeal to their prior knowledge to interpret these expectations and prescriptions, adjusting their behaviors accordingly. Research suggests that students' knowledge of micro-level education – specifically, their knowledge of how education is provided to students – often diverges from the actual learning environment presented to them. This discrepancy in students' so-called 'instructional knowledge' may adversely affect their learning behaviors and outcomes. To ensure effectiveness of learning environments, it is therefore essential to take this type of knowledge into account. However, current research shows considerable fragmentation, which not only poses challenges in navigating and interpreting it, but also limits opportunities to build a research agenda. This scoping review therefore aims to provide a thorough and comprehensive review of the empirical literature on instructional knowledge among students in higher education. After an initial database search, systematic snowballing methods were employed to find relevant literature. Following data screening and analysis, relevant conclusions are drawn.

Instructional Design of Time-Management Interventions to Improve Performance in Higher Education

Time management is an important skill for succeeding in higher education. However, university students often demonstrate poor time-management skills. Interventions have the potential to improve students' time-management and academic performance, but previous studies have reported rather mixed effects on academic performance. A frequent point of criticism is that the instructional design of the interventions often lacks an appropriate conceptual basis. This, in turn, could be a possible reason for the inconsistent effects on academic performance. Wolters and Brady (2020) have addressed this issue by developing a conceptual framework of time management that refers directly to self-regulated learning theory and the processes within its underlying phase structure. This framework can be used to develop and evaluate the instructional design of time-management interventions. We conducted a systematic review of the current state of relevant research and then applied this conceptual framework to examine the extent to which the instructional design of previous time-management interventions has been aligned with the self-regulated learning process, and whether the effects on students' academic performance differ depending on this design aspect. The results showed that time-management interventions with an instructional design more closely aligned with the self-regulated learning process were more likely to yield beneficial effects on students' academic performance. Overall, our findings support the consideration of the self-regulated learning process as a comprehensive conceptual basis for investigating and improving students' time management. Identified issues with previous intervention studies and implications for future intervention designs are discussed.

Learners' Perceived Relatedness in Hybrid Collaboration Compared to F2F or Remote Settings

Sabine Schermeier, Anne Deiglmayr, Nikol Rummel

Hybrid collaboration, where onsite and remote learners work together using online tools, is becoming increasingly relevant to education due to its high degree of flexibility. There is extensive research contrasting face-to-face (F2F) to remote collaboration, but much less research on hybrid learning formats. The scarce available research on hybrid collaboration indicates that the remote learners in such settings often feel less related to their peers than the onsite learners. Research on socio-affective factors such as relatedness in hybrid learning is particularly lacking, even though these factors play a crucial role for learners' interaction. In this paper, we experimentally investigate the different perceptions of learners in hybrid, F2F and remote collaboration. In a laboratory study conducted in the context of higher education, $n = 180$ students rated their socio-affective state after participating in one of the three group work modes (F2F, remote, hybrid). The study revealed statistically significant differences between the three conditions in terms of learners' perceived relatedness. Learners in the remote condition reported lower perceived relatedness than learners in the other two conditions and even lower than the remote participants in the hybrid condition. We use the findings of our study to discuss key issues of hybrid collaboration that should be addressed in future research.

Learning Analytics for Exercise Sessions: Addressing the Tensions of Cognitive & Metacognitive Goals

Zhenyu Cai, Richard Davis, Roland Tormey, Pierre Dillenbourg

A range of learning analytics (LA) tools have been designed and integrated into university classes to facilitate teachers' reflection and orchestration. However, exercise sessions, the educational setting that complements lectures with practical activities, are commonly overlooked by LA researchers and designers. Little work has focused on involving the key stakeholders, teaching assistants (TAs), and incorporating human-centered design approaches in this context. To address this gap, we conducted a qualitative, task-based study to understand the common practices and challenges for teaching and learning in exercise sessions, and to explore TAs' visions for LA dashboards that could be adapted into their current practices. Our results indicated that TAs in exercise sessions had markedly different needs compared to instructors in lectures. Specifically, TAs held two levels of goals in supporting students' cognitive and meta-cognitive activities, and while LA tools were seen as offering numerous potential benefits, they were also seen as introducing tensions threatened to disrupt the delicate balance of goals at both levels. We propose ways of designing dashboards to respect students' privacy, autonomy, and meta-cognitive development while also helping to meet their learning needs.

14:35 - 15:35 - Session C

ICT Demo

ICT 1

Enhancing STEM Education with an AI-powered System that promotes Interactive Learning and Engagement

Marei Beukman, Björn Rudzewitz, Daniela Verratti Souto, Mingjing Zhu, Xiaobin Chen

We introduce an innovative AI-powered collaborative learning environment that aims at enhancing Science, Technology, Engineering, and Mathematics (STEM) education by implementing an extension of the Learning-by-Explaining (LbE) pedagogical approach based on the Interactive, Constructive, Active, and Passive (ICAP) learning framework. The system

features a teacher module that enables teachers to create classes and lessons, upload multimedia learning materials, and manage students' collaborative learning synchronously. The student module allows students to join classes and lessons, be involved in LbE activities in groups under the assistance of the teacher and a generative AI. The system is designed to allow learners to learn in all four engagement modes of the ICAP framework, extending the traditional LbE approach which includes mostly only passive and constructive components. Following the Three Basic Dimensions of effective teaching, the system can offer classroom management for teachers, high cognitive activation through active and interactive activities at the learning phase, as well as constructive feedback from both teachers and the generative AI at both the learning and the explaining phases, potentially providing an effective learning environment for enhancing STEM education. The system is designed for synchronous classroom teaching, but can also be used for asynchronous self-paced learning.

ICT 2

AutoTutor for Adult Reading Comprehension (ARC) 2.0: Present and Imagined Designs

John Sabatini, Arthur Graesser, Blake Telfer, John Hollander, Tenaha O'Reilly

The purpose of this session is to demonstrate and discuss AutoTutor for Adult Reading Comprehension (AutoTutor-ARC) 2.0, an intelligent tutoring system being developed and piloted by our research team. The initial AutoTutor-ARC version was developed over a decade ago and evaluated with a sample of adult literacy learners in classrooms, as supplemental practice to an aligned curriculum program. It utilized dialogues with two conversational agents, tailored question feedback, and a modest adaptive design. Supported by a federal grant, the R&D team has undertaken a redesign of the system with the goal of enhancing and modernizing it, as well as evaluating its suitability in different adult learning settings. In the redesign, we are integrating formative assessment, adding elements for aiding learners in consolidating strategy use, and piloting background knowledge, meta-cognitive reflection, and self-regulation activities.

ICT 3

Graveler - Experiencing Knowledge through Play

Kevin Körner, Esther Fink

Graveler is a browser-based e-learning tool designed for developing Serious Games and Game-based Learning approaches and integrating them in higher education. It combines functionalities of learning management systems, conferencing software, and includes a 2D multiplayer role-play game editor. The latter allows for managing classes and creating virtual worlds to explore with students. Graveler features chat and interactive elements, permitting educators to easily design engaging interactive walkable spaces with minigames and activities, embed external webpages, web apps, and spatial chat. Graveler was developed to promote inter- and transdisciplinary perspectives among students from different backgrounds and to foster intercultural competence, but it is not limited to a single game and can be adapted infinitely.

Posters - Group A

A1

A Psychological Platform for GenAI and Human Co-Piloting in Education

Luke Fryer

GenAI (Generative Artificial Intelligence) will have a growing role within formal education. What should that role be? How do we treat GenAIs as an opportunity to enhance and reenergise teaching and learning? This position paper suggests that answers to these questions should start with our foundational psychological theories about what students need to function and develop well. This position article outlines how psychological needs theory, focusing on students' basic psychological needs for competence and relatedness might be a path forward. Teacher behavior supporting these psychological needs (i.e., involvement and structure), which have established relationships with learning outcomes, are used as a base for assessing the potential roles of human and AI instructors. A balanced approach that draws on the strengths of each instructor is suggested as a possible way forward for research and practice in this area. Co-piloting the educational ship forward could herald a brighter future for students across educational levels and contexts.

A2

Chatbots in Education: A Systematic Review of the Underlying Technology and their Grounding Theory

Tim Debets, Seyyed Kazem Banihashem, Desirée Joosten-ten Brinke, Tanja Vos, Gideon Maillette de Buy Wenniger, Gino Camp

In recent years, the advances in Artificial Intelligence (AI), embodied by ChatGPT among others, have propelled significant breakthroughs across various domains, coinciding with the increasingly digitized landscape of education. This shift and the advances in AI sparked considerable interest in leveraging AI to support both students and teachers. Within the existing AI applications in education, chatbots, also known as conversational agents, have emerged as a prominent focus due to their round-the-clock availability, empowering students to seek assistance or engage in learning at their convenience. Data from the Scopus database illustrates an exponential growth in research on chatbots in education, surging from 53 in 2019 to 255 in

2023, paralleled by a rise in literature reviews on this topic. However, an analysis of recent literature reviews identified two common gaps: insufficient discussion of (1) the underlying technology behind AI-powered chatbots in education and (2) the educational theories informing the integration of chatbots in educational settings. To address these gaps, this study conducts a systematic literature review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method. Following the screening of 581 publications identified through keywords in the Web of Science and Scopus databases, 71 publications are included in the analysis. Results will be discussed during the presentation.

A3

Digital Media Education Approaches to GenAI in Schools: a Latent Profile Analysis

Tessa Consoli, Konstantinos Michos, Dominik Petko

The introduction of generative artificial intelligence (GenAI) in education presents both new opportunities for teaching and learning but also many challenges, particularly within school contexts. Students are encouraged to learn how to use GenAI tools efficiently, ethically, and responsibly, and a critical-reflective approach to AI in education has been recommended. Although previous research explores the use of GenAI tools in schools, limited research has been conducted on media education approaches regarding GenAI. To address this gap, we conducted a survey study with N = 2357 upper secondary school students in the German-speaking part of Switzerland. Through latent profile analysis, we investigated which combinations of three different media education approaches (preventive-protective, critical-reflective, and functional) to GenAI students experience in Swiss upper secondary schools. Our findings reveal that the majority of students (n=908) experience a combination of the preventive-protective and critical-reflective approach toward GenAI, with few teachers actively encouraging its use for learning and productivity. Students who experienced the most critical-reflective approach responded having significantly higher responsibility and skills about GenAI. These findings highlight the need of clear media education strategies for GenAI in schools, aiming to effectively cultivate students' skills and responsibility in using GenAI, and to inform teachers' pedagogical interventions.

A4

Empowering Teachers to Co-Create Learning Experiences With AI

Thomas Frøsig

When looking at Technology Enhanced Learning (TEL) and AI in Education (AIED) through the lens of the emerging field of teacher agency; the literature seems to support the notion of AI tools having the potential to negatively effect professional agency due to teachers limited power to (i) act, (ii) to affect matters and (iii) to make decisions or choices, as well as the possibility to (iv) take a stance. This is supported by new research emphasizing agency as being a key factor in teachers ability to trust AI. Likewise the term Algorithmic Aversion has emerged, defined as the phenomena that teachers expect a generated output to be fully compliant with their own opinion. If not, teachers disagree with the output, and perceive it as being useless. Inadvertently a decrease in agency will also have a decreasing effect on the biggest impact factor of teaching, being teacher self-efficacy. What this research suggests is to investigate if an increase in teacher agency can be achieved by giving EFL teachers the possibility to create intelligent AI driven conversation avatars, for either their class or individual students, with which these can practice their speaking skills in an 3D Digital Educational Escape Game.

A5

How Chatbots Support Student Motivation in Learning: A Scoping Review

Weijiao Huang, Juming Jiang, Luke Fryer

Students' learning experiences are deeply shaped by their motivation. The potential of using chatbots to support student motivation remains largely untapped by the current literature. Recognizing the increasing interest in using chatbots as a learning tool, including ChatGPT and its variants, and their continued influence on the future of education, we conducted this scoping review to synthesize empirical research on the use of chatbots to support student motivation in learning environments. Three research questions were addressed in the included studies: (1) the underlying theories, (2) the features of chatbots, and (3) the types of motivational variables investigated. A systematic search for literature published between 1956 and 2023 identified 41 relevant studies. The results showed that 31 studies employed at least one theoretical model, with a total of 26 different theories or models used. The included studies incorporated various educational theories and designed chatbot activities to create interactive learning environments. Chatbot features included predominantly text-based communication, with a recent attention to generative chatbots and advanced interactions. Thirty-two motivational variables were examined, with interest, intrinsic motivation, and self-efficacy being the most studied. However, most studies measured motivation as a static outcome, suggesting that future research should focus on the process and development of student motivation. This review highlights the potential of chatbots to support student motivation and the need for further research in this field.

A6

Is ChatGPT a beneficial peer? Analysis of peer assessment behavior and critical thinking

Weijun Li

The value of ChatGPT in the field of education has garnered attention from researchers, particularly regarding concerns about its impact on critical thinking. Paradoxically, numerous studies have shown that technology-assisted learning can indeed facilitate the development of critical thinking. As an emerging technology, it is meaningful to explore how ChatGPT can be better utilized to promote critical thinking beyond concerns about its negative effects. However, empirical research on this topic is limited. Furthermore, although peer assessment is a significant method for promoting critical thinking, its effectiveness is subject to interpersonal relationship issues such as friendship and emotional conflicts. As a chat-based AI, ChatGPT presents the possibility of serving as a peer companion without such interpersonal issues. Therefore, we propose utilizing ChatGPT as a companion for peer assessment, using lag sequential analysis to dissect learners' peer assessment behavior and the process of critical thinking development. The aim is to identify mechanism of learning behavior and development of critical thinking, and to validate the potential of ChatGPT as a peer to foster critical thinking. Additionally, through interviews with learners, we seek to explore their perceptions and evaluations of ChatGPT as a companion, aiming to discover better ways to harness its value effectively.

A7

Human-Centered AIED - Ethical Agents in Education

Birk Thierfelder, Dirk Werth

AI in education AIED has seen a resurgence in the last couple years with emerging technologies like LLMs and generative AI. On one hand, educators see big benefits for educational settings ranging from stimulating critical thinking (Cotton, Cotton & Shipway, 2023) to more natural interactions with the learner as a peer and adaptive personalized learning experiences (Farrokhnia et al., 2023). On the other hand, there have been concerns about the ethical dimensions of such disruptive technologies on human learning (Nguyen et al, 2023). As a result a large number of ethical frameworks or guidelines by governments, NGOs and the private sector were proposed to address these issues. More recently a push by the EU to regulate AI usage in "high-risk systems", including the area of education resulted in regulatory actions (European Parliament, 2024). In this paper we explore and conceptualize how "human-centeredness" can be used as a bridge between the abstract theoretical frameworks proposed by Governments and NGOs for ethical AI and practical application contexts. Based on a characterization of prior work in human-centered AI (HCAI), we synthesize a set of tenets that can guide educators in an AI agents implementation process. Through examples, we illustrate how the guiding principles of human-centered AI can be used to overcome ethical challenges of AI in education (AIED) and envision new possibilities for human-centered agents in AIED.

A8

Integrating Student Stakeholders in the Design of a Conversational Agent for EFL in German Schools

Elizabeth Bear, Xiaobin Chen, Daniela Verratti Souto, Luisa Ribeiro-Flucht, Björn Rudzewitz, Detmar Meurers

Task-based language teaching (TBLT) is a widely researched approach to foreign language instruction emphasizing meaningful language use. Recent AI advancements, namely dialogue system and automatic speech recognition (ASR) technologies, support a growing number of conversational agents designed within a TBLT framework. Despite their potential, the development of such an agent requires important design considerations, including aligning pedagogical approaches with technological affordances/limitations and providing tasks at learners' proficiency levels that spark and maintain interest. As part of an iterative evaluation process incorporating student stakeholders, we examine the design and early learner data of a task-based conversational agent for English as a foreign language (EFL) in the German school context. Students from three 7th grade classes (N = 84) interacted with five tasks and completed a questionnaire assessing their needs and perceptions. The needs analysis revealed that most students speak some English outside of class and that they wish for tasks targeting both authentic and curricular needs. The interaction logs showed a strong preference for typing over speaking, as well as differing rates of task success and interest, confirming the importance of task characteristics. Despite some noted limitations, student perceptions were largely positive, with the tasks appearing more fun and more challenging for students who speak less English outside of class. Overall, our findings highlight the promise and challenges of designing educational technologies for the authentic school classroom, offering insights into balancing pedagogical and technological design, the demands of official curricula, and students' authentic needs.

A9

Will GenAI Make the World a Better Place? Let's Explore Students' Expectations

Chiara Antonietti, Tessa Consoli, Maria-Luisa Schmitz, Alberto A.P. Cattaneo, Dominik Petko, Philipp Gonon

This study critically examines the perceived impacts of Generative Artificial Intelligence (GenAI) on future education and broader societal and private domains. More specifically, this study aims to assess upper-secondary students' expectations of GenAI's impact on education, democracy, economy, health, personal relationships, privacy, and security. In addition, we analyse the relationship between students' expectations and their skills related to the use of GenAI. Data from a survey of 2357 Swiss upper secondary students indicate positive expectations for GenAI in education, health, and work, as well as concerns around privacy and relationships domains. Multiple linear regression analysis confirms a positive association between GenAI skills and overall positive expectations, highlighting the importance of promoting critical GenAI skills among students. The study provides insights into upper secondary school students' perceptions of GenAI, shedding light on both positive impact expectations and areas of concern.

A10

Exploring the Effect of Content Placement when Learning in Augmented Reality in Nature

Jule Krüger, Daniel Bodemer

Augmented reality (AR) is an innovative way of combining virtual and physical elements. The visual positioning of virtual instructional information in a relevant physical context is a promising feature of AR. In the current study, the influence of this positioning on learning behaviour, processes, and outcomes was investigated in an exploratory study. Virtual information on native plants was either anchored to the corresponding physical plant in nature (near) or positioned separately in the vicinity of the plants (far). We expected an impact of the placement on knowledge, behaviour, cognitive engagement, immersion, and positive emotions. N = 18 students took part and responded to questionnaires, interviews, and a knowledge test after interacting with the application. The data show that learners' knowledge about tree names increased more and that they looked into their physical environment more often when the information was placed near than when it was placed further away. This was supported by the interview responses. Concerning the other variables, we only found effects for subgroups. Specifically, presence and pride were increased only for learners with low and not high task expectancy in the near in comparison to the far condition. The study provides initial insights into the potentially positive effects of positioning virtual information in AR in the vicinity of corresponding physical objects. Also, it highlights the importance to examine effects dependent on learner characteristics.

A11

Modality Principle in Immersive Virtual Reality: An Eye-tracking Study

Noé Monsaigneon, Jean-Michel Boucheix, Stéphane Argon

According to the modality principle of the Cognitive Theory of Multimedia Learning, learning is facilitated when visual content is accompanied by vocal narration compared to text explanation. However, the application of this principle in immersive virtual reality (IVR) remains unclear. In the present experiment involving 101 middle school students, we compared the application of the modality principle in IVR and on desktop. Measurements of learning outcomes, eye movements behaviour, presence and cognitive load were carried out during a lesson about forest, in IVR or on desktop, with vocal narration or with text, involving four experimental groups. A modality effect was found for the desktop but not for the IVR condition, suggesting a reversed modality effect. The desktop condition was associated with less visual distraction, while the IVR condition led to higher presence. This study showed that the content of lessons in IVR should be adapted to avoid distractions.

A12

Immersive VR Learning Environments: Coherence Formation and Effects of Environmental Details

Christian Hartmann, Christian Kosel, Maria Bannert

In immersive VR learning environments, verbal information is embedded in environmental details. It remains to be clarified what learning benefits environmental details have for processing verbal information and how learners establish coherence between verbal and environmental representations. Our experiment, funded by the German Research Foundation, addresses these research gaps. As a between-subjects-factor, the interior of the Sistine Chapel was presented in the IVR-environment as a full background or as a simple 2D-image in a white room, both in a 360°-VR-setting. Coherent or incoherent learning content (presented in text boxes) was varied as a within-subjects-factor. While the coherent text was strongly related to the environment (painting structure of the interior), the incoherent text (interpretation of a single mural) was less so. N=49 of the targeted 70 university students (the pre-registered experiment will be fully conducted and analyzed by the conference) were randomly assigned to the between-subjects-factor (environmental details) and then studied (in random order) the two topics (content coherence) for 20 minutes each. After each session, learners' perceived spatial presence, cognitive load, enjoyment, and recall were assessed. Attentional processes were recorded by measuring eye movements to analyze the students' coherence formation process, e.g., how the gaze was distributed over the background and the text boxes. Our final results will allow conclusions about the specific effects of environmental details in VR learning and provide information about how IVR learners establish coherence between verbal and environmental details through detailed process analyses in the context of experimental manipulations.

A13

When seeing is not helping: Signaling germ contamination hinders performance and immersion in iVR

Juliette C. Désiron*, Aline Wolfensberger*, Tino Endres, Beatrice Domenech-Jakob, Dominik Petko, Walter Zingg

In immersive VR learning environments, verbal information is embedded in environmental details. It remains to be clarified what learning benefits environmental details have for processing verbal information and how learners establish coherence between verbal and environmental representations. Our experiment, funded by the German Research Foundation, addresses these research gaps. As a between-subjects-factor, the interior of the Sistine Chapel was presented in the IVR-environment as a full background or as a simple 2D-image in a white room, both in a 360°-VR-setting. Coherent or incoherent learning content (presented in text boxes) was varied as a within-subjects-factor. While the coherent text was strongly related to the

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Posters - Group B

B1

Addressing Teachers' Needs: Design-Based Research to Sustainably Implement an ITS

Julia Schmidt-Peterson, Florian Berens, Katharina Wendebourg, Mareike Kholin, Manuel Hopp, Stephen Bodnar, Leona Colling, Tanja Heck, Detmar Meurers, Ulrich Trautwein, Benjamin Nagengast, Florian Nuxoll, Katja Krey, Elena Nowitzki, Christoph Deeg, Walid El-Hefny, Josef Schrader, Hannes Schröter

Many teachers are familiar with a wide range of digital tools to tailor learning to students' needs. For the most part, they are not linked to didactic theories, scientific findings from educational research or domain-specific requirements. Literature reports the benefits of using an ITS in education (Kulik & Fletcher, 2016), but also educational concerns: difficulties to integrate an ITS into education (e.g. the division of labour with an ITS) becoming a source of frustration and after a while only being used for voluntary work or homework (Utterberg Moden 2021). So what is needed to provide teachers with sustainable support when using a digital ITS such as ? Our research has addressed this question by designing a teacher training in 4 consecutive stages: I) Expert group and developer meetings: regular meetings from February 2021 on teaching quality, second language acquisition, digitalization whilst consulting literature and interviewing teachers. II) Piloting I with pre-post tests and process evaluation (TEAiTime) with nine English teachers (Oct 2022- May 2023), evaluating content modules and timeframes. Teachers and their students* filled out questionnaires about personality, motivation and dimensions of teaching quality (pretesting). Posttest after the training, plus a follow-up questionnaire half a year later. III) Piloting II with process evaluation (Dec 2023 – Mar 2024) with twelve English teacher trainers for wider dissemination. This stage is also co-constructive and evaluated after each session. IV) Teacher Training study with pre-post tests for teachers and students and process evaluation (Feb 2024 – June 2024)

B2

Can Using an ITS Accompanied by Teacher Training Foster Teachers' Motivation?

Katharina Wendebourg, Florian Berens, Mareike Kholin, Julia Schmidt-Peterson, Leona Colling, Manuel Hopp, Tanja Heck, Stephen Bodnar, Walid El Hefny, Hannes Schröter, Josef Schrader

Individual differences between learners are directly relevant to language acquisition (Ellis, 2004; Skehan, 1991), making language teaching an area where many resources are needed to support learners individually. This is sometimes challenging due to time constraints in the classroom. The intelligent tutoring system (ITS) provides targeted support for learning through individualized, adaptive feedback and additionally reduces teachers' workload by analyzing the students' performance in a teacher dashboard. To support teachers holistically, we conduct teacher training fostering integrated knowledge about the pedagogical and technological content of teaching (TPACK). TPACK-oriented teacher training has been shown to positively influence motivational variables, such as teachers' perceived self-efficacy (Lachner et al., 2021). The teacher training is accompanied by a large-scale RCT (N = 47 teachers). We aim to investigate whether teachers benefit from the use of the ITS per se and whether the training program can (further) foster their motivation. The first results will be available at the conference in August.

B3

Does Student Agency Effect Learning Behavior and Success in a CBLE with Automated Formative Feedback

Vroni Barkela, Miriam Leuchter

The importance of summarizing as an effective learning strategy, particularly for university students, is underscored by its role in enhancing cognitive abilities, communication skills, and information processing. However, undergraduates often struggle with writing concise summaries due to difficulties in comprehending complex texts and synthesizing key information. To address this, computer-based learning environments with instructional prompts and automated formative feedback offer valuable support. Yet, research suggests that the effectiveness of such environments hinges on individual engagement and the level of student agency. Student agency, defined as the freedom and control in interacting with learning support, influences learning behavior and outcomes. However, learning success is also associated with motivation and self-regulation. The study aims to explore how different levels of student agency impact learning behavior and -success in a computer-based learning environment about summarizing, while controlling for motivation and self-regulation. A pilot study will be conducted in an elementary education program using the FALB learning environment. Two conditions, differing in student agency levels, will

be tested, with students prompted to utilize summarizing strategies and receive automated formative feedback. Initial findings will be presented at the conference, shedding light on the optimal level of student agency in a computer-based learning environment about summarizing.

B4

Does the Gamification of an Intelligent Tutoring System for 7th Graders Affect Their Motivation?

Cora Parrisus, Katharina Wendebourg, Ines Pieronczyk, Heiko Holz, Hannah Deininger, Torben Schmidt, Detmar Meurers, Benjamin Nagengast, Ulrich Trautwein

Derived from situated expectancy-value theory, we implemented a learner dashboard, a pedagogical agent, and individualized feedback into the intelligent tutoring system FeedBook for learning English as a foreign language. Using a randomized controlled field trial with $N = 618$ seventh-grade students, we tested their efficacy in fostering students' self-concept and subjective task values, as well as individual differences in the gamification effects as a function of students' gender and initial motivation. We observed positive effects of the learner dashboard and the pedagogical agent on student motivation for students who additionally received control (i.e., true/false) feedback instead of individualized feedback. Students with high initial motivation reported higher subsequent motivation if they had access to the dashboard or agent. However, they also consistently reported lower subsequent motivation if they received individualized feedback. The gamification elements thus showed mixed effects and only under certain conditions. More research is needed that disassembles the various psychological processes that different gamification elements can trigger.

B5

Tech-Assumptions and Innovation: A study of Robotic Interactive Learning in Social Work

Anne-Friederike Hübener, Noemi Altendeitering, Marc Heimann

This study deepens the investigation of the implicit assumptions and perceptions of social work and computer science students regarding artificial intelligence and robotics, with a particular focus on simulation through social robots. By integrating social robots as a central element in the research methodology, this work broadens the understanding of how future professionals view interaction with AI in social and ethical dimensions. Through focus groups and the application of Grounded Theory Methodology (GTM), data is collected and analyzed to develop a nuanced picture of student perspectives, particularly with regard to the practical application of social robots in educational contexts. The preliminary results indicate an implicit duality in the perception of AI, which manifests itself in an ambivalence between technological optimism and profound ethical concerns. While social work students primarily focus on risks and emotional aspects, computer science students emphasize the technical possibilities. Both groups emphasize the urgency of an expanded educational initiative that integrates hands-on experience with AI and social robots to close skills gaps and promote critical understanding. This research contributes significantly to the development of a theory that illuminates the implicit duality in perceptions of AI and social robots and highlights the central role of educational institutions in providing a balanced understanding of AI that takes technological, ethical and social considerations equally into account. This approach is particularly relevant to the topic of "Instructional Design - Technology Enhanced Learning" as it shows how technological innovations can be meaningfully integrated into learning environments to create a holistic educational experience.

B6

Relationship Between the Usage of ITS and Learning Gains in Mathematics in Secondary Education

Julius Schaaf, Tobias Rolfes, Gabriel Nagy, Aiso Heinze

Intelligent tutoring systems (ITS) are characterised by their direct and adaptive feedback as well as their capability of assessing the knowledge of students and administering exercises based on those assessments. The state of research regarding the effectiveness of ITS in math is inconclusive (Steenbergen-Hu & Cooper, 2013; Kulik & Fletcher, 2016). Hence, in this study, we examined the impact of utilising an ITS on the learning gains in mathematics for students in grades 7 and 8. This longitudinal investigation was conducted with students from 55 classes in grades 7 and 8 in northern Germany. Mathematics performance was measured at the beginning and end of the school year, and activity data within the Intelligent Tutoring System (ITS) were recorded throughout the academic year. A total of 940 students provided values for pre- and posttests, along with ITS activity data. The data were scaled using the Rasch model and analysed within a multilevel framework. The multilevel analysis revealed that the frequency of ITS usage had no significant effect, neither at the class level nor at the individual level. A plausible explanation for these results is that the positive effects (direct and adaptive feedback, identification of knowledge gaps) and negative effects (less class discussion of tasks, more work done alone, limitation of task formats) cancelled each other out.

B7

Exploring Uncertainty Management in Engineering Design Teams in a CAD-enhanced Learning Environment

Hannie Gijlers, Chandan Dasgupta, Sara Boros

This qualitative study investigates how university students navigate and manage uncertainty while collaborating on computer-aided design (CAD) engineering tasks. With a focus on uncovering the types of uncertainties students face and the strategies

they employ to manage these uncertainties, this research aims to enhance our understanding of collaborative problem-solving processes. Preliminary findings suggest that students encounter various uncertainties, including technical challenges with CAD tools and gaps in scientific knowledge required for task completion. Strategies for managing these uncertainties ranged from reducing, maintaining, increasing, and ignoring uncertainty. Participating groups oscillated between these strategies in different ways. The study's insights are poised to contribute significantly to instructional design by highlighting the importance of supporting students in managing uncertainties, thereby facilitating more effective CAD-enhanced collaborative learning environments in engineering education.

B8

Exploring Students' Perceptions of Engaging in Anonymous Discussions in UK University Classrooms

Peiyu Wang, Shaaron Ainsworth, Xin Gao

With the rapid increase of globalisation in education, many university students are studying for degrees outside their home country. These students not only face learning new content, but also learning in new ways and in an additional language. Small group discussion is common in most of the social sciences and arts courses in Europe. Consequently, some international students may be reticent to participate in group discussions and that can have negative impacts on their and other students' learning experiences. One possible solution is to employ digital technology to create peer anonymous written discussions when students are anonymous to each other but not the teacher. Influenced by the Deindividuation Theory, anonymity may help create a "safety net" for students, thereby encouraging them to engage in more group discussions. 56 postgraduate students in three seminar classrooms from a UK university experienced three types of group discussion (face-to-face spoken, online written real-name, and online written anonymous discussions) using a within-groups design over three weeks. After classroom intervention finished, 31 students completed an online survey, and 12 students took part in semi-structured interviews. Positively, the results showed that many participants improved their engagement in discussion when anonymous and written. Furthermore, students experienced more fairness and flexibilities in sharing opinions. However, they also reported feeling a reduced connection to their peers and more off-task behaviours. These findings provided valuable insights into how to best to include written anonymous discussions into face-to-face classrooms.

B9

Instructional Effectiveness of Comics in Science Education. A Meta-Analysis

Tom Jungbluth, Martin Schwichow, Silke Mikelskis-Seifert, Josef Künsting

Comics in science education are an increasing kind of visual narratives used to promote students' learning in science education. Their instructional design is rarely investigated in studies, which is why there is currently no developed framework that identifies the general conditions under which comics need to be designed to be effective and used in science education. Therefore a systematic literature review was conducted to analyze the relevant literature aiming to answer under which conditions educational comics are effective for learning, both in terms of context and instructional design. In addition, a meta-analysis (k = 31 studies) was conducted to investigate the overall effectiveness of using comics in science education. Based on the results a framework of effective comic designs for science education was developed. Of these 31 studies, 25 are published in English (80.6%) and 6 in German (19.4%). The studies originate from Europe (Germany: 6, Turkey: 6, Czech Republic: 1, United Kingdom: 1), Asia (Indonesia: 5; Taiwan: 4; Philippines: 3; South Korea: 2), North America (USA: 2), South America (Brazil: 1) and no study from South Africa or Australia. Overall, learning with comics has positive effects on the affective and cognitive learning processes, even in comparison to other text-based media. Based on the results a framework of effective comic designs for science education was developed. Literature search and study inclusion criteria (e.g. databases, Boolean operator, study coding) and the framework for instructional design of comics based on the results will be presented at the conference.

B10

Predictors and Consequences of Learning Behavior: Personality, Motivation, and Learning Outcomes

Hannah Deininger, Cora Parrisius, Rosa Lavelle-Hill, Detmar Meurers, Gjergji Kasneci, Ulrich Trautwein, Benjamin Nagengast

This study investigates the link between personality traits (particularly conscientiousness) and motivation with students' learning behavior within an intelligent tutoring system (ITS) and their impact on learning achievement. Utilizing the ITS FeedBook, we collected and analyzed behavioral trace data from 507 7th-grade students during the school year 2021/2022. We aim to identify distinct learning behavior patterns through cluster analysis and explore their association with students' personality and motivation. Furthermore, we seek to understand the relationship between these behavior clusters and students' English proficiency scores. Preliminary analyses indicate a promising relationship between behavioral trace data and English achievement, that is, between students' learning behavior and later performance. This research highlights the significance of tailoring digital learning experiences to accommodate diverse learners. With regards to theory, it advances our understanding of individual differences in learning within digital environments. Practically, it highlights the importance of adaptive learning systems and suggests that insights into learner clusters could be instrumental for teachers and developers in customizing instruction.

B11

Exploration of Gender Differences in Engagement and Learning in a Collaborative Climate Change

Game

Chi-Tsun Wang, Chia-Yu Wang, Hsiang-Yi Chang, Hsin-Yi Lee

Gender differences have been consistently reported in studies of science and engineering education, and the effectiveness of some pedagogical approaches aimed at reducing gender differences is inconclusive. This study investigates gender differences in engagement and learning outcomes in a serious digital collaborative game on climate change. The sample consists of 91 university students interested in climate change issues, 36 males and 55 females. Participants were asked to make individual and collective decisions to mitigate and adapt to the climate change problem in the online educational game in teams of 4 to 5. Research instruments include a post-survey on game engagement and a pre- and post-test, self-perceived competence on climate change, covering cognition, attitude, problem-solving, and action efficacy scales. The results showed that there were no significant gender differences on the four engagement scales, nor on the pre- and posttest of their self-perceived competence scales. The findings were in contrast to those of some previous studies in environmental education and game-based learning. In addition, both gender groups showed significant improvement from pretest to posttest on their self-perceived competence in all four constructs, suggesting that this educational game is beneficial for both genders in increasing young adults' knowledge, attitude, problem-solving, and action efficacy in a short period of time. Based on this study, future research should explore small group discourse on content of interest and reasoning patterns between male and female players to gain deeper insights.

B12

Does Segmenting Work? Enhancing Teachers' Professional Vision

Franziska Tschönhens, Tim Fütterer, Kathleen Stürmer, Andreas Lachner

Professional vision is a crucial prerequisite for teachers' effective technology integration. To foster professional vision in the early phases of pre-service teacher education, annotation tools are frequently used. Annotation tools per se, however, do not necessarily contribute to professional vision and require additional instructional support. In this study, we compared different versions of prompts (segmented prompts versus non-segmented prompts) to trigger pre-service teachers' professional vision for technology integration, that is the ability to notice and reason relevant classroom situations when watching and annotating classroom videos. We adopted a between-participants design comprising three conditions: non-segmented prompts, segmenting-prompts, and no prompts. A total of 169 pre-service teachers participated and watched two classroom videos depicting technology-enhanced teaching scenarios. We asked them to tag and annotate relevant situations while utilizing annotation software. The annotation of the pre-service teachers is currently coded into recognized relevant classroom situations (noticing) and interpretation of these situations (reasoning). To analyze the predicted effect of prompts we will conduct contrast analysis. This study will help to better understand the implementation conditions of annotation tools in pre-service teacher education.

B13

Does Video Playback Speed Affect Learning in Different Age Groups?

Martin Merkt

This online experiment investigated the generalizability of the effect of video playback speed on knowledge acquisition across different age groups. Whereas previous research found no detrimental effects of increasing video speed for learners in their early 20s, it remains an open question whether increasing video playback speed affects older learners. In a 2x2-factorial design with 118 participants divided into a "high age" (MAge = 64.32 years) and a "low age" (MAge = 24.25 years) group, half of the participants within each group watched a video at normal (1x) speed, whereas the other half of the participants watched the video in increased (1.5x) speed. Contrary to our pre-registered hypothesis that increasing playback speed should negatively affect the older participants, we did not find an interaction of age group and video playback speed on learning outcomes. There also were no main effects regarding the learning outcomes. However, interestingly, the normal speed was universally perceived as more appropriate than the increased speed. Even though this experiment did not provide any evidence for an age-specificity of the effect of video playback speed; future research is warranted to further substantiate this finding and identify potential boundary conditions.

16:05 - 17:05 - Session D

Single papers - Artificial Intelligence

Co-Designing a Rapid Review: What do Teachers Want to Know About AI Use in K-12 Classrooms?

Meg Farrell, Annika Diery, Claudia Müller-Kreiner, Tina Seidel

In recent years, the proliferation of AI use in schools, next-generation AI, and research thereof has ushered in a new era of AI in education. In this rapidly changing landscape, teachers are challenged with following the evolving discourse and deciding on application approaches for their practice. Rapid reviews are an accelerated, stakeholder-focused study design which could

offer a needs-based approach to addressing what teachers find most relevant about research on AI in schools. In the present study, we aim to (1) prototype a co-design process for rapid review with teachers; (2) elicit teachers' informational needs about research on AI in schools; (3) develop a rapid review decision template to facilitate choices on our methodological approach, and (4) perform and present them with a needs-specific rapid review. In a collaborative planning stage, we are eliciting teachers' informational needs about AI in schools with a short survey, then using their responses to tailor the design of the rapid review. According to preliminary findings, teachers are most interested in the topic of their own use of AI (e.g., motivation, assessment) focused on students. After this planning phase, we will begin the rapid review. This study will leverage the rapid review characteristic of stakeholder involvement to offer a model for teacher-relevant research possibilities, as well as inform teachers on the topic of AI in schools, which best meets their current informational needs.

Exploring GenAI Use Patterns in Swiss Upper Secondary Schools: Insights from Latent Profile Analysis

Miria Hartmann, Tessa Consoli, Chiara Antonietti, Konstantinos Michos, Alberto A.P. Cattaneo, Philipp Gonon, Dominik Petko

This study explores use patterns of Generative Artificial Intelligence (GenAI) among students in Swiss upper secondary schools. Specifically, it addresses the overall use, the frequency of use across different settings (e.g., leisure activities, school-related activities in class) and GenAI based school-related activities (e.g., finding an answer or explanation, translating a text), aiming to identify distinctive GenAI use patterns by employing latent profile analysis (LPA). Our data is based on a survey of 2357 upper secondary school students. Results show that GenAI is used by 87% of the participants in this sample, especially for school-related activities at home (38% of the students use it at least once a week) and in class (37%), followed by leisure activities (29%). The LPA, based on the different school-related activities, indicates three distinct use patterns: The Text-Based User, The Extended User and The Abstainer. The study offers insight into GenAI use patterns among upper secondary school students, highlighting the necessity to further explore how the adoption of GenAI will impact the educational field.

Preservice Teachers' Perceptions of and Readiness for Teaching and Learning with AI

Eliana Brianza, Mirjam Schmid, Dominik Petko

As artificial intelligence (AI) applications gain prominence in educational settings, there is a growing demand for teacher education institutions to equip teachers with the skills to integrate AI into their teaching practices. To meet this demand, it is essential for teacher training programs to be customized based on the unique characteristics of preservice teachers. This study, utilizing the Will Skill Tool Pedagogy model (Knezek & Christensen, 2016), explores the perspectives of early preservice teachers regarding AI in education and examines how these perceptions correlate with their motivation (Will), competence in using AI (Skill), awareness of various AI applications (Tool), and proficiency in applying AI for teaching and learning (Pedagogy). The results reveal diverse attitudes among preservice teachers, categorized as critical, positive, or unperturbed, with corresponding differences in their Skill and Tool components. Notably, those with unperturbed views demonstrated limited awareness of various AI applications. These findings offer valuable insights for teacher training institutions, highlighting the varied perspectives of incoming preservice teachers, and suggest avenues for future research.

The Role of Teaching and Teachable GPT-Based Agents in Computer-Supported Collaborative Learning

Albulene Grajcevcic, William Pfannenstiel, Armin Weinberger

Computer-supported collaborative learning (CSCL) may be fundamentally changing with the introduction of GPT based systems in online collaborative learning settings. Conversational Agents building on GPT based large language models are being utilized to enhance learning. This research explores the impact of teachable and teaching agents in a 1x3 experimental design with the factor Conversational Agent (without, with teaching, with teachable CA), with participants from a variety of European Higher Education Institutions. The aim is to explore differences in learners' experiences and knowledge gains depending on the CA used. The findings from this research reveal that while learning gains in terms of critical thinking, referencing and participation remain constant regardless of the type of CA used, learners' experiences are different. To that end, when interacting with a teachable CA learner participants not only reported having experienced a more interactive learning environment, but also their individual learning needs being better supported as well as being provided with more relevant feedback. When interacting with the teaching bot, participants reported that the overwhelming amount of information generated interfered with their thinking. In conclusion, this study points to teachable CA being better at scaffolding CSCL by "knowing" less.

Single papers - Immersive Technologies I

Becoming a Tree: Immersive VR Induces Compassion for Nature

Pia Spangenberg, Jule Krüger, Sonja Geiger, Georg Reuth, Lena Baumann, Steve Nebel

The potential of immersive VR (iVR) applications for processes underlying pro-environmental behaviour has recently received more attention in education for sustainable development. Moreover, there is limited knowledge about how far different emotions and compassion, which can be readily elucidated through iVR, are relevant for fostering pro-environmental behaviour. Hence, the goal of this study is to offer deeper insights into the affective processes initiated by iVR on nature connectedness. Subsequently, we will focus on emotions and compassion induced by embodying a representative of nature (a tree) and investigate the role of underlying affective processes in a mediation analysis (N = 85). Prior research also has observed that disruptive events, such as the experience of a climate catastrophe, can lead to an increase in pro-environmental behaviour. Thus, we will also look at the impact of a positive and negative ending on affective processes while virtual embodying a tree in a moderation analysis. The findings of the mediation analysis suggest that people who felt more embodiment also felt more compassion. And this compassion explains more nature connectedness. Embodiment also influenced the intensity of negative (anger, anxiety, sadness) and positive emotions (joy), but we found no mediation effects of these emotions on nature connectedness. Regarding the moderation analysis, we found a group effect of the ending: In a negative ending, the level of embodiment was related to the intensity of negative emotions as well as compassion. We further discuss these results, in specifically, on the relevance of virtual embodying nature for inducing compassion.

Leveraging the Potential of Immersive Virtual Reality Environments for Creativity Development

Enikő Orsolya Bereczki, Albert L. Lehrman, Zsafia K. Takacs, Juho Hamari

Immersive Virtual Reality (IVR) emerges as a novel technological avenue for enhancing creativity, offering immersive and interactive experiences that non-digital or traditional desktop-based approaches cannot provide. IVR lends itself especially well to promoting figural creativity, which requires individuals to visualize complex shapes, understand spatial relationships, and manipulate objects or patterns to construct novel and appropriate visual forms and images. In a randomized controlled experiment we investigated the effects of an IVR-based cognitive figural creativity training on creative thinking, engagement, and user experience among young adults. Conducted with 111 university students, the experiment compared the outcomes of a 90-minute IVR intervention against a matched conventional paper-based and a passive control condition. Findings revealed that participants in the IVR condition exhibited significant improvements in figural creativity, particularly in originality and abstract imaginative thinking, compared to the ones in the paper-based intervention and the control condition. Moreover, IVR participants reported higher levels of interest, motivation, engagement with the training and higher flow in creative tasks, alongside a high-quality user experience, with minimal discomfort. These results underscore IVR's promising potential for creativity enhancement, suggesting implications for educational practices and future research into technology-mediated creativity development.

Look at Me! Can a Pedagogical Agent Facilitate Orientation and Support Learning in VR?

Daniela Decker, Martin Merkt

In a pre-registered laboratory experiment, we investigated the effects of cueing provided by the position and gaze shifts of a pedagogical agent (PA) and light cues compared to a control group in a virtual reality (VR) learning environment on search times, learning outcomes, mental representation, and presence. Participants were asked to find 12 craft objects in a virtual workshop, while information about the respective object was either narrated by a male off-screen voice or by the PA. Both cueing methods significantly decreased search time but did not affect learning outcomes or the mental representation of the learning environment. Additionally, the PA cue reduced physical presence compared to the control condition and self-presence compared to both other conditions. These results imply that the successful attention guidance was probably not freeing enough cognitive resources to facilitate overall performance.

Virtually Calling: How Online Prompting Can Make or Break the Immersive Learning Experience

Valentin Riemer, Eva Wierzba, Julian Kreiser, Alexander Hann, Monika Engelke, Dorothea Henniger, Tina Seufert

Immersive virtual reality (IVR) simulations offer learners a sense of presence and agency, presenting comprehensive experiences of complex situations. However, the extensive visual data in IVR may overwhelm learners, especially those new to the technology, potentially hindering learning-relevant information processing. This study examines the potential of audiovisual online prompting in IVR simulations for enhancing learning performance. Specifically, it explores how such prompting during a colonoscopy simulation affects learners' recall, situational awareness, cognitive load (CL), presence, and agency, considering their prior IVR experience. A sample of 79 medical and psychology students underwent a pre-training session, a pre-test, and an IVR simulation of monitoring a patient during a colonoscopy. Participants were divided into groups receiving audiovisual prompts and a control group without prompts. Post-simulation assessments measured learning performance, extraneous, intrinsic, and germane load, presence, and agency. The interaction between prompting and prior IVR experience significantly affected recall and situational awareness, with prior experience participants benefiting from prompts. However, prompts adversely affected those without prior experience. No significant overall effects of prompting or prior experience on cognitive load were found, but specific interactions suggested that immersive tendency moderated the impact of prompting on certain cognitive load types and agency. The study highlights the need to tailor prompt design to individual learner characteristics, such as prior IVR experience and immersive tendency, to optimize learning outcomes in immersive environments.

A Talking Head as a Retrieval Cue? Instructor Presence in the Learning and Testing Phase

Christina Sondermann, Kim West, Hannes Schröter, Martin Merkt

When considering to include a visible instructor (e.g., a talking head) in educational videos next to the learning content, different theories and prior research point to both potential advantages (e.g., a social cue leading to deeper processing) and disadvantages (e.g., distraction and enhanced cognitive load). However, prior research primarily focused on an instructor's visibility during the learning phase and did not examine the effects of (additionally) seeing the instructor during the testing phase. In this regard, it is conceivable that the talking head, when visible in both phases, serves as a retrieval cue facilitating the retrieval of information. In our preregistered online experiment, we varied whether a talking head was visible in the learning phase, in which learners watched four educational videos, and/or the testing phase using a 2x2-between design. Data of N=162 learners revealed no significant effects of a visible talking head in the learning and/or testing phase on knowledge test performance, thus not supporting the idea of talking heads serve as effective retrieval cues. Further, the talking head did not affect learners' ratings regarding the videos they watched in the learning phase (e.g., satisfaction, social presence). Potential explanations for the findings and directions for future research are discussed.

Investigating the Effects of the Instructor's Accent on non-Native Learners in Multimedia Learning

Felicia Meusel, Lukas Wesenberg, Sascha Schneider, Günter Daniel Rey

The voice principle states that people learn better when the instructor speaks with a standard rather than a foreign accent. Thus, native American students learn better when the instructor speaks with a standard American accent than when the instructor speaks with a foreign accent. This learning benefit for a standard accent can be explained by a higher familiarity of the learners with a standard rather than a foreign accent and by easier processing of standard-accented speech than foreign-accented speech. However, for non-native learners, a shared accent may be more familiar and more accessible to process than a standard accent. Thus, this study investigates the effect of the instructor's accent (foreign vs. standard vs. shared) on non-native learners' cognitive load, credibility ratings, and learning outcomes. The learner's familiarity with the instructor's accent was considered a moderator. One hundred thirty-four German participants watched one of three versions of an instructional video in English about the human vocal tract and human speech sound production. The videos differed in the instructor's accent, and all participants were randomly assigned to one of the three videos. After watching the video, the participants rated the instructor's credibility, filled in a questionnaire on cognitive load, and answered learning questions measuring retention and transfer performance. The results do not show a significant effect of the instructor's accent on learning outcomes, cognitive load, and credibility ratings of non-native learners. Moderation analyses did not yield significant results. The results are discussed in terms of cognitive and social processes.

Should the Instructor be Shown in Instructional Videos in Higher Education? Three Field Experiments

Steffi Heidig, Maik Beege, Sascha Schneider, Günter Daniel Rey

In formal educational settings, such as online university lectures, instructional videos often comprise PowerPoint slides accompanied by an instructor's video or audio explanation. It is assumed that the social cues provided by showing the instructor's video may facilitate affective processes and affect learning outcomes. Research on instructor presence in instructional videos mainly focused on laboratory and online studies not embedded in the courses the learners are enrolled in. Therefore, we present three field studies examining instructor presence in instructional videos embedded in courses in higher education to strengthen external validity (exam-relevant topic, >30 minutes long, personally known instructor). The results of these studies show positive effects of a visible instructor compared to no visible instructor on some affective ratings: social presence in Experiment 1 (n=18, d = .85) and well-being in Experiment 3 (n=38, d = 1.01) but not on others (well-being in Experiment 1 & 2 (n=53); motivation in Experiments 1-3, social presence in Experiments 2 & 3). They further indicate no effects on extraneous processing or learning outcomes (Experiments 1-3). Hence, a general effect of instructor presence can also not be shown for instructional videos embedded in university courses in higher education, but there are also no detrimental effects. That leads to implications for future research, teaching, and designing practice.

17:10 - 18:10 - Session E

Single papers - Cognitive skills & Processes II

A Mixed-Methods Study on Learner-IVR Interactivity, Agency, Cognitive Load and Learning Outcomes

Anu Lehikko, Mikko Nykänen

Interactivity is considered a focal design element that may influence the learning experience and the learning outcomes in immersive virtual reality (IVR) training. We applied a mixed-methods empirical approach to study the learners' sense of agency, cognitive load and learning outcomes in IVR safety training by comparing two training scenario versions designed for either high or limited learner-IVR interactivity. Training interventions were implemented in two work organizations for 68 learners in total. Quantitative and qualitative data were collected before, during, and after the interventions by single and repeated measure questionnaires, external video and head-mounted display recordings, field notes and stimulated recall interviews. Our quantitative results revealed that high interactivity was associated with an increase in the learners' germane cognitive load. Based on our qualitative findings, we suggest actively supporting the learners to direct their focus to the IVR learning content. We also propose that IVR learning research would benefit from more sensitivity to not just individual cognitive and affective factors, but also sociocultural and contextual factors that influence the learners' training and learning experiences and outcomes.

Exploring the Visual Aesthetic Principle in Instructional Design

Diana Pak, Sascha Schneider, Juliette Désiron

Oftentimes, experimental studies investigating the effect of design features as colors and shapes link their material manipulations to aesthetics. However, a gap exists in conceptualizing an aesthetic design and its influence on learning processes. Moreover, the seductive detail effect postulates that learning-irrelevant details, such as additional aesthetic features, compromise learning. This study aimed to discover how presentation slides varying in their perceived aesthetics influenced learners' cognitive processes, performance, and motivation. In the preliminary study, 42 designs created applying the visual aesthetic principle were evaluated according to their perceived aesthetics ($n = 70$). In the main study, 105 university students were randomly assigned to one of the four conditions in a 2-decorative shape (round vs. abstract angular) by 2-color scheme (chromatic vs. achromatic) design. The results revealed that either round decorative shapes or chromatic designs were perceived as aesthetically higher compared to abstract angular decorative shapes or achromatic designs. Further, while round decorative shapes reduced extraneous cognitive load and led to better learning performance, chromatic designs had a significant statistical effect on motivation. The interaction between independent variables was not significant for perceived aesthetics. These results are interpreted within the frameworks of Emotional Design, Cognitive Load Theory, and the Cognitive-Affective Theory of Learning with Media. Future perspectives would be exploring and applying the visual aesthetic principle in instructional design.

Generative Learning by Learning Journals. Mechanisms Underlying the Medium Effect

Florian Luft, Ai Miyamoto, Matthias Nückles

Learning journals facilitate the use of cognitive and metacognitive learning strategies and improve learning outcomes. We investigated how the medium (written vs. oral) impacts the effectiveness of learning journals. We conducted two randomized controlled field experiments to investigate the role of the medium for students' strategy use and learning outcomes. In Experiment 1, secondary school students ($N_1 = 137$) created a journal entry in written or oral format. In Experiment 2 ($N_2 = 125$), we introduced a second factor: Students were (or were not) provided with an example of a high-quality learning journal entry. This example illustrated how to generate a journal entry by freely expressing one's thoughts without attending to rhetorical or grammatical form ("genre-free principle", cf. Nückles et al., 2020). In both experiments, students watched a video-lecture on a psychological topic. Then, they wrote or recorded orally a learning journal entry. Afterward, they revised their journal entry using the transcribed lecture text. Finally, students took a comprehension test. The results of Experiment 1 showed that spoken journals led to significantly better comprehension than written journals. Spoken journal entries also contained significantly more cognitive and metacognitive strategies than written journal entries. Cognitive and metacognitive strategy use fully mediated the effect of the medium on learning outcomes. Data from Experiment 2 on the effects of the learning journal example illustrating the genre-free principle will be available at the conference. These experiments demonstrate a medium effect in the domain of journal writing and provide insights into the mechanisms underlying this effect.

The Interplay of Narrative and Feedback in Educational AR Games

Julia Flottmann, Kevin Palzer, Daniel Bodemer

Digital game-based learning (DGBL) has great potential to facilitate learning, especially in terms of motivation. Previous research has shown that narratives and feedback in DGBL environments can have positive impacts on learning outcome. Augmented reality (AR) provides a unique gaming environment that integrates virtual elements with the physical world, showing promise for enhancing learning processes and outcomes. However, it is unclear how narratives and feedback may interact with each other in AR learning games. This laboratory study ($N = 123$) investigates the influence of narrative and feedback on learning in AR games and their potential interaction effects. Using a 2×2 factorial design, participants played an AR learning game with or without a narrative and received process-oriented feedback (PF) with detailed information, or outcome-oriented feedback (OF) with only information about the correctness of the learner's answer. The game included two levels addressing topics in pedology in which players must solve problems in a laboratory setting. Results revealed significant

interactions between narrative and feedback on motivation-related variables, indicating that PF led to higher scores compared to OF only in the AR game without a narrative. Additionally, PF was found to significantly enhance immersion experience, flow experience, and transfer learning outcomes. However, the expected positive impact of narrative presence on learning outcomes was not supported, possibly because participants tended not to be aware of the narrative while playing. These findings suggest the importance of carefully considering the interplay between narrative and feedback in instructional design, particularly regarding motivation and learning outcomes.

Single papers - Emotion, Affect & Self-regulation

Capturing Students' Emotional Responses during Scientific Inquiry with a Sensor Wristband

Heide Sasse, Miriam Leuchter, Timo Reuter

This study explores the complex relationship between planned teacher guidance and students' basic emotional responses during inquiry-based science lessons, using sensor wristbands for data collection. Building on previous research highlighting the central role of emotional states in learning outcomes, the study aims to address gaps in understanding how different levels of teacher guidance influence emotional responses in primary school students. A cohort of 164 students from six rural German primary schools participated in a lesson focusing on thermal insulation. Each student wore a sensor wristband to collect psychophysiological data, which were subsequently translated into basic emotional responses using an advanced algorithm. Results showed comparable frequencies of emotional responses under conditions of high and low teacher guidance, with "attention" being the predominant response in both scenarios. Further analysis revealed distinct trajectories for specific emotional responses, such as "passivity", which significantly increased during high teacher guidance and decreased during low guidance. These findings underscore the nuanced interplay between levels of teacher guidance and students' emotional experiences, and highlight potential implications for optimising inquiry-based science teaching in primary schools.

Feedback on Self-Assessment Accuracy: Challenge or Threat?

Tamara Van Gog, Eva Janssen, Florence Lucas

Accurate self-assessment is key for effective self-regulated learning with problem-solving tasks: Without accurate self-assessment, students are unlikely to select a new task that is suitable for their current level of performance. Prior research has shown that self-assessment and task-selection skills can be trained. However, there was substantial variability in the effectiveness of the training, and room for further improvement. First attempts to further improve self-assessment and task-selection accuracy after training, by providing feedback on students' self-assessment accuracy (a pre-condition for accurate task selection), proved unsuccessful. That could have been due to the fact that most students overestimated themselves, resulting in 75% of the feedback having double-negative valence: Informing students that their self-assessment was incorrect and that their performance was lower than they thought. This might have resulted in high feelings of threat, low self-efficacy, and therefore, failure to see the usefulness of adopting the feedback in task selection. We present a study (currently being conducted) in which we test this hypothesis, by experimentally manipulating self-assessment feedback valence (negative-negative, negative-positive, no feedback) and investigating the effects on students' feelings of challenge/threat, self-efficacy, and task-selection accuracy.

Separating Prior Knowledge From Acquired Knowledge in PISA - Learning in the Digital World

Leonard Tetzlaff, Lothar Persic-Beck, Ulf Kröhne, Carolin Hahnel, Frank Goldhammer

The innovative PISA domain "Learning in the digital world (LDW)" integrates the assessment of knowledge and skills with opportunities for learning. To investigate whether learning took place during the assessment, we analyzed data from 737 German PISA 2022 students and modeled individual differences in test performance that could not be explained by students' prior knowledge and skills. We then related these differences to learning activity (the use of worked examples during a task) and learning prerequisites (general intelligence and mastery orientation) to validate their interpretation as performance based on knowledge and skills acquired during the task. We found substantial remaining variance in performance after controlling for prior knowledge (21% of variance). Significant relationships of these differences with both learning prerequisites and learning activity provide further evidence for interpreting found differences as a result of learning during the task.

Shifting Relations: Time-Dependent Effects of Emotion Regulation in Educational Gaming

Valentin Riemer

This study investigates the impact of emotion regulation (ER) strategies—reappraisal and suppression—on managing frustration and metacognitive strategy use in technology-mediated learning. Conducted with 82 psychology and STEM undergraduate students, the research focused on their experience playing an educational game designed to improve financial literacy. Through self-report questionnaires and behavioural data, the study examined the use of ER strategies, the experience of frustration, and engagement in progress monitoring across five game rounds. Results indicated a significant preference for

reappraisal over suppression, with both strategies negatively related to self-reported frustration. However, the relation between reappraisal and suppression diminished over time. Conversely, suppression showed a positive and increasing relation to progress monitoring. Mediation analyses revealed frustration as a mediator between ER strategies and progress monitoring, with progress monitoring positively predicting learning performance. This study highlights the temporal dynamics of ER strategy effectiveness in learning environments and provides insights for designing educational technologies that support emotion regulation and metacognitive strategies.

Single papers - Educational Technologies

Benefits and Pitfalls of Integrating Mindfulness into Digital Learning Games

Enikő Orsolya Bereczki, Zsófia K. Takacs, Elizabeth J. Richey, Huy A. Nguyen, Michael Mogessie, Bruce McLaren

We investigated the integration of mindfulness exercises into a digital math game with the aim of enhancing students' executive function (EF) skills, and consequently mathematical learning outcomes. Digital game-based learning presents a promising avenue for addressing the challenges students face in learning mathematics, a subject often perceived as difficult. Mindfulness, characterized by focused attention to the present moment without judgment, has been shown to foster EF skills, crucial for both academic learning and digital gameplay. We conducted a randomized controlled classroom experiment involving 177 5th and 6th grade students from three public schools in the U.S.. Participants were assigned to one of three conditions: a mindfulness-enriched version of Game X, a story-enriched version, or the original Game X. The study tested the hypothesis that mindfulness practices (mindfulness inductions at the beginning of the game sessions and short mindfulness practice reminders after three consecutive errors) would lead to increased maths learning gains and more effective in-game problem-solving behaviors. Results indicated no significant effect of the mindfulness intervention on maths learning outcomes, and the manipulation check for state mindfulness showed no significant differences across conditions. However, mindfulness reminders led to a meaningful increase in problem-solving accuracy after errors for the mindfulness group, in contrast to the story-based group, suggesting potential benefits of mindfulness cues in specific contexts. This research contributes to understanding mindfulness integration into digital learning games, highlighting challenges and potential impacts on educational outcomes. Further investigation is needed to optimize mindfulness-based interventions within digital learning environments.

Effects of Using Digital Technologies in Learning

Margus Pedaste, Doris Kristina Raave

Our study focused on the question of how different profiles of teachers' practices in technology use predict students' learning outcomes, taking into account various student and class-level variables. We used data about four profiles of practices in 171 Math, Science and Language lessons and math competence, science competence, communication competence, digital competence, learning competence and social and emotional skills scores of 959 students in the 3rd, 6th and 9th grade in 14 schools. Findings of the study showed that interactive and constructive technology use has a neutral or positive effect on various learning outcomes while active or passive use of technology might lead to either positive, neutral or negative effects.

How can Teachers be Supported in Interpreting Computer-Based Formative Assessment Results?

Sarah Bez, Sebastian Wurster, Samuel Merk

Computer-based formative assessment systems have the potential to enhance student learning and to support teachers concerning adaptive instruction by providing high-quality measures of competence levels and making learning progress visible using dashboards. Studies focusing on how teachers use this systems, especially how they use the results dashboards and interpret them, show that teachers struggle with the interpretation of the results and their transformation into conclusions for adaptive instruction. Against this background, this contribution investigates how teachers can be supported in interpreting results of computer-based formative assessments by innovative visualizations. In a preregistered randomized control trial, we asked N = 204 pre-service teachers to group students in homogenous learning groups for adaptive instruction and set appropriate learning goals for each group informed by computer-based formative assessment results. Results show a small to moderate positive significant effect on accuracy of grouping, a moderate to large positive significant effect on efficacy of grouping, and a small positive effect on formulating appropriate learning goals if the assessment results were presented as a heatmap instead of a common table. Based on the insights of this study, implications for the design of dashboards in computer-based formative assessment platforms are discussed.

Thursday 22.08.2024

9:00 - 10:00 - Keynote

Martina Rau

Visual representations play an important role in MINT learning. Many concepts are fundamentally visual-spatial but cannot be observed with the naked eye. Therefore, instructors use a variety of visual representations to illustrate these concepts in a way that makes them accessible to students. However, students often fail to understand how a visual representation depicts conceptual information. Instructors in turn often fail to recognize students' difficulties with visual representations. In this talk, I present research that has investigated which competencies students need to benefit from visual representations and through which learning processes students acquire these competencies. Throughout, I discuss the role of educational technologies in research on visual representations.

10:30 - 11:50/ 12:00 - Session F

Symposium III - Innovative methodologies to capture dynamics of collaborative learning in digital environments

Organizer: Chia-Yu Wang

Discussant: Anne Deiglmayr

This symposium will present four collaborative learning studies, each highlighting the integral role of technology across diverse settings ranging from solving clinical cases through virtual meetings (study 1), songwriting in a metaverse environment (study 2), using digital collaborative scaffolds to support the application of educational theories to solve educational problems (study 3), and addressing climate change issues through a digital game (study 4). The diverse contexts and scenarios also demonstrate the broad application of collaborative learning across disciplines in virtual settings. The research collectively explores the influence of learner diversity on collaborative processes and outcomes, revealing characteristics of cultural heterogeneity versus homogeneity, active versus passive groups, or knowledge heterogeneity, and identifying learner types through an unsupervised analytics approach. A primary focus lies in exploring how this diversity influences both the dynamics of collaboration and the resulting learning outcomes. Employing diverse coding schemes and mapping tools, such as epistemic network analysis, we aim to capture the intricacies of the collaborative learning processes. The symposium explores the cognitive, social, socio-emotional, and behavioral dimensions of collaboration, underscoring the importance of these factors in knowledge co-construction and effective problem solving. By presenting diverse design and analytical approaches, the studies offer new insights into the complex processes of collaborative learning. Our goal is to stimulate further discussion on innovative educational designs and methodological approaches that improve our understanding, visualization, and implementation of collaborative learning, highlighting its multidimensional and dynamic characteristics.

Impact of Cultural Diversity in Collaborative Clinical Reasoning Argumentation in Synchronous CSCL

Hannie Gijlers, Chrissa Manoli, Hsin-Chueh Chen, Bas de Leng

Computer-supported collaborative learning (CSCL) environments, widely used for teaching Collaborative Clinical Reasoning (CCR), offer controlled settings for students to apply domain knowledge and collaborate in teams. Given the multicultural nature of medical teams today, understanding the impact of cultural factors on the CCR process and discourse quality is crucial (Hornikx & ter Haar, 2013). This study aims to explore CCR instruction in multicultural CSCL contexts by comparing argumentation differences between culturally heterogeneous and homogeneous groups. 67 undergraduate medical students (31 Dutch, 36 Finnish) were randomly assigned to either homogeneous Finnish or Dutch groups, or heterogeneous group, and tasked with solving 8 CCR problems. Their dialogues were recorded, transcribed, and analyzed based on Weinberger and Fischer's (2006) framework. Each student completed a questionnaire assessing their satisfaction with the collaboration and problem-solving process. Using ENA (Epistemic Network Analysis), the study revealed that culturally diverse groups engaged in more active discussions than their homogeneous counterparts. Heterogeneous groups showed stronger connections among claims, qualifiers, rebuttals, and warrants, while homogeneous groups mainly connected claims, warrants, and data. Specifically, the homogeneous Finnish group emphasized evidence and questioning, relying on concrete data, while the Dutch group leaned more towards theoretical or hypothetical reasoning. The Dutch group showed more frequent speech, highlighting their open and direct communication style, which encouraged discussions and helped consensus-building. Conversely, the Finnish group engaged actively in discussions, clearly expressing their ideas with a careful and thoughtful approach, achieving consensus through active questioning. We will present our ENA analysis at the upcoming symposium.

When Talkative Wrongs Impede the Rights: Scaffolding Novelty and Reference for Transactive Discourse

Nóra Éva Spengler, Freydis Vogel, Armin Weinberger

Providing sentence starters to scaffold transactivity in digital learning environments is a promising strategy to facilitate collaborative learning. This study investigates the effects of transactivity scaffolds on learning outcomes and discourse quality among collaborative learners. Specifically, we observe the dynamics of learner diversity related to heterogeneous prior knowledge in the collaborative discourse. For this purpose, 154 participants worked in pairs on applying an educational theory to solve problems in a digital learning environment in which they communicated via a text chat. In a 2x2-factorial pre-post design, two differentiated transactivity scaffolds were experimentally varied. Depending on the experimental condition, learners could select from a set of sentence starters either scaffolding novelty by inducing the contribution of new ideas (e.g.: "My idea is...") or scaffolding reference by inducing referring to earlier contributions (e.g.: "I don't agree with what you said because..."). Through a mixed-methods approach, we examined the impact of these scaffolds and the role of learner diversity on learning. Findings indicate that all learners significantly improved their knowledge between pre- and post-test, particularly when novelty scaffolds were provided. Additionally, the study shows significant effects of both scaffolds on discourse quality. However, the results also reveal that knowledge sharing might not always lead to beneficial outcomes in heterogeneous dyads, suggesting the spread of inaccurate information. This may be related to learners with less prior knowledge overestimating themselves, known as Dunning-Kruger effect. This study contributes to the discourse on scaffolding collaborative learning in digital environments, particularly related to the dynamics of learner diversity.

Analyzing Learner Types and Outcomes for Learning Dynamics in a Collaborative Climate Change Game

Chia-Yu Wang, Hsin-Chueh Chen, Jr-Hung Lin

Educational approaches are central to promoting climate action, and serious games are emerging as effective tools for improving understanding and changing attitudes about climate change through immersive scenarios (Yu, et al., 2021). This study examines the influence of a digital game on cognitive and affective learning outcomes, focusing on the role of perceived social engagement, interactive behavior, and mental effort. Engaging 82 undergraduate students in a role-playing, collaborative game to solve climate change problems, the study uses cluster analysis to identify four distinct learner types: Most Improved, Disengaged, Socially Engaged, and Actively Behaving. Cross-group comparisons for the resulting learner types revealed that frequent interactive behaviors among role-players (Socially Engaged and Actively Behaving) were consistent with self-perceived social engagement in collaboratively solving climate change problems. Surprisingly, higher social engagement and frequent interactive behaviors during the game were not necessarily associated with conceptual understanding and attitude change about climate change issues. A segment of 'disengaged' participants showed minimal mental effort and unchanged attitudes, highlighting the need for active engagement in learning processes. Scaffolds for cognitive or social support may need to be designed to meet the varying needs of different types of learners in such complex learning tasks. Recognizing these variations allows for better design of digital scaffolds and serious game pedagogy to better align with educational goals.

Symposium IV - The elements of emotional design under the microscope of multimedia learning

Organizers: Nadine Scheller, Sascha Schneider

Discussant: Juliette Désiron

Whenever specific instructional design features of digital learning materials trigger positive emotions facilitating learning, the emotional design (ED) principle is applied. In the last few years, numerous ED studies have concluded contradictory results. It can be explained by the assumption that different ED cues affect learning differently which allows for a critical reflection of the current definition of ED. This symposium aims to describe and discuss the empirical effects of various ED cues. The first contribution focuses on the effects of color variations depending on the relevance of the presented information. They found significant effects of the interplay of information relevance and colorful representations on cognitive processes, metacognitive appraisals, and affective experiences. The second contribution investigates anthropomorphism in instructional images, discovering enhanced learning scores using high level of anthropomorphism and positive valence in learning materials. The fourth contribution examines the moderating effects of emotional pedagogical agents on learning outcomes. His first study revealed a positive effect of an enthusiastic agent on learning and a low mental load. His second experiment showed a positive effect of enthusiasm in general, mainly when the gender of an agent and a learner matched. The fourth contribution explores narratives, suggesting that a narrative context of a learning environment should coincide with learners' contexts. Preliminary analyses demonstrated evidence for a learning-facilitating effect of narratives, particularly when the appearance of characters in learning materials is different from learners'. Using her critical review of the ED literature, the discussant will reflect on the presented studies and combine them with her findings.

The Intertwining of Information Relevance and Colorfulness in Multimedia Learning

Sascha Schneider, Juliette Desiron

Recent advancements in multimedia learning research have underscored the intricate interplay between cognitive and affective processes. Drawing upon the emotional design hypothesis, this study delves into the potential of color manipulation in learning materials to evoke positive emotions, enhance attentional focus, bolster motivation, and facilitate learning. However, while colors can effectively guide attention, their efficacy may diminish when applied to learning-irrelevant features, as suggested by the seductive detail effect. Past investigations primarily manipulated colors across entire learning materials irrespective of information relevance. This study fills this gap by scrutinizing the impact of color variations contingent upon the relevance of presented information. Employing a 2 (colorfulness of learning-relevant information: black/white vs. colored) × 2 (colorfulness of learning-irrelevant information: black/white vs. colored) between-subjects design, the main and interaction effects of colors as attentional cues were explored in multimedia learning material about hurricane formation. Two distinct samples were utilized: University students in laboratory settings and school students in the field. In addition to gauging learning outcomes, cognitive load, metacognitive judgments, and affective states were assessed. Findings reveal that the dynamic interplay between information relevance and the colorfulness of representations significantly influences learners' cognitive processes, metacognitive appraisals, and affective experiences.

Make it Human: Enhance Learning and Motivation Through Anthropomorphism

Nadine Scheller, Sascha Schneider

Anthropomorphism is the attribution of human characteristics or behaviors to non-human entities. It is researched as an emotional design principle supporting positive emotions and learning. The reasons for this still need to be made clear. There is no consensus on how many anthropomorphic characteristics are required. Emotion, mainly conveyed through facial features, is crucial for humanizing entities. The interaction between anthropomorphism levels and learning impact is still under investigation. Can anthropomorphism be an emotional design cue? Therefore, this study examines its effect on learning outcomes and intrinsic motivation by analyzing instructional images with different anthropomorphism levels as well as positive and negative facial expressions. One hundred sixty-one students were randomly assigned to a 2 (anthropomorphism: high vs. low) × 2 (valence: positive vs. negative), factorial between-subjects design. In addition, a control group without human features was used. In addition to prior knowledge, learning outcomes, mental load and mental effort, emotional contagion, and intrinsic motivation, were measured. The findings suggest that human features are more effective than none of these features. Human features increased perceptions of positive emotions. Regarding high anthropomorphism, the positive valence condition leads to better learning scores (retention and transfer) and increased mental effort compared to the negative valence condition. Conversely, learners report a higher need for external regulation in the negative valence condition than in the positive valence condition.

Benefits and Moderators of Enthusiastic Pedagogical Agents in Digital Learning Environments

Maik Beege

Recently, research pointed out that learners detect emotions performed by pedagogical agents comparably to emotions performed by real humans. However, the effects of these emotions on learning processes are still under investigation. This contribution will discuss two experiments outlining effects of emotional pedagogical agents on learning outcomes. Furthermore, moderating effects will be outlined. In the first experiment (N = 118), the enthusiasm of the pedagogical agent as well as the mental load of the learner was varied. Results revealed that an enthusiastic agent only fostered learning processes when the mental load of the learner was low. Consequently, emotions have to be processed by the learners to unfold positive effects. When learners are already heavily loaded through the learning task, emotions might have detrimental effects. In the second experiment (N = 129), the enthusiasm of the agent, as well as the gender of the agent was varied. Results revealed that enthusiasm was generally beneficial for learning. However, when the gender of the agent and the gender of the learner matched particularly strong effects were found. Consequently, gender matching (model-observer similarity) might act as an important social cue that strengthens the positive activation of the learner through enthusiastic agents.

Look Like Me, Act Like Me? Key Requirements of Model Observer Similarity in Emotional Design

Charlotte Vössing, Alexander Renkl, Tino Endres

Beyond its appealing and warm audiovisual elements, Emotional Design is considered to enhance learning by fostering the development of value for the learning content through narratives involving social agents. Attributing value to learning content supports the learner's motivation and facilitates longer engagement. However, evidence on narratives in Emotional Design shows mixed results, therefore new approaches to understand and improve Emotional Design are crucial. Insights from model observer similarity research could provide valuable techniques for refining the narrative elements in Emotional Design. We aim to explore, what specific model observer similarity approach is needed to support value attribution and enhance learning within Emotional Design. Therefore, we differentiate a superficial approach, focused on similarity in the social agents' appearance, from a structural approach, focused on similarity in the social agent's behavior, aims, and everyday context. We varied both approaches (yes vs. no) via different value-evoking narratives including different social agents in 18-minute-long Emotional Design learning videos. Additionally, we implemented a within-subjects factor to compare the beginning and end of the learning phase. We assessed our 2x2x2 design in a classroom setting (N = 136, Mage = 14.72). We explored whether learners need to be supported with both model observer similarity approaches or whether one approach has a superior

beneficial impact on learning within Emotional Design. Preliminary analysis suggests only the structural similarity approach enhanced learning. We will discuss the motivational and cognitive pathways that may mediate these benefits.

Single papers - Higher Education & Self-regulation

Interleaved practice in foreign language grammar learning: A field study

Judith Schweppe, Annika Lenk-Blochowitz, Magdalena Pucher, Almut Ketzer-Nöltge

Interleaving is an effective strategy to improve lasting learning. The underlying idea is to practice related, but distinct concepts in combination rather than separately. According to the discriminative contrast hypothesis, a prerequisite for its effectiveness is that the to-be-learned concepts are highly similar and thus hard to distinguish. This prerequisite may explain mixed evidence for interleaving in foreign language learning, as it may not apply to all areas of language learning. We investigated the effect of interleaved practice in foreign language grammar learning. In two field experiments conducted in introductory Spanish classes at university, learners had to learn to distinguish in which context which of the two verbs “ser” and “estar”, which both translate to “to be”, is used. In the blocked condition, participants worked on separate fill-in-the-blank practice tests on “ser” and “estar”, while in the interleaved condition, participants worked on a combined fill-in-the-blank practice test. The final test was a new fill-in-the-blank test where participants had to choose between “ser” and “estar”. Experiment 1 manipulated learning condition (blocked vs. interleaved practice) between classes. Experiment 2 replicated Experiment 1, but varied learning condition within class (random allocation). A medium-sized significant advantage of interleaved practice was found in both experiments. Our results thus corroborate previous evidence that interleaving can be effective for foreign language learning if the to-be-learned concepts are hard to distinguish.

Investigating the Screen Inferiority Effect in a Naturalistic and Ecologically Valid Setting

Emely Hoch, Stefan Stürmer, Kathrin Jonkmann, Katharina Scheiter

There is ample evidence for a screen inferiority effect, which is characterized by lower performance and a more pronounced metacognitive bias when reading or solving problems on screen than on paper. However, most of the research has been conducted in the laboratory with tasks of low ecological validity. Some studies, however, showed that screen inferiority might be attenuated if in-depth processing is induced, as is presumably the case when solving real (i.e., high-stakes) exams at school or university. For the presented field study, data was collected as part of a university initiative to introduce e-exams, thereby making use of a naturalistic setting with exam performance being highly relevant to the participants. After students (N = 2,250) took their exams on either paper or tablet, they were asked to judge their performance and effort. This data was connected to the exams’ corresponding performance data from the examination office. We did not find any evidence for a screen inferiority effect regarding performance or metacognitive accuracy. Still, participants reported more effort and judged exams as more difficult when they completed them on paper. The results suggest that performance and metacognitive accuracy do not differ as a function of medium under high-stakes testing conditions, thereby supporting the shallowing hypothesis as an explanation of the screen inferiority effect.

Learning with Interactive, Dynamic Visualizations - Effects of Technology and with Technology

Josef Guggemos, Stefanie Findeisen

Visualizations play a crucial role in learning. In view of technical innovations, dynamic, interactive visualizations are increasingly being used. However, the empirical evidence on their impact on learning outcomes is inconclusive. In particular, there is a need for research about the understanding of the learning processes and conditions under which interactive, dynamic visualizations yield positive learning outcomes. We have developed an online learning platform focusing on economics that includes interactive, dynamic graphs of economic models where students can actively manipulate parameters. In a laboratory experiment, participants (n = 106) were randomly assigned to a treatment and a control group. We assessed students’ knowledge before and after the intervention with the Test of Economic Literacy (TEL). Students in the treatment group used the interactive, dynamic graphs, while students in the control group used static graphs. Process data, including task performance and timestamps, provide data about the learning processes. This allows for an evaluation of the learning efficiency (learning outcome per time taken). The results show no significant differences in learning gains between groups (no effect of technology). However, the treatment group achieved significantly higher solution rates (effects with technology) for difficult tasks and showed advantages regarding learning efficiency for easy tasks. Our study contributes to the understanding of interactive, dynamic visualizations by elucidating conditions for positive effects of technology and with technology. The development of the learning platform offers potential benefits for classroom use and aims to improve pedagogical practice with interactive, dynamic visualizations.

Promoting Self-Regulation During Inquiry Learning in Science Education

Tessa Eysink, Alieke van Dijk, Patrick Sins, Jaap de Brouwer, Vivian Santing, Lida Klaver

Self-regulation is an important skill for success in learning science in computer-based inquiry learning environments. These environments are characterized by a high degree of learner control and offer learners a variety of options to choose from. This implies that in order to be successful, learners need to consider how they are learning the content and monitor whether their learning processes help them meet their goals. However, learners seem to find it hard to self-regulate during inquiry learning, which undermines the effectiveness. Moreover, in inquiry learning little attention is paid to promoting self-regulation and hardly any attention is paid to differences in self-regulation skills that exist between learners. This study aimed to investigate the effectiveness of supporting learners in self-regulation during inquiry learning. 105 primary school students worked on a science problem for seven weeks. The lessons were based on the differentiated jigsaw method which used homogeneous and heterogeneous grouping and differentiation in content, tasks and instructions based on competence level. Learners in the experimental condition additionally received - adapted to their availability and use of self-regulation skills - explicit instructions and integrated support for self-regulation. Results showed that adding differentiated support for self-regulation during inquiry learning did not lead to the expected positive outcomes on self-regulation and domain knowledge. Two possible explanations are put forward. First, adding SRL support is not needed if the inquiry learning tasks are already differentiating on competence level. Second, implementing differentiation based on both self-regulation level and competence level asks too much from the teacher.

The Use of AI-Generated Learning Journals to Support Learners' Use of Effective Learning Strategies

Nina Udvardi-Lakos, Tino Endres, Matthias Nückles, Alexander Renkl

Learning journals can be used to support learners' acquisition of self-regulated learning skills and content knowledge. When writing learning journals, learners can apply cognitive and metacognitive learning strategies, which support comprehension. However, learners often perceive journal writing as a high-effort activity, leading to low motivation for this task. Asking learners to generate journal entries using AI and then enriching such journals by applying learning strategies (e.g., elaborations in the form of own examples) could be an option for reducing the effort associated with journal writing. When revising a journal entry, learners can add their own elaborated examples, organize the generated content, and monitor their understanding of the content. Thus, revised AI-generated learning journals might support learning to a similar extent as writing the whole journal entry. We used a waitlist-control design over the course of a semester to assess motivation, invested mental effort, and learning outcomes for undergraduate psychology students writing learning-journal entries themselves compared to students who generated and revised learning-journal entries. Mixed factorial ANOVAs showed differences in cognitive load demanded, mental effort invested, and motivation between the tasks, but not in content-related self-efficacy or interest in the task. However, the majority of students reported not having read instructions attentively for the task of generating journal entries using AI. The full dataset (including learning outcomes and learning strategy use) will be available from the end of May, with analysis planned in June and results and issues for discussion finalized in time for the SIG6/7 conference in August.

13:00 - 14:20/ 14:30 - Session G

Symposium V - Instructional Principles for Teaching and Learning with Immersive Virtual Reality Technology

Organizer: Miriam Mulders

Discussant: Christian Hartmann

The immersion principle in multimedia learning asserts that people learn more effectively with highly immersive media (e.g., Virtual Reality (VR)) when lessons are based on effective instructional principles that amplify the benefits or mitigate the drawbacks of immersive media (Makransky & Mayer, 2022; Mayer et al., 2022). However, research on immersive VR is influenced by various disciplines (e.g., cognitive psychology) and diverse designs (e.g., media comparisons), yielding heterogeneous findings. Both educational practice and research need to elaborate on which findings are cross-contextually valid and which are context-specific. Therefore, the symposium collected four contributions with the aim of (a) demonstrating the diversity of study characteristics, (b) identifying consistent cross-study effects, and (c) exploring study-specific effects. All contributions share the characteristic of being (planned) experimental between-subject studies investigating the impact of instructional principles for teaching and learning with immersive VR. However, they are heterogeneous in terms of content, hypotheses, and methods: First, they are situated in four domains and therefore utilize entirely different learning applications (history, laboratory, nature, science). Second, they capture learning at different cognitive (e.g., recall, transfer) and affective (e.g., perspective-taking, interest) levels and also controlled to varying degrees for variables such as cognitive load and presence. Third, they examine different instructional approaches by testing the value-added of generative learning strategies, comparing different social forms, and investigating multimedia principles such as pre-training and signaling. The participants of the symposium will identify commonalities and differences between their studies and critically discuss the implications for practice and research.

A Value Added Study: Drawing and Explaining as Generative Learning Strategies when Learning with VR

Miriam Mulders, Kristian Träg

Learning in Virtual Reality (VR) can be highly motivating and conducive for affective learning outcomes, but it can also lead to distraction and cognitive overload. Generative learning activities may alleviate some of the limitations of learning with VR applications by helping learners to focus on the learning material. This study investigates the effectiveness of the generative learning strategies of explaining and drawing in VR. 74 undergraduate students explored the room of Anne Frank where she had to hide during World War II. For the experimental conditions, the students had to either create drawings of Anne's room and their own room or explain how Anne's living conditions would feel for them afterward the VR experience. For the control condition, the students did not engage in any subsequent generative learning activity. The results revealed that adding generative activities after a VR experience did not have an additional effect on perspective-taking in Anne. More empirical studies are needed to examine the effect of generative learning activities on affective learning outcomes using more valid measurement methods and controlling for activity-related cognitive load.

Re-Experiencing: a Novel Generative Learning Strategy in Extended Reality

Valdemar Stenberdt, Guido Makransky, Lilli Aalbæk Mortensen

In this study, we introduce a new generative learning strategy (GLS) named "re-experiencing" and investigate the potential benefits of re-experiencing for learning in extended reality (XR). Re-experiencing involves observing oneself performing a task via video playback or XR simulation and reflecting on the experience. Video playback has shown promise in fields such as teaching and nursing with beneficial effects on various learning outcomes (e.g., reflective skills, self-efficacy, and procedural knowledge). Our aim is to conceptualize re-experiencing based on the GLS literature and to investigate its value in XR, capitalizing on XR's unique ability to provide presence and agency. We will compare re-experiencing to summarizing in XR in a sample of 50 university students. The learning content of the XR-simulation is the scientific procedure of using a pipette. We hypothesize that re-experiencing will outperform summarization in terms of learners' declarative and procedural knowledge, as well as transfer.

Collaborative Learning in VR: Impact of Signaling on Learning Outcomes and Cognitive Load

Patrick Albus, Tobias Drey, Tina Seufert

Virtual reality (VR) is an emerging technology that offers great potential for collaborative learning, which can have a positive impact on learning outcomes and cognitive load. At the same time, virtual learning environments are highly visual and learners need instructional support like signalling. In this study, we investigated the effects of two different approaches to collaborative learning (symmetric vs. asymmetric) and the effects of signalling on learning outcomes and cognitive load in a highly immersive VR learning environment. We analysed N=148 learners who were randomised in pairs to the signalling or non-signalling condition and to the symmetric or asymmetric collaborative condition. We measured learning outcomes (recall, comprehension & transfer) and cognitive load (intrinsic, extraneous & germane cognitive load) as dependent variables. The signalling condition achieved significantly higher recall and comprehension performance compared to the non-signalling condition. There was also a significant reduction in extraneous cognitive load when signals were used. We found no significant differences in learning outcomes between the symmetric and asymmetric conditions, but we did find significant higher intrinsic and germane cognitive load in the asymmetric condition than in the symmetric condition. The results highlight the importance of signalling in collaborative VR learning environments and show that both symmetric and asymmetric collaborative learning approaches can be appropriate in VR learning environments in terms of learning outcomes.

Combining Instructional Design Principles Enhances Learning with Immersive Virtual Reality

Josef Buchner

The aim of this study is to test the complement hypothesis when learning with immersive virtual reality (IVR). IVR can be motivating but cognitively demanding and distracting for learners. Therefore, the immersion principle in multimedia learning suggests applying effective instructional design principles when learning with IVR. However, no study has investigated if two instructional design principles are better for learning than one as suggested in the complement hypothesis of multimedia learning. In this study, this gap in the literature is addressed by presenting the results of a between-subject study conducted in the field with 98 students (mean age = 13.5 years, SD = 0.74). In one lesson, students (n = 50) learned with IVR accompanied by pre-training and the generative learning activity of explaining to a peer. In the other lesson, students (n = 48) learned with IVR and pre-training only. The results show that using two instructional design principles is significantly better for knowledge acquisition (d = 0.36) and situational interest (d = 0.42). No significant differences were found for presence, motion sickness, or perceived learning. The results support the complement hypothesis and the theoretical assumptions of the immersion principle in multimedia learning. For educational practice, combining effective instructional design principles can be recommended when using IVR in school lessons. Further implications for theory and educational practice are discussed.

Symposium VI - Customizable Classrooms: Adaptive Learning Environments in Schools

Organizer: Katharina M. Bach

Discussant: Leonard Tetzlaff

Adaptivity in schools allows for customizing instruction and teaching approaches to students' individual prerequisites and needs (Plass & Pawar, 2019). Since classroom compositions are becoming increasingly diverse in various aspects, there is a need for instruction that is not just suitable on average but caters to each individual. Given the importance of the K-12 period in laying the foundation for students' professional endeavors and societal participation, ensuring no one is left behind is essential. So, in contrast to the traditional one-fits-all approach, adaptivity aims to guarantee optimal, tailored instruction, support, and challenge to every student, thereby maximizing their learning outcomes. Beyond fostering performance, adaptive instruction seeks to enhance emotional and motivational factors, such as students' engagement or self-concept (Chu et al., 2021). There are different ways of implementing adaptivity in schools. Educational technologies, such as learning platforms or applications, enable the automated adaptation of content, difficulty levels, pacing, and learning paths based on students' performance metrics. Additionally, teachers' responses to observed student behavior (i.e., adapting curricula or giving feedback at the moment) represent another critical dimension of adaptivity. Often, technology serves as a conduit for augmenting teacher-led adaptivity. For example, teachers can receive information about the students' learning via teacher dashboards, which enables them to adapt their instruction and support accordingly without having to assess or observe themselves. The four contributions to the symposium offer a comprehensive insight into customizable classrooms by presenting a systematic overview of adaptivity in schools alongside three empirical examples of its varied implementations.

Adaptivity in Schools: A Review of Context, Implementation, Learner Characteristics, and Goals

Katharina M. Bach, Sarah Hofer, Sarah Bichler

Adaptivity allows for meeting students' needs in heterogeneous classrooms, for example, by customizing materials, guidance, or pacing based on learner characteristics (Corno, 2008). In this review, we systematically summarized research to investigate 1) in which contexts (subject, grade, school type), 2) by whom (teacher/technological system), 3) based on which learner characteristics, and 4) to what end adaptations are made in schools. Considering the wide range of possibilities for adaptivity in classroom instruction, a systematic review is beneficial for understanding research priorities and further research potential. We searched the databases ERIC and PsycInfo for peer-reviewed English publications about adaptive learning, instruction, and teaching (LIT) in schools from 2018-2022. We identified 136 relevant publications through title and abstract screening of 555 unique search results. Following a codebook, we double-coded the full-texts, resulting in a final selection of 85 papers. We found that research on adaptive LIT is predominantly conducted in elementary schools, followed by secondary schools, and the least in schools for students with special needs. Most studies investigate adaptivity in STEM subjects, especially Math. In more than half of the studies, adaptivity was implemented through technological systems. Adaptations were primarily based on performance measures and aimed to improve performance, focusing less on motivational-emotional outcomes. These results reveal the aspects of adaptive LIT in schools we know most and least about. This overview of the status quo of research can guide the implementation of adaptive LIT and be used to derive an agenda for future research on yet unknown aspects.

Individualizing Learning From Instructional Videos with Adaptive Practice Questions

Shelbi Kuhlmann, Brandon M. Booth, Noelle Patterson, Haley Siegfried

Instructional videos are powerful tools for learning because they help students engage in generative cognitive processes by integrating visual and verbal representations into a meaningful mental model. However, researchers have found that this is not always the case, and students struggle to engage generatively with videos. This shortcoming can be ameliorated by designing videos to support generative processes via the embedding of cognitive strategies within videos and individualizing engagement in those strategies by individual learner characteristics, such as students' prior knowledge. In this study, students will be randomly assigned to two groups: an adaptive practice group and a static practice group. In the adaptive practice group, students will watch an instructional video and receive only those embedded practice questions with which they have little prior knowledge. Students in the static practice group will receive all embedded practice questions. Students' engagement during learning will be measured via their digital behaviors with the video and their learning will be assessed with a post-test. We will test whether students in the adaptive practice group have improved post-test scores over those in the static practice group, and for learning differences between students with lower and higher prior knowledge in the adaptive practice group. We will also test for differences in and the potential mediating effects of digital behaviors between each of the practice groups and those students with lower and higher prior knowledge in the adaptive practice group. This research will inform the design of instructional videos and adaptive testing with videos.

Primary School Teachers' Skills to Perceive, Interpret and Make Decisions Based on Dashboards

Stefanie Vanbecelaere, Antje Demulder, Line Deprez, Fien Depaep

Digital tools are increasingly used in primary education for learning purposes. These digital tools often contain a dashboard which shows the teacher aggregated data of the interactions between the learner and the digital tool. Teachers need to transform the data presented on dashboards into information which they can use to inform their teaching. Whether these dashboards improve teaching quality and lead to more personalization in the classroom depends to a large extent on the teacher's competence. According to the competence model of Blömeke and colleagues (2015), competence is viewed as a continuum consisting of dispositions, situation-specific skills and performance. So far, limited empirical evidence is available

about teachers' competence to use dashboards. In this study, we focus on teachers' situation-specific skills (i.e. how teachers perceive, interpret and make decisions based on the data presented on dashboards). In total 45 primary school teachers participated. Each participant participated in an interview measuring their situation-specific skills. Coding categories were developed based on evidence on how teachers use dashboards. The interviews were transcribed and coded based on the coding scheme. Results regarding teachers' situation-specific skills showed high variability across teachers. On average, for most subdimensions of perception, teachers address several aspects of the dashboards in detail and concretely. However, the subdimensions of interpretation and decision-making were fairly limitedly addressed. Moderate to high correlations were observed between perception, interpretation and decision-making skills. It can be concluded that teachers' situation-specific skills are currently limited, especially when it comes to interpreting and making decisions based on data.

Adaptive Constructive Support in Dyadic Teacher-Student Interactions

Britta Wenzel, Jasmin Decristan

Research has emphasized constructive support as a key dimension of teaching quality (e.g., Klieme et al., 2009; Lipowsky et al., 2009). In general, constructive support aims to provide high-quality support to all students. Constructive support in teacher-student interactions has rarely been analysed, and inter-individual differences have rarely been taken into account. This does not take into account that teachers respond differently to the various needs of students. In this study, we address this research gap by developing an observational tool to assess the dyadic teacher-student interactions in terms of constructive support. In this tool, the current division of constructive support (socio-emotional and instructional support) is considered separately for the first time. Two research questions are focussed: (1) How often do teachers provide socio-emotional and instructional support in adaptive learning environments in primary school? (2) Does the teacher adapt the constructive support to individual student characteristics? The sample consists of 310 primary school students and 14 teachers in adaptive learning environments. Using low-inference and high-inference ratings, we code teachers' constructive support to each student at the dyadic level.

Single papers - Instructional Design & Text Graphics Comprehension

Fostering Deep Understanding of Science Concepts in an Online Learning Environment

Man Su, Justin Gole, Tomohiro Nagashima

This study investigates the effectiveness of the Pattern, Agents, Interactions, Relations, and Causality (PAIR-C) framework, combined with Agent-Based Modelling (ABM), in teaching complex system concepts like natural selection to improve understanding and reduce misconceptions among students. Fifty undergraduate students were divided into two groups in an online course, comparing the PAIR-C approach with a traditional method. The intervention group used online modules to explore natural selection scenarios (peppered moths and rock pocket mice) through PAIR-C and ABM visualizations, while the control group studied the same content via Darwinian principles supported by similar ABM visuals. Both groups interacted with ABM through simulations, videos, and screenshots. The study assessed learning outcomes using various methods including pre-post-tests, surveys, and interviews, with misconception patterns identified through epistemic network analysis (ENA). Results showed that the PAIR-C instruction significantly enhanced students' deep understanding of natural selection, leading to fewer and less complex misconceptions. ENA highlighted differences in misconception patterns between groups, with the intervention group exhibiting fewer cases of misconception co-occurrences in the post-test. This research underscores the potential of integrating the PAIR-C framework with ABM in science instruction. It suggests that PAIR-C not only promotes deeper comprehension of complex system concepts but also offers a generalizable approach that could enhance learning across various scientific domains, paving the way for improved instructional strategies and a solid foundation for students to grasp emergent phenomena in a technology-enhanced learning environment.

Influence of Erroneous Examples on Learning Gain and Cognitive Load in Chemistry

Sonja Dieterich, Marc Rodemer, Stefan Rumann

Due to complex concepts such as chemical bonding, the subject of chemistry is susceptible to teaching-induced errors, which may inhibit the learning process (Hunter et al., 2022). Knowledge of errors can be conducive to learning if they are explicitly instructed in the form of erroneous examples. Our systematic literature review on erroneous examples shows contradictory findings on the influence of prior knowledge, cognitive load, and learning activity on learning outcomes. Hence, the present intervention study investigates the learning effectiveness and cognitive load of an instruction based on either correct examples, erroneous examples, or a combination of both depending on prior knowledge using the example of ionic bonding in lower secondary school. Preliminary results show significant learning gains, particularly when contrasting correct and erroneous examples.

Sequence Analysis in E-Book Learning Patterns: Insights for Teachers, Students, Developers

Yaroslav Opanasenko, Margus Pedaste, Leo Aleksander Siiman

This study investigates the potential insights derived from sequence analysis of log-data from interactive E-Books, focusing on how these insights can inform students, teachers, and designers of E-Book content. Log data from the Estonian interactive E-Book Opiq, engaging 498 students across 11 schools during the 2021/2022 academic session as part of the DigiEfekt project has been used. Sequence analysis, a categorical longitudinal modeling procedure, was employed to provide a comprehensive overview of how learners engage with digital content. The analysis revealed possible ways of applying sequence analysis along with its potential value, including identifying periods of high engagement, chapters that are frequently skipped, session patterns indicating the most effective combinations of content types, transitions between different types of interactions, and patterns in test-taking behavior. These insights offer valuable feedback for educators, content developers, and E-book designers, suggesting that a detailed understanding of learner behaviors can lead to the creation of more effective and engaging educational tools. This study underscores the significance of sequence analysis in enhancing the educational potential of interactive E-Books by providing a richer understanding of student interaction and learning patterns, providing insights for all the stakeholders of educational process.

The Influence of Hand Proximity on Text Comprehension: The Role of Individual Differences.

Romy Brömme, Birgit Brucker, Maike Tibus, Peter Gerjets

The advent of multi-touch devices, like smartphones and tablets, has transformed the access to digital contents, raising questions about the impact of hand proximity on text comprehension during reading on handheld devices. Previous research has shown benefits for visuospatial information processing (e.g., pictures) but detrimental or no effects for simple semantic information processing close to the hands (e.g., words and sentences). The present study extends the inquiry to complex text comprehension processes, such as the formation of causal bridging inferences, emphasizing individual differences. Forty-eight participants read scientific expository texts with bridging inference positions in a near hand and far hand posture (within-subjects design). The pre-posttest bridging inference gain as well as cognitive and motivational factors were assessed. Contrary to expectations, results showed no significant difference in pre-posttest bridging inference gain between hand postures, indicating no direct influence of hand proximity on the formation of causal bridging inferences. However, an interaction with participants' A-level grade revealed that participants with a poorer grade benefited from reading texts closer to their hands, whereas those with a better grade benefited from reading texts farther away. These outcomes highlight the complex interplay between hand proximity and semantic processing, emphasizing the importance of individual differences. Further research is needed to identify the specific aspects of the A-level grade contributing to the observed interaction effect and to optimize digital reading environments through adaption for various user groups.

The Role of Study Sequence and Self-Explanation for Primary Students' Conditional Strategy Knowledge

Nike Scheitz, Lea Nemeth, Nicole Hollmann, Johannes Osterberg, Frank Lipowsky, Rita Borromeo Ferri

Mastering the flexible and adaptive use of subtraction strategies poses a challenge for primary school students. Acquiring this proficiency, students must cultivate adaptive expertise, encompassing conditional strategy knowledge (CSK), e.g., knowing when and why a strategy is appropriate. In contrast to blocking, interleaving stimulates comparison processes that foster abstracting conditions for strategy use, potentially facilitating CSK development. Increasing interleaving might optimize interleaved practice: starting with a blocked phase helps students gain confidence in strategies before diving into the interleaved phase. Moreover, prompting students to self-explain why a specific strategy is appropriate for a particular problem could also help strengthen the task characteristics-strategy-association. Therefore, this study investigates whether interleaving fosters CSK and how increasing interleaved practice as well as self-explanation prompts might enhance its effectiveness over the longterm. Approximately 243 German third graders are randomly assigned to a blocked, interleaved or increasing interleaved condition. All groups are taught to use three number-based strategies for solving subtraction problems. CSK is measured at an immediate posttest, an eight- and 16-week follow-up. Preliminary descriptive data from the immediate posttest indicates that students in the increasing interleaved condition show the highest CSK, followed by those in the pure interleaving condition, while students in the blocked condition demonstrate the lowest CSK. Moreover, self-explaining aids students' CSK. For the follow-up test, we also expect that increasing interleaving will outperform pure interleaving, with both interleaving conditions surpassing blocking. Final results will be presented at the conference. Practical implications and implications for future research will be discussed.

14:35 - 15:35 - Session H

ICT Demo

ICT 1

DOCommunication: A Digital Game-Based Learning Tool to Foster Doctor-Patient Communication Skills

Marco R uth, Rainer Weber, Christian Albus, Kai Kaspar

Doctor-patient communication trainings have become a central component of medical education. Meta-analytic results indicate that trainings via digital media can promote communication skills as effectively as more traditional approaches. In this context, digital games could provide medical students with valuable interactive learning opportunities to enhance their communication skills, for instance, via engaging experiences and learning from failures. However, the value of such tools is yet underexplored. Here, we present DOCommunication, a digital game-based learning tool for self-paced learning of doctor-patient communication skills. DOCommunication is a video- and web-based digital game that has been developed at the University of Cologne. The video scripts were created iteratively in cooperation with a doctor experienced in doctor-patient communication and a trainer for simulation patients, with reference to didactical guidelines. In DOCommunication, players take on the role of a doctor and have to decide how the conversation continues by choosing one out of two to four options. They receive a summative conversation score and can eventually review and reflect on their individual conversation based on a video summary. This ICT demonstration will provide insights into the design, development, and features of the tool. Participants will then be able to try out the tool for themselves. Finally, the learning and game features of the tool as well as possibilities for learning, teaching, and research will be discussed.

ICT 2

The ClassVRoom App for Teacher Education

Dominik Petko, Eliana Brianza, Juliette D siron

The ClassVRoom app offers a virtual classroom for teacher education, distinguishing itself from similar apps by not being confined to specific pre-programmed interactions, such as dealing with disruptions. Instead, it allows for training and reflection on a broad range of core teaching practices. Trainee teachers assume the role of the virtual teacher, while peers and mentors can adopt the roles of virtual students, engaging in realistic exchanges. The app facilitates direct feedback, reflection, and re-enactment of critical situations through streaming, recording, and reviewing these interactions. In a live demonstration, we will showcase the different functions of the app in detail.

Posters - Group C

C1

A Review of Large Language Model (LLM) Chatbot-Enhanced Instructional Activities in Higher Education

Ismail Celik, Piia Naykki, Megumi Iwata, Jari Laru, Signe Pirkko Siklander, Kati M kitalo

The current review explores the potential of large language model (LLM) chatbot-enhanced teaching, specifically through the integration of chatbots like ChatGPT, in higher education. It aims to investigate how instructional activities are designed with LLM chatbots and the roles of university teachers in chatbot-assisted instruction. Through accessing prominent scientific journals indexed by the Web of Science (WoS) database, we analyzed 24 empirical articles in terms of multiple aspects: the distribution of LLM-powered chatbot types, emerging teacher roles, reasons for using LLM chatbots, learning contexts, and domains of use. Results indicate ChatGPT as the most prevalent LLM chatbot in the reviewed articles. Teachers in LLM chatbot-assisted instruction play crucial roles in monitoring and evaluation, facilitating collaborative learning, and promoting ethical and responsible use of AI. Personalized and immediate feedback emerged as the main reasons for using LLM chatbots in instruction, potentially fostering student engagement and reducing teacher workload. Engineering and medical education are prominent fields where LLM chatbots are deployed for instructional activities. The study provides practical implications for integrating LLM chatbots effectively into higher education.

C2

Co-Designing AI-supported Instructional Approach to Enhance Science Learning

Man Su, Justin Gole, Tomohiro Nagashima

In response to persistent challenges in science education, such as superficial understanding, robust misconceptions, and lack of transfer, this exploratory project aims to design an AI-supported science tutor by integrating an innovative instructional framework - the Patterns, Agents, Interactions, Relations, and Causality (PAIR-C) framework to address these challenges. This tutor aims to offer a multidimensional knowledge structure for explaining scientific phenomena, thereby deepening students' scientific comprehension. A controlled experiment, comparing the PAIR-C Tutor with a traditional Hypothesis-driven Science (HdS) tutor will be conducted to evaluate its effectiveness. This project features iterative design and development of an AI-supported tutoring system in collaboration with teachers and students. It also involves experiments to assess tutor effectiveness through pre-post testing, student-system interactions, and evaluation through reflective gatherings. We hypothesize that integrating the PAIR-C framework into an adaptive learning system can significantly enhance science teaching methods, potentially transforming science education, and offering a model for wider application.

C3

Teacher Orchestration (Load) in Synchronous Hybrid Education: Towards a Conceptual Framework

Tine Keulemans, Annelies Raes, Fien Depaepe

More than ever, rapid technological developments are reshaping the way we teach and learn around the world. One specific development that has gained attention due to the Covid-19 pandemic is synchronous hybrid education (SHE), i.e. an educational model in which some students follow learning activities onsite (in the classroom), while others follow remotely (e.g. in another classroom, at home). Despite its numerous opportunities, SHE also comes with challenges. A major challenge is the higher orchestration load reported by teachers, which can be defined as the attentive load teachers encounter when regulating multiple activities and learning processes. To date, only a few studies on teacher orchestration load (TOL) in SHE have been presented, despite the identified need for research in this area. The main aim of the current study is to propose a conceptual framework on TO(L) and its influencing factors in SHE. To address this conceptual challenge, semi-structured interviews took place with lecturers and professors having experience with SHE. An abductive thematic analysis was conducted to combine the theoretical inferences based on a scoping review, with the new inductive elements from the interview analysis. Preliminary research findings indicate that TOL in SHE is multifaceted. Next to a cognitive and physical facet stated in literature, teachers highlighted the emotional demands of teaching hybrid courses. Furthermore, TOL in SHE can be influenced by the different process variables teacher orchestration entails (e.g., the teaching activity) and by a broad set of background factors (e.g., the teaching space).

C4

Effects of Generative Artificial Intelligence on Instructional Design Outcomes

Kristina Krushinskaia, Jan Elen, Annelies Raes

Generative artificial intelligence (GenAI) is increasingly becoming a tool used in many spheres, including education. A key question is whether GenAI can support teachers in one of their major roles: designing learning environments. This research aims to bridge the gap in understanding how different types of GenAI use impact instructional design outcomes. To achieve this, the study design includes three experimental conditions: 1) with GenAI, 2) with a GenAI bot pre-trained as a co-instructional designer, 3) automated by GenAI and one control condition (no use of GenAI). Participants, who are pre-service teachers, are tasked with designing a lesson blue-print and developing a lesson plan. The quality of instructional design outcomes and any common patterns across conditions are evaluated. Moreover, the impact of teachers' interactions with GenAI on the instructional design outcomes are analyzed. Additionally, the study aims to reveal a relationship between participants' prior familiarity with instructional design tasks and the way they design instruction with and without different uses of GenAI. This research study is crucial for exploring GenAI's potential to become a valuable partner for teachers in co-designing instruction and providing students with better learning opportunities.

C5

Natural Language Processing for Automated Adaptive Guidance

Sarah Bichler, Libby Gerard, Brian Riordan, Jonathan Lim-Breitbart, Marcia Linn

As education is shifting away from a one-size-fits-all model, teaching and instruction becomes more tailored to individual learner needs. This study developed natural language processing (NLP) algorithms to score students' written science explanations on disciplinary dimensions and the level of knowledge integration (KI). Four adaptive guidance activities were designed to target distinct patterns in student understanding. A classroom implementation of the Genetics of Extinction curriculum by 4 high school science teachers and their 436 students revealed that students progressed on the disciplinary dimension of inheritance of traits and KI but not on the disciplinary dimension of variation of traits in response to the adaptive guidance. The adaptive guidance helped students to move from descriptive to mechanistic reasoning, but students need support to carry over their reasoning from the guidance activity to the explanation of the phenomenon under study. Further, adaptive guidance designs must be strengthened to support students' development of variation of traits ideas. The intensive human workload of developing NLP scoring for nuanced insight into students' disciplinary thinking might be reduced through artificial intelligence while preserving the needed human expertise.

C6

Embracing the Challenge: Predicting Self-Testing in Non-Formal Online Courses Using Machine Learning

Maria Klose, Philipp Handschuh, Diana Steger, Cordula Artelt

Self-testing is a powerful learning tool that allows individuals to identify gaps in knowledge and reinforce learning outcomes. However, not all learners readily engage in self-testing activities, as these are often seen as a tedious task. Especially in non-formal online learning contexts, learners are provided with autonomy in determining when and how to participate in learning, and therefore are responsible to regulate their own learning. In the study, we aim to predict self-testing behavior from users of non-formal online courses to identify learner-related and course-related characteristics that may impact learners' self-testing behavior. Analyses were based on N = 1,405 participants between age 16 and 84 who enrolled at least in one of 51 non-formal online courses offered by Bavarian universities. We included 51 variables—comprising self-report data, process data, and meta data—to predict the use of self-tests within the online course using elastic net regressions. In total, 17% of the

variance in the logged self-testing could be explained by learner and course characteristics, and the degree of overfitting was rather low ($\Delta R^2 = .06$). Moreover, we identified variable types that are particularly informative when predicting self-testing in non-formal online courses (e.g. survey participations, enrollment intentions, and course type). Eventually, we want to derive implications for improving course design decisions and recommendations for possible interventions for enabling self-testing behavior within non-formal online courses for a meaningful learning experience.

C7

Role of Teacher Ownership in Technology Integration in K-12 Education System.

Bikash Chetry

This research focuses on the critical aspect of teacher ownership in effective technology integration within educational settings. While existing research has provided theoretical models guiding technology use in education, a significant gap remains regarding the role of teacher ownership. Grounded in the psychological ownership theory, this study explores factors influencing ownership of educational technology, and how the ownership influences technology integration in K-12 schools. Teacher ownership, defined as a teacher's alignment with an educational initiative, is seen as crucial for achieving meaningful educational reforms. This study seeks to bridge the existing gap in understanding the dynamics of teacher ownership and its impact on technology integration. The study will involve teachers from both private and public schools. Employing semi-structured interviews, the study captures the nuanced experiences and perspectives of in-service teachers currently using different types of technology in their classrooms. The qualitative content analysis method is applied to systematically analyze the data, aiming to identify recurring themes and patterns in teachers' narratives. The findings are anticipated to contribute valuable insights that inform technology-enabled educational practices, policies on educational technology, and research in the domain.

C8

Pre-Service Teachers' Characteristics' Influence on Pupils' Outcomes in Digitization-Related Lessons

Nicoletta Bürger, Mira Wittenberg, Tobias Kantorski, Katrin Hauenschild, Barbara Schmidt-Thieme, Christof Wecker

The promotion of pupils' competences in a digital world has long been a declared goal. We developed practice-based curricular units to promote pre-service teachers' pedagogical content knowledge about teaching with digital technology as well as attitudinal and motivational characteristics concerning teaching with digital technology and used them as a context to investigate to what extent these pre-service teachers' characteristics affect their pupils' acquisition of competences in digital world as well as their interest regarding digital technologies in lessons taught during the internship. Pre-service teachers' pedagogical content knowledge about teaching with digital technology as well as attitudinal and motivational characteristics concerning teaching with digital technology were measured before and after the curricular unit and pupils completed a test regarding specific competences in a digital world before and after the lesson. In a multi-level path analysis, we found that pre-service teachers' computer anxiety was negatively related to pupils' acquisition of competences in digital world and pre-service teachers' interest regarding the usage of digital technology in classrooms, perceived subjective norm, perceived ease of use and pre-service teachers' enthusiasm was related to pupils' development of interest regarding digital technologies. In order to gain a deeper insight into the mediation of the influence of pre-service teachers' characteristics on pupils' previous competences in digital world, the videotaped lessons from the internship will be used for further analysis.

C9

Detecting distributed practice in trace data: A comparison of different operationalizations

Lea Nobbe, Jasmin Breitwieser, Garvin Brod

Distributed practice is a well-researched learning strategy. Results show benefits when study sessions are distributed rather than crammed. Often, however, these results are based on either participant self-report or manipulation of student study behavior. Based on trace data from medical students preparing for a high-stakes exam in an online learning environment, we were able to examine the effect of distributed practice using an objective measure of when and how much students study. The main study activity in the learning environment was answering practice questions. These questions were not on a single topic, and the same questions were not repeated over and over, as is often the case in laboratory studies investigating the distributed practice effect. The fine-grained longitudinal data allowed us to analyze the predictive value of three different operationalizations of distributed practice for students' performance on the high-stakes exam: The number of days students studied, the shape of their learning trajectories as captured by time series clustering, and their learning regularity as captured by entropy scores. Only the operationalization that defined distributed practice as study activity over more days, controlling for the total amount of studying, predicted exam scores. The implications of our findings are discussed in relation to theories of distributed practice and (research) practice.

C10

Comparing Online and In-Person Grades with the Same Instruction: A Natural Experiment in COVID-19

Caitlin Kirby, Min Zhuang, Jon Stoltzfus, George Mias, Jinjie Liu, Katie Krueger, Kirstin Parkin

There is continued debate about the impact of online course delivery on undergraduate student learning outcomes. Due to distancing measures during the fall of 2021 for instruction during the initial COVID-19 pandemic, undergraduates were divided into online and in-person groups in the same biological sciences course for synchronous blended delivery. This offered a natural experiment to explore what impact modality had on student learning outcomes, as measured by their grades on summative exams. The context for this course was a research-intensive university in the United States. We conducted a regression analysis to investigate how modality influenced student summative exam grades when considering student demographics and completion of other course materials. Our approach utilized linear regression on data from fall semester 2021 (n=853). Students in online sections had lower exam scores than in-person sections. The resulting regression model indicated that modality was not a significant indicator of students' summative exam scores (p=0.10) when models controlled for other factors, such as student participation in other course assignments. Students' grades on formative assignments were significant predictors of their exam grades, among several demographic features. The findings indicate that students in online modalities were less likely to engage as fully in course activities and other formative assessments, but when they did engage consistently, they were able to achieve similar mastery as in-person students.

C11

Associations of Digital Feedback, School Achievements and Absences

Sanna Oinas

Teachers can record digital feedback notifications related to their students' learning and learning related behavior. A digital platform tailored mainly to communication between teachers and families in Finland enables feedback notifications seen also by students themselves. Earlier research has strong evidence that this type of feedback is associated with students' motivation, academic well-being, and school absences. Also, negative impact between this digital feedback and students' equal treatment has been reported. Therefore, school administrators have tried to instruct teachers to develop their digital feedback to support students learning better. Due to continuously increasing hours of school absences, administrators are interested to find explaining associations between digital feedback and absences. The current study analyses longitudinal data (N=592), consisting of authentic digital feedback notifications recorded in the platform between 2017 and 2023. Data has been driven directly from the platform for research purposes with the permission of school administrators of nine municipalities in Finland. Ethical approval has been received and followed. Preliminary results show that most of the digital feedback is positive by content. Teachers also record a high amount of feedback related to forgotten homework or antisocial, disturbing behavior. The aim of the conference presentation is to show associations between digital feedback and school outcomes with absences in order to make conclusion, whether the type of digital feedback is purposeful for students. Results are important to develop instructions for teachers and digital platform providers when designing feedback tools for learning.

C12

An fNIRS Study on Reading Sentences in h'Hand Proximity: The Influence of Cognitive Flexibility

Birgit Brucker, Romy Brömme, Antonia Bernecker, Beatrix Barth, Ann-Christine Ehlis, Peter Gerjets

As digital media, such as tablets and smartphones, become increasingly prevalent for reading, the proximity of the users' hands to the text emerges as a significant consideration. This study aims to explore the impact of hand proximity during text reading in terms of semantically meaningful and nonsensical sentences, seeking to replicate and extend previous findings on possible negative effects of hand proximity on semantic processing. Functional near-infrared spectroscopy (fNIRS) was used to identify neuronal correlates alongside behavioral measures to provide insights into this phenomenon. The results partially replicate the reported negative effect of hand proximity on semantic processing: individuals with lower cognitive flexibility exhibited increased errors in interpreting both meaningful as well as nonsensical sentences when reading text near the hands. However, there was no clear neural correlate for this finding. The results identify cognitive flexibility as an additional factor influencing semantic processing when reading text in hand proximity.

Posters - Group D

D1

Effectiveness of 4Cs Skills Transfer from Sandbox Gaming Environment to Near and Far Contexts

Yuchun Zhong, Luke Fryer, Shiyue Zheng, Samuel Kai Wah Chu

Esports or competitive video gaming has been increasingly utilized to enhance essential 21st century skills. However, there is a lack of concrete evidence on the extent to which the skills acquired from a gaming environment can effectively transfer to other settings. This study employed an experimental design to investigate the effectiveness of a competitive sandbox game environment in enabling the transfer of 4Cs skills to both near and far tasks, in contrast with a non-game environment. A cohort of 110 students from a university were randomly allocated to both conditions for 4Cs skills training. The extent of skill transfer for both groups was measured through self-reports and observations. The findings showed that no significant differences in the transfer of creativity, critical thinking, and communication skills were observed in near and far settings following both training environments. Interestingly, a competitive gaming environment significantly facilitates the transfer of collaboration skills to near tasks evidenced by performance-based assessments. Moreover, even though the hypotheses 1c and 3c were not statistically supported, the medium effect size suggests that there were some practical differences between

the groups in self-reported collaboration skills in near and far tasks. Keywords: 4Cs skills, esports, sandbox game, competitive gaming environment, skills transfer, experimental design.

D2

Collaborative Diagnostic Reasoning in Simulations: Insights from two Disciplines

Anu Lehtikko, Chia-Yu Wang

Simulations facilitate diagnostic reasoning a crucial professional skill in various disciplines through approximation of practice (Heitzmann et al., 2019). In knowledge-rich disciplines diagnosing collaboratively is particularly relevant. According to the Collaborative Diagnostic Reasoning model (CDR model; Radkowsch et al., 2022), collaborative diagnostic activities (e.g., eliciting and sharing evidence) mediate the link between individual prerequisites (e.g., professional knowledge, collaboration knowledge, and social skills) and diagnostic outcomes.

We empirically examine this model in medical and teacher education, assuming positive associations between individual prerequisites and collaborative diagnostic activities. These activities are positively associated with diagnostic outcomes and mediate the relationships between individual prerequisites and diagnostic outcomes. We tested our hypotheses using structural equation models, analyzing data from 194 teacher students and 160 medical students who collaborated in discipline-specific simulations that were video-based and agent-based, respectively.

Both models demonstrated a good fit. For teacher and medical education, we found direct effects of professional knowledge on diagnostic outcomes. Additionally, in teacher education, evidence sharing significantly mediated the relation.

The good model fits indicate the applicability of the CDR model to explain collaborative diagnostic reasoning across different disciplinary scenarios. Comparing the paths of the teacher education model with the medical education model, some differences in significant paths can be identified. These differences could be partly attributed to the fact that not identical measures were employed. Moreover, in the teacher education simulation, collaboration occurred between individuals, whereas in the medical education simulation, participants collaborated with an agent, potentially leading to differences in the use of collaborative diagnostic activities.

D3

Unlocking the Power of Immersive Learning: The FAIRI Instructional Design Framework for IVR

Gilles Obourdin, Piet Van den Bossche, Sven De Maeyer

Immersive Virtual Reality (IVR) has risen as a promising tool for providing immersive and adaptive learning experiences. It achieves this by immersing learners in realistic future work environments and gathering data on their IVR interactions, which can then be used to offer personalized instructional content. However, recent reviews show mixed results about IVR's learning effectiveness. Even more so, reviews show that a majority of IVR studies lack guidance from established instructional design principles or learning theories. IVR is a highly intensive learning experience due to the dual challenges of managing extrinsic cognitive load and sustaining self-regulation. A suitable instructional approach mitigating these challenges is therefore imperative for effective IVR-supported instruction. To address IVR's associated challenges, this study conducts an integrative literature review to investigate the application of the Four Component Instructional Design (4C/ID) model and Intelligent Tutoring Systems in IVR-supported domain-specific training contexts. Based on this application and current IVR literature, this research identifies two key instructional principles for IVR-supported instruction: limiting IVR use to tasks that benefit from its enhanced realism, and using its adaptive features to manage the intensity of the IVR experience. From these insights, the FAIRI (Four-Component based, Adaptive, Immersive, Realistic, and Intelligent) instructional design framework is proposed. FAIRI offers a blueprint for designing effective IVR-supported learning environments, aiming to maximize learning efficiency while managing IVR challenges. By incorporating learning theories and instructional design principles, FAIRI aims to be an instructional design foundation for IVR developers and instructional designers to create effective and personalized IVR-supported instruction.

D4

The Effect of Different Backgrounds on Information Recall when Using 360° Videos to Assess Learning

Alberto A.P. Cattaneo, Vito Candido

The principle of situatedness in cognition and learning is particularly relevant in vocational education due to the intrinsic link between theory and practice, and it is increasingly explored with immersive technologies like virtual reality (VR). Moreover, considering the context-dependent nature of memory, investigating the effectiveness of presenting learning and assessment materials within the same VR environment is an additional interesting research question. While the potential of computer-generated VR in this context is acknowledged, the use of 360° videos (360°VR), especially when used for assessment of learning, remains almost underexplored. This study aims to assess the general effectiveness of situatedness through 360°VR on learning and to examine the impact of presenting assessment questions within the VR context using different contextualization backgrounds on answer accuracy. A sample of 137 apprentice chefs participated, split as follows: one group attended traditional instruction and assessment methods and other four groups experienced immersive 360°VR instruction. For three out of these four groups the assessment questions were presented either in the same background environment as the learning materials (a professional kitchen), or in unrelated environments (classroom or blank space), and the fourth group received a traditional paper-pencil test. Findings indicate a significant advantage for contextualized VR instruction over traditional methods in immediate retention (assessment mode being equal). However, no significant difference across groups was observed in longer-term retention. This study underscores the potential of contextualized VR for enhancing learning

outcomes in vocational education while highlighting the need for continued investigation into its mechanisms and long-term effects.

D5

Learning with Instructional Videos: Prompting is Enough, Really?

Anke Wischgoll, Monika Post

Instructional videos have become more and more common for learning purposes in pre-service teacher education in recent years. There is still more to know how engagement with instructional videos should be designed for the learners' benefit. According to Chi & Wiley's (2014) ICAP-framework, it is assumed that constructive engagement is superior to active engagement. Constructive engagement, such as generating written explanations or note taking, offers a means for deep learning that can additionally be supported by prompts to focus on relevant information. Compared to that, active engagement offers a means of shallow learning. We aimed to find out whether constructive engagement is superior to active engagement in terms of learning outcome. More specifically, whether prompting for relevant information has an additional benefit on constructive engagement such as generating written explanations or note taking for the learning outcome. Therefore, we designed a digital learning environment on part-whole relationship in probability theory with three experimental groups for constructive engagement and one control group for active engagement. 292 pre-service math teachers participated in the intervention study with pre-, post-, and delayed post-test. Results revealed that the experimental groups with constructive engagement supported by focused prompts outperformed the control group with active engagement significantly. The experimental group that was asked for written explanations showed the highest sustainability in the learning outcome.

D6

Domain Specific Challenges in Developing an e-Learning Tool for Organic Chemistry

Katrin Schuessler, Michael Giese, Maik Walpuski

Digital learning environments that fulfill domain specific requirements have the potential to enhance domain specific learning. Organic chemistry requires providing options that allow to enter and automatically evaluate drawings of organic molecules. Even though the technical development of a tool that fulfills these requirements has successfully overcome many obstacles, new instructional challenges arise and must be met. Results of evaluation studies show that: (1) Students need an appropriate introduction into the digital tool and a sufficient time of practicing to be able to enter their intended answer correctly. (2) A comparison between the digital and a paper-pencil based format indicate that entering an answer using skeletal formula may be an additional obstacle. (3) Learners use markings or numbering of substituents within molecules in the paper-pencil format when working on tasks dealing with chirality. The digital tool currently does not allow the use of markings within molecules which appears to impair performance and increase cognitive load. These obstacles need to be addressed to better understand their influence on learning and to use the full potential of digital learning environments within specific subdomains.

D7

Using Badges and Leaderboards to Support Secondary School Students' English Language Learning

Chunqi Li, Luke Fryer, Alex Shum

English language learning (ELL) is crucial in formal education. A few researchers have started to use gamification to support students' ELL within formal education as gamification has been demonstrated to boost students' learning outcomes like motivation and engagement. However, these studies generally viewed gamification as a holistic construct, which makes it impossible to identify the individual effects of a single gamification element. Badges and leaderboards are two popular gamification elements in education. Prior research suggested that badges and leaderboards can potentially support students' interest and self-efficacy, which are important for improving students' learning experiences and academic achievement. Besides examining the individual effects of badges and leaderboards, comparing their individual effects with their holistic effects may also be important because it can help ascertain the condition in which badges and leaderboards work most effectively (individually versus concurrently). Nevertheless, no study was identified investigating the individual effects of badges and leaderboards or comparing their individual effects with their holistic effects on students' interest, self-efficacy, and academic achievement, in especially ELL formal educational contexts. Notably, most gamification studies have been performed in higher education and neglected other formal educational levels. To address these gaps, this study aimed to investigate how badges and leaderboards influenced secondary students' interest, self-efficacy, and academic achievement in an ELL course when they were implemented individually versus together. The data were collected and will be analysed using MANCOVA. The relevant findings will be reported at the conference if this study is accepted.

D8

Supporting University Students' Use of Retrieval Practice during Their Self-Regulated Learning

Louise David, Felicitas Biber, Anique de Bruin

Effective self-regulated learning is crucial for students' academic success, however many students struggle to use effective learning strategies consistently. Transitioning students' knowledge about effective learning strategies from training programs and applying it to self-regulated learning consistently remains challenging. This gap between knowledge and behavior could

potentially be overcome by supporting students to form habits, which incorporate effective learning strategies. Habits, behaviors initially driven by goals, become automatic and guide behavior effortlessly and goal-independent once formed. Research in social psychology has introduced goal achievement to be effectively supported by extending the initial goal intention with a detailed if-then plan (implementation intention). Evidence from education research remains mixed. In the current study, we aim to investigate whether supporting students to set and achieve goals through implementation intentions increases their regular use of effective learning strategies. We will monitor medical bachelor students' practice testing behavior through a five-week longitudinal study utilizing experience-based sampling method (ESM). Participants will be randomly assigned to experimental or control groups, with the experimental group setting goals via implementation intentions related to flashcard use. Daily questionnaires will track students' study behaviors and goal achievement. We will assess participants' habitual study behavior, attitudes, satisfaction with study methods, behavioral change intentions, and study goals via pre- and post-questionnaires. We will analyze the impact of implementation intentions on practice testing and explore associated changes in study behavior and attitudes. We aim to present preliminary findings via a poster.

D9

Training Self-Regulation Skills: Effects on Self-Efficacy, Challenge/Threat, and Learning Outcomes

Jane Piepenbosch, Vincent Hoogerheide, Gesa van den Broek, Florence Lucas, Barbara Flunger, Tamara Van Gog

Effective self-regulated learning with problem-solving tasks requires that students accurately assess their performance and select suitable next tasks, but many students struggle with this. Fortunately, these skills can be trained through video modelling examples, in which self-assessment and task-selection are demonstrated by peers: Research has shown that students who engaged in self-regulated learning after receiving the training, showed higher learning outcomes on a posttest than students who did not receive this training. These findings have also been replicated. However, that replication study was conducted with the exact same learning materials. Hence, it is important to also conduct a conceptual replication with different problem-solving tasks. Moreover, there was substantial variability in students' posttest performance, and prior research suggested that the individual differences could be explained by motivational mechanisms (i.e., self-efficacy and challenge/threat states). However, those studies did not yet investigate whether and how motivational mechanisms affect students' self-regulated learning outcomes after the training. Therefore, the present study was designed to investigate 1) if we can replicate the beneficial effects of training self-assessment and task-selection skills on self-regulated learning outcomes with different problem-solving tasks, and 2) if self-efficacy and challenge/threat experiences after the training predict self-regulated learning outcomes.

D10

Investigating Cognitive, Affective, and Motivational Effects of Game Elements for Learning

Stefan Huber, Antero Lindstedt, Kristian Kiili, Manuel Ninaus

The use of game features in learning tasks is often justified by their capabilities to increase learners' engagement, motivation, and consequently, cognitive learning outcomes. Even if game features lack a direct effect on cognitive outcomes, they can be beneficial if they keep learners engaged and support long-term loyalties. Discussing three consecutive studies, we present insights on the mechanisms underlying such affective and motivational effects of game features. All three studies comprise value-added research comparing less gameful and more gameful versions of a specifically developed, associative learning task. The first study was conducted online, focusing particularly at behavioural engagement and attrition over the course of the learning task. We found that game features significantly mitigate participant dropout and enhance behavioural engagement. In a second online study, we found that game features were especially suited to serve learners' motivation. This effect was further partially mediated by an increase in positive affect. In a third, and currently ongoing laboratory study, we explore the relations between game features and affective dynamics supposedly mediating their motivational effects. All three studies aim for a better understanding of how or under which circumstances game features may be beneficial or detrimental for learning. The resulting, refined conceptual understanding shall then support the development of both more engaging and more effective educational experiences.

D11

Testing the Effectiveness of an Individualized Assignment of Motivational Interventions

Liene Brandhuber, Cora Parrisius, Lisa Baulke, Benjamin Nagengast, Thorben Jansen, Daniel Wiczorek

With the present 2-study research, we aimed to test the effectiveness of an individualized (i.e., needs-matching) assignment of motivational interventions in fostering students' achievement motivation. In Study 1, undergraduate students received one out of five motivational interventions (i.e., growth mindset intervention, attributional retraining, social belonging intervention, achievement goal intervention, or utility-value intervention) either based on their individual need for one specific intervention or based on random assignment (i.e., needs-nonmatching) to one of the other four interventions not matching their need. Following a pretest-posttest-design in Study 1, we collected data from 149 German undergraduate students. Results of multiple regression analyses provided first evidence for the benefit of selecting and assigning motivational interventions based on the learner's specific need instead of a random assignment (as typically done in a one-size-fits-all approach). A replication study (Study 2) with a larger sample is currently planned to probe into these promising findings. In Study 2, we will additionally use logfile data to test whether behavioral data provide additional information regarding intervention effects. Results of both studies will be presented and discussed at the upcoming conference.

D3

Is Two Better Than one? Effects of Sequencing a Retrieval Task and a Learning Protocol on Learning

Alina Timmermann, Sara Holtkamp, Christoph Kiefer, Julian Roelle, Robert Gaschler, Vincent Hoogerheide, Veit Kubik

Both retrieval practice and generative learning (i.e., writing a learning protocol) are effective follow-up learning tasks after an initial study phase. While retrieval practice is supposed to enhance the consolidation and generative learning to support the construction of coherent mental representations, it is theoretically and practically relevant to examine how effective the sequential combination of both follow-up learning tasks is. In this preregistered study, we investigate whether the sequencing of retrieval practice and generative learning in a closed-book format benefits students' learning outcomes after 1 week. We hypothesized that repeated retrieval practice benefits long-term retention more than a repeated learning protocol, while the latter should enhance long-term comprehension. Furthermore, we explore whether a combination of the two learning tasks (i.e., two different learning tasks vs. same learning task twice) and the specific order of the two learning tasks (learning-protocol-before-retrieval-task et vice versa) is more effective. In this study (Nplanned = 224), we employ a one-factorial, between-subjects design with four different sequences of the two follow-up learning tasks: repeated retrieval-practice tasks, repeated learning protocols, retrieval-task-before-learning-protocol, versus learning-protocol-before-retrieval-task. More specifically, participants receive a video lecture, followed by two learning activity phases, in which participants work on either a retrieval-practice task or on a learning protocol followed by a self-paced review opportunity of the lecture transcript. After 1 week, participants receive a posttest. We are currently collecting data. The study contributes to the understanding of how retrieval-practice and generative learning tasks can be combined in the most beneficial way for long-term learning.

D2

How Are Students' pre-Tutorial Learning Behaviors Associated with Student Engagement in Tutorials?

Linyuan Wang, Roeland M. Van der Rijst, Wilfried Admiraal, Arjen de Vetten

In this research, we will explore the correlation between students' pre-tutorial learning behaviors and their engagement during tutorials within two blended courses in the Humanities faculty. Our study involved gathering data from first-year bachelor students through biweekly logbooks, focusing on their approaches to various study activities, such as literature reading, watching knowledge clips, and completing assignments. Additionally, we conducted interviews with 20 students selected based on their initial motivation and self-regulation profiles to gain insights into their methods of approaching different learning activities. We collected data on students' motivation, self-regulation skills, cognitive strategies, and tutorial engagement. The analysis will involve employing techniques such as multivariate regression analysis, profiling clustering, ANOVA, Structural Equation Modeling (SEM), and Epistemic Network Analysis (ENA) to derive meaningful insights from the data.

D4

Phoneme-Grapheme Recognition Testing and Gamification in Primary school classrooms

Lishi Liang, Quint Oga-Baldwin, Kaori Nakao, Luke Fryer, Alex Shum

Phonological processing of written characters has been recognized as a crucial element in acquiring literacy in any language, both native and foreign. This study aimed to assess Japanese primary school students' phoneme-grapheme recognition skills using both paper-based and touch-interface tests. Differences between the two test formats and the relationship between phoneme-grapheme recognition skills and interaction with gamified digital tests were investigated. Participants were sixth-grade students from two public schools. The results of comparison tests indicated that the touch-interface test had lower success rates compared to the paper-based test for most items, suggesting a difference in performance patterns. A consistent relationship between tested phoneme-grapheme knowledge and successful gamified interaction was found. Findings highlight the potential of touch-interface assessments for assessing phoneme-grapheme recognition skills in primary school classrooms and suggest incorporating more digital tasks to enhance student adaptation.

Friday 23.08.2024

10:30 - 11:50/ 12:00 - Session I

Symposium VII - Teaching STEM with XR

Organizer: Zoya Kozlova

Discussant: Guido Makransky

Visualizing otherwise invisible objects, such as magnetic fields, and offering learners the opportunity to manipulate objects that would typically be impossible or dangerous to interact with in reality, such as performing spinal surgery, are two STEM-associated learning actions enabled by the multiple affordances of extended reality (XR) (Ghaednia et al., 2021; Yoon et al., 2014). XR in education refers to the use of immersive technologies, such as virtual reality (VR), augmented reality (AR), and mixed reality (MR) (Çöltekin et al., 2020). In this symposium, we aim to provide a snapshot of recent research questions examined in learning STEM with AR and VR. The first contribution explores the relationship between representational competence and conceptual prior knowledge when learning physics with AR. The second contribution focuses on which kind of AR representation best supports learning the Lorentz force in a physics lesson. In the third contribution it is examined how annotations and quizzes can serve as instructional aids when high school students acquire knowledge about environmental engineering in VR. The fourth contribution examines the impact of VR interaction modalities on learning outcomes, cognitive load, and embodied learning in the field of health science. In summary, the contributions investigate the learning mechanisms and instructional techniques associated with learning STEM with AR and VR. These findings can help shape a future XR research agenda.

Exploring the Role of Conceptual Knowledge and Representational Competence in Augmented Reality

Zoya Kozlova, Max Warkentin, Christoph Hoyer, Peter Edelsbrunner, Stefan Kuechemann, Jochen Kuhn, Bermann Steinmacher, Kristin Altmeyer, Roland Bruenken, Barbara Grawnz, Andreas Lichtenberger, Sarah Malone, Roman Schmid, Ralph Schumacher, Elsbeth Stern, Andreas Vaterlaus, Sarah Hofer

The use of augmented reality (AR) technology has proved to have a powerful impact on learning in STEM disciplines. However, at present, little is known about the learning mechanisms triggered by AR representations. Considering both learners' conceptual knowledge and representational competence before and after learning with AR allows us to determine specific prerequisites and consequences - and, hence, mechanisms - of learning with AR representations. Therefore, in this study, we aim to analyze developmental interrelations of conceptual knowledge and representational competence from before (T1) to after (T2) a physics lesson in which students learn about the superposition of magnetic fields and the resulting direction of the Lorentz force through guided experiments supported by AR representations. The data from a sample of N = 100 ninth- and tenth-grade students is collected in March and April 2024 and the analyses (cross-lagged path model) will be completed by June 2024.

Augmented Reality in Electromagnetism: Which Representations Best Support Students' Understanding?

Bermann Steinmacher, Barbara Graenz, Andreas Lichtenberger, Kristin Altmeyer, Roland Bruenken, Peter Edelsbrunner, Sarah Hofer, Christoph Hoyer, Zoya Kozlova, Stefan Kuechemann, Sarah Malone, Roman Schmid, Ralph Schumacher, Max Warkentin, Elsbeth Stern, Jochen Kuhn, Andreas Vaterlaus

We have developed an Augmented Reality (AR) learning setup in which students investigate the Lorentz force and the superposition of magnetic fields with virtual representations including field vectors, field lines, a vector tripod, and combinations thereof. In an experimental classroom study with N = 77 students, we found no significant differences in conceptual understanding between the different AR conditions. However, exploratory analysis revealed that conditions employing the vector tripod showed better learning results regarding the conceptual knowledge of Lorentz force. Offering multiple as opposed to single virtual representations did not seem to enhance or hamper the acquisition of conceptual knowledge.

Learning with Annotations and Quizzes in VR: How Beneficial Is It, and What Mechanisms Play a Role?

Maximilian C. Fink, Bianca Watzka, Bernhard Ertl

Acquiring knowledge in Virtual Reality (VR) can be challenging. Learning environments can include distracting stimuli and conventional study strategies like creating written summaries are unavailable. To compensate for these drawbacks and convey declarative knowledge, it may be beneficial to integrate instructional aids into VR learning environments. Delving into how annotations and quizzes can serve as instructional aids within VR, we conducted an experiment. N = 126 German 10th-grade students completed the experiment wearing head-mounted displays. The learning environment focused on water treatment and was implemented using 360° videos and an interactive console. All students completed a pre-test and a post-test measuring declarative knowledge. Moreover, perceived attention and competence experience were assessed in the post-test. A 2x2 design with the factors annotations and quizzes was utilized for the intervention. The annotations consisted of additional cue words,

colors, and arrows and were added to explanatory figures contained in the learning material. Quizzes were embedded at multiple stations of the learning environment and contained feedback about the correct answer. Our results show that annotations positively affected post-test scores on declarative knowledge and improved the perceived attention of participants. While quizzes did not affect post-test declarative knowledge, they improved the competence experience of learners. These results substantiate that instructional aids can improve knowledge acquisition and provide attentional and motivational benefits when learning in VR.

Embodied Learning in Virtual Reality: A Comparative Study on Interaction Modalities

Patrick Albus, Julian Kreiser, Valentin Riemer, Tina Seufert

This study investigates the impact of virtual reality (VR) interaction modalities on learning outcomes, cognitive load and embodied learning. Embodied Learning is an approach that states that cognitive processes are closely linked to the physical activity of the learner (Wilson, 2002; Glenberg, 2010). In a randomized between-subjects design involving 48 participants, the study explored the impact of interaction modalities in VR on learning an endoscopic examination procedure, comparing the "Grab" condition (natural movements) and the "Laser" condition (laser beam interaction). Pre-tests assessed prior knowledge, motivation, and spatial ability. Learning outcome measures, focusing on procedural sequence, were conducted within the VR environment. Cognitive load and embodied learning were assessed in a post-test after the intervention. Results indicated that the Grab condition led to significantly higher embodied learning, but did not show a difference in learning outcomes or intrinsic cognitive load compared to the Laser-condition. While no significant differences were found in extraneous cognitive load, interestingly, a significantly higher germane cognitive load was found in the Laser-condition, suggesting that the cognitive demands of engaging with less intuitive interfaces may stimulate deeper cognitive processing. These findings suggest that natural movements enhance embodied learning without necessarily improving learning outcomes. The study adds valuable insights to the existing body of research on the role of embodied learning and cognitive load in VR and calls for further research to optimize VR-based learning environments.

Symposium VIII - How to Optimize the Benefits of Generative Learning Tasks

Organizer: Andreas Lachner

Discussant: Vincent Hoogerheide

The benefits of providing learners with generative tasks are beyond dispute. It is well established that generative tasks such as learning by teaching, generative drawing or example-generation tasks foster comprehension. However, there are still several important open questions concerning generative tasks, which relate to factors that moderate the effectiveness of generative tasks. Thus, the aim of this symposium is to extend our knowledge on moderators of the benefits of generative tasks. Contribution 1 investigates whether the widespread generative task of learning-by-teaching can be optimized by adding drawing in an authentic, large-scale classroom-setting with secondary students. Contribution 2 also relates to learning-by-teaching. By proposing a conceptual framework for learning-by-teaching, the contribution integrates the existing knowledge concerning moderating factors in a roadmap on how to design learning-by-teaching interventions. Contribution 3 focuses on the generative task of learning-by-drawing. The authors investigate whether the benefits of learning-by-drawing concerning long-term learning depend on whether retrieval practice is integrated into the drawing procedure. Contribution 4 relates to enhancing the benefits of generative tasks through retrieval practice. The contribution analyzes whether the effects of example generation on long-term comprehension depend on whether learners engage in retrieval practice before or after the example generation. The four contributions will be discussed by Vincent Hoogerheide, who is an expert in the field of generative learning. His view on the presented research will help to draw fruitful conclusions regarding moderators of the effectiveness of generative tasks and hence regarding ways on how to enhance the benefits of generative tasks even further.

Combining Explaining and Drawing Fosters Inquiry Learning in Physics Classes

Heike Russ, Leonie Sibley, Salome Flegr, Jochen Kuhn, Katharina Scheiter, Andreas Lachner

Inquiry-based learning is demanding for students, which can limit knowledge acquisition. Whether generative activities, such as explaining and drawing, can enhance inquiry-based learning is an open question. We conducted a large-scale randomized controlled field trial in an inquiry-based classroom setting in physics with secondary school students (N = 590) to examine whether the combination of explaining and drawing fosters (meta-)cognitive learning from inquiry, pertaining to immediate and lasting learning. We contrasted the following four conditions: Students either (a) explained the contents to a fictitious peer, (b) explained with an additionally provided picture, or (c) explained and made a drawing themselves. A control group (d) restudied the contents. We applied both immediate and delayed assessments (after 8 weeks). Regarding immediate cognitive outcomes, results demonstrated that the three generation conditions outperformed the control condition, but additional visualizations (provided and self-generated) did not affect learning compared to the explaining-only condition. Interestingly, the combination of explaining and generating a drawing enhanced learning relative to explaining with a provided picture. Contrary to our hypotheses, those in the restudy condition showed more accurate monitoring accuracy than the three generation conditions, as the latter underestimated their knowledge. Overall, no other contrasts were significant in the delayed test, neither for cognitive nor for metacognitive learning. Explorative serial mediation analyses revealed that combining explaining and drawing was more effective than explaining with a provided picture, as the former raised situational interest, which resulted in more complete explanations. The findings demonstrate that combining generative activities enhances meaningful learning from inquiry.

A Preliminary Conceptual Framework of Learning by Teaching

Jesús Ribosa, David Duran Gisbert

Learning by teaching refers to the learning opportunities that the teaching activity brings about for the person who is teaching someone else. This paper presents a preliminary conceptual framework of learning by teaching, based on a narrative literature review on this concept. It is based on the three primary situations (i.e., learning by preparing-to-teach, learning by presenting, and learning by interactively explaining), which have been used to organize the learning-by-teaching landscape. They are framed by the three agents involved (i.e., learner, audience, and material) and the moderators (i.e., learner-level, audience-level, material-level, and task-level moderators). All in all, this conceptual framework may provide researchers and practitioners with a roadmap to carefully plan their interventions.

Enhancing Lasting Learning by Generative Drawing Through Integration of Retrieval Practice

Seokyoung Kim, Roman Abel, Philipp Schmiemann, Detlev Leutner, Julian Roelle

Engaging learners in drawing after reading expository texts is a promising means to foster comprehension. It is an open question, however, whether generative drawing alone is sufficient for lasting comprehension. A promising means to consolidate knowledge and hence enhance lasting learning is engaging learners in retrieval practice. Therefore, integrating retrieval practice into generative drawing could potentially enhance the effects concerning lasting comprehension. This study investigates whether incorporating retrieval practice into generative drawing fosters lasting comprehension compared to the established generative drawing procedure, which does not require learners to practice retrieval of the content that is to be learned. Participants were N = 311 secondary school students from Grade 8 and 9 in Germany. After reading an expository text, students were randomly assigned to one of two conditions: closed-then-open-book generative drawing or open-book generative drawing. In the closed-then-open book condition, learners first generated their drawings without the text (closed-book) and then revised them using the text (open-book). In contrast, the learners in the open-book condition could access the text in all phases. After completing the initial drawings, both groups generated new drawings for each paragraph, either from memory (closed-then-open-book drawing group) or with text access (open-book drawing group). Finally, all students could revise their drawings again with the text passages. Two posttests were conducted, two weeks and eight weeks after the learning session. The data collection is complete, but analysis is ongoing. Results will be available at the conference. All hypotheses and analyses of this study were preregistered (see <https://aspredicted.org/sr6vu.pdf>).

Combining Generative Learning and Retrieval Practice: Investigating the Role of Learning Task Delay

Niklas Obergassel, Alexander Renkl, Tino Endres, Matthias Nückles, Shana Carpenter, Julian Roelle

Combining generative learning and retrieval practice tasks is an effective means to promote concept learning. However, to date, research has largely ignored the role of the sequence of the two types of tasks (i.e., generative-before-retrieval vs. retrieval-before-generative sequence) and the question of whether the effects between these sequences depend on circumstantial factors. Theoretically, due to inducing a unique interplay of generative and retrieval processes, both sequences should produce different effects on learning. However, one factor that could affect these unique interplays and thus modulate the resulting sequence effects is the delay between the initial study phase and the learning tasks. Specifically, given that this delay should be negatively related to concept availability at the time of the learning tasks, changes regarding its length should modulate sequence effects as follows: In case of an increased delay, sequence effects should likely shift towards a retrieval-before-generative sequence, given the role of preceding retrieval in increasing concept availability for subsequent learning tasks. In case of a shortened or eliminated delay, however, sequence effects should likely shift towards a generative-before-retrieval sequence, given that, at least if concept availability is largely intact, effects of subsequent retrieval on consolidation are superior. In the present study, we investigated the role of the delay of learning tasks for sequence effects in combining generative learning and retrieval practice tasks. Analyzing the data of N = 208 participants, we found better long-term comprehension following a generative-before-retrieval sequence. Contrary to our hypothesis, however, this effect emerged irrespective of delay of learning tasks.

Single papers - Multimedia Learning

Alt: Intention-preserving Automatic Alt-text Generation for Educational Content

Julia Chatain, Gerd Kortemeyer, Andreas Fender

While educational materials include more and more visual content, these are often not accessible to visually impaired learners. Recent advances in artificial intelligence make Automatic Alt-Text Generation (AATG) from images increasingly reliable. While the precision of such methods is likely improving even further in the future, we argue that besides model performance, it is crucial for alt-texts to also retain the intention of the content author. Such intention is often implicitly contained in language in puts used within the content design and implementation process. A minimal example is a text-to-image prompting interface. Similarly, code for generating vector graphics contains important semantics that can be useful for AATG. Especially for educational materials, the

semantics and intention of the author are of high importance when describing contents like graphs of mathematical functions for visually impaired people. In this paper, we present the concept of AATG from language inputs contained in the content design and implementation processes, specifically prompts and code. We implemented a front-end using generative AI technology and evaluated our concept using a mixed-method methodology. We included a quantitative study to measure the quality of the produced alt-texts compared to two baselines commonly used in higher education institutions, and a qualitative study focusing on the perspectives of content authors and accessibility experts. Overall, our approach performs significantly better than the compared alternatives on scientific figures. We also discuss challenges and directions for future work.

Effects of Collaborative Learning from Dynamic Multimedia – A Systematic Review

Laura Schultze, Nicoletta Bürger, Christof Wecker

How dynamic multimedia can be embedded in various learning arrangements in a classroom setting has not been investigated intensively. One possible way of using dynamic multimedia in a classroom is by arranging settings in which students engage in a collaborative transactive discussion about information from dynamic multimedia. However, there seems to be no comprehensive summary of research on such settings and their effects. This review presents a systematic overview of research regarding collaborative learning from dynamic multimedia and offers a comprehensive summary of effects on knowledge and competencies of students. Additionally, it aims to examine the role of cognitive load in these settings. Journal articles and dissertations in English and German were searched in APA PsycInfo and ERIC. Abstracts and titles were coded for quantitative methods, collaborative settings, use of dynamic multimedia as an information source and a learning setting. To be included, studies had to investigate dynamic multimedia or collaboration as an independent variable and learning outcomes as dependent variables, and to report effect sizes. While the majority of the studies reports positive effects both of dynamic multimedia and of collaboration in this setting, it is still an open question why some studies found negative effects. That in the majority of the studies which examined cognitive load the load was higher than in the control conditions suggests the possibility that the additional effort to form a collective working memory might contribute to extraneous load detrimental to learning.

Stepwise Presentation of Worked Examples to Foster Retrieval Practice and Improve Learning

Margot van Wermeskerken, Gesa van den Broek, Tamara Van Gog

There is much evidence that example study is an effective way to learn problem-solving tasks and that retrieval practice is effective for strengthening the retention of learned information over time. Yet, combining these two strategies has not proven successful thus far. In the current study, we investigate if a novel way of inducing retrieval practice during example study, by means of stepwise presentation, improves retention and transfer on a one-week delayed test. Participants (Bachelor/Master students recruited on Prolific) are randomly assigned to 1) a no retrieval condition, studying pairs of regular examples, or 2) a retrieval condition, studying pairs of a regular and stepwise example, which is presented step-by-step with a few seconds delay in between the appearance of each next step during which students are encouraged to engage in a retrieval attempt. After the learning phase, participants engage in a delayed knowledge test in which they answer conceptual and recall questions as well as solve isomorphic and transfer problem-solving tasks. It is investigated whether stepwise retrieval during example study is more effective for problem-solving performance than regular example study.

Supporting EAL Learners with Video Subtitles and Transcripts

Alice Shihua, Thi Kim Anh Dang, Shihua Yu

The study focuses on how subtitles and transcripts mediate learners' engagement in mathematical learning through video lectures and understanding of mathematics content, particularly in the context of Content and Language Integrated Learning (CLIL). Utilizing video-stimulated recall (VSR) and semi-structured individual interviews with mathematics students at an Australian university, the research highlights the distinct advantages of subtitles and transcripts in enhancing English as an Additional Language (EAL) learners' comprehension of complex mathematical concepts. Importantly, the findings indicate that narration alone in an additional language may not effectively aid the formation of mathematical concepts without accompanying textual information, such as subtitles, transcripts, or other in-video text (e.g., whiteboard writings or PowerPoint slides). The findings also reveal that while transcripts provide robust textual references for efficient navigation through mathematical content, bilingual subtitles foster translanguaging and crosslinguistic strategies, enabling learners to utilize their full linguistic and cognitive repertoire. This study refines existing knowledge on instructional video design, emphasizing the complementary roles of subtitles and transcripts in meeting the varied learning needs of EAL learners, with broader implications for educational video production and implementation strategies.

The Presence of Learning Partners and Choice as Motivation Support Features in Multimedia Learning

Ömer Tuğşad Akgül, Sascha Schneider

This research investigates the impact of autonomy and relatedness support on learners' motivation and performance in online environments. Drawing on the basic psychological needs theory of self-determination theory, the study examines how providing

autonomy (choice options) and relatedness (presence of a learning partner) support influences learners' perceptions and outcomes. Using a 2 (relatedness support: the presence of a learning partner) × 2 (autonomy support: options to choose) between-subject design with 74 students, the study found that autonomy support increased perceptions of autonomy. In contrast, relatedness support heightened perceptions of relatedness. Additionally, the presence of a learning partner increased retention but not transfer knowledge, while choice options only increased transfer scores. An interaction effect revealed that relatedness support only influenced retention when no choice was provided. Furthermore, autonomy and relatedness support enhanced perceptions of intrinsic motivation but do not reduce perceptions of extrinsic motivation. These findings underscore the importance of incorporating autonomy and relatedness support in online learning environments to enhance learners' motivation and performance. The study sheds light on the intricate dynamics between different forms of support and provides insights for future research and educational practices.

13:00 - 14:00 - Session J

No or not perfect data - II

A Questionnaire to Assess Teachers' Knowledge About Multimedia Principles in Instructional Videos

Sandra La Torre, Juliette Desiron, Mireille Bétrancourt

Learning from instructional multimedia material, such as videos, is known to be cognitively demanding. A large body of empirical studies have established that instructional video complying with multimedia principles support learners' cognitive processes and increase learning (Brame, 2016; Fiorella, 2021; Mayer, 2021). However, in classroom situations, teachers use instructional materials, such as videos, that rarely integrate these multimedia principles (La Torre, 2022; Oh et al., 2020). The research also indicates that teachers tend to select videos according to pedagogical content regardless of multimedia learning principles (Hobbs, 2006; La Torre, 2022). Furthermore, misconceptions about multimedia learning, as well as neuromyths, are prevalent among teachers (Dekker et al., 2012; Eitel et al., 2021; Tardif et al., 2015). Little research has been conducted to systematically assess how teachers' knowledge of multimedia learning principles and their beliefs in learning myths relate to the way they select and use instructional videos. To investigate this question further, a two-part questionnaire is being developed. The first part of the questionnaire is based on The Misconceptions Multimedia Learning Questionnaire from Eitel et al. (2021). The second part of the questionnaire, which seeks to investigate the declared use of instructional video by teachers, is based on Brame's Principles and Guidelines for Maximizing Student Learning from Video Content (Brame, 2016). The questionnaire will be presented in a no (or not-so-perfect) data format in order to get insights and feedback from colleagues as well as inspire similar research.

Comparing Performance-based versus Cognitive Load-based Assessment in Adaptive Learning Systems

Luisa Wellert, Sara Becker, Vincent Aleven, Andreas Lachner

Adaptive Systems are educational technologies to foster personalized learning, particularly during individual learning and practice phases. However, most of the current adaptive systems have not gone beyond the status of prototypes, likely because the design and implementation of adaptive systems across subjects are financially intensive and demanding. A potential solution could be to decrease the complexity of an adaptive system, for instance, by simplifying the underlying assessment models. Based on previous research on quizzing, in the current mixed-method study, we compared two different assessment models (load-based assessment of mental effort versus performance-based assessment) to adapt the difficulty of practice tasks. In our quantitative study, we realized a Many-Classes experiment to compare load versus performance-based assessment to a control condition, which received a random order of practice tasks. We implemented sequences of our three conditions (within-participants design) into a set of $k = 7$ classes ($N = 126$ students). To draw a broad picture of student learning, we assess cognitive, metacognitive, and motivational outcomes. In our qualitative study, we conducted focus group interviews to better understand the boundary conditions of load-versus performance-based assessments. This procedure allows us to examine the effects of load-based versus performance-based adaptation on student's cognitive and metacognitive learning and motivational processes across different study contexts.

Embodied Learning and Mixed Reality in Physics Experimentation

Ipek Paksoy, Martina Rau, Jochen Kuhn, Stefan Küchemann, Christoph Hoyer

Embodied learning is an instructional approach that highlights the significance of the body, movement, and sensory experiences in the learning process. The connection between body and cognition can be particularly crucial in physical learning experiences, such as experimentation. During science experiments, students explore phenomena that often involve bodily experiences. For instance, exploring friction force involves moving objects over various surfaces, manipulating force or mass, and students can feel the effects in their bodies. Therefore, the instructional activities and used technologies should help students to connect embodied experiences with abstract concepts. Mixed reality (MR) technologies offer opportunities to augment bodily learning experiences with virtual representations, for example by making friction forces visible in physics experimentation. This study examines how MR-supported physics experiments can leverage embodied learning mechanisms. Within an MR environment, we investigate how virtually augmented visual cues can help students connect embodied experiences to abstract physics concepts. Participants complete a

pretest and then perform physics experiments about friction force. During the physics experiments, they wear an MR headset that provides visual cues fading in the students' field of view designed to help them make sense of the friction forces they observed. After the learning intervention, participants complete a posttest as well as a delayed posttest assessing the reproduction and transfer of knowledge about friction force and spatial skills. The findings will yield new knowledge about how visual cues and embodied learning mechanisms interact and will suggest principles for designing MR environments for embodied learning in science experimentation.

Generation and Evaluation of Synthetic Text Data for the Students' Conceptions Identification Task

Judith Stanja, Anett Hoppe, Sarah Dannemann, Johannes Krugel

Synthetic data generation is a solution to mitigate data scarcity. We investigate the generation of synthetic text data via prompting a pre-trained Large Language Model (LLM). The prompt design is based on reconstructive analyses from biology education of real student texts. Prompts were designed for the generation of positive and negative samples for intentional explanation patterns for the evolutionary adaptation of whales. We propose a mixed methods approach for the evaluation of the dataset: investigating statistical commonalities and differences between synthetic and real data and assessing frame-related aspects and correctness via an annotation study. Our preliminary findings show that ranges for text lengths and number of sentences are similar for synthetic and real data. We get mixed results for the similarity and lexical complexity of texts. The range of vocabulary sizes is similar in both datasets. We find that it is possible to generate data with indicators for the intentional patterns though we also get false samples. Generating positive samples worked better than for negative samples. Due to generation errors, further usage as training data requires cleaning of the synthetic data. The inter-annotator agreement in the annotation study was high. The study revealed crucial differences in frame annotations for correct positive and negative samples. We identify open questions and further steps for future research.

No or not perfect data - III

Developing Cases for Problem-Based Learning in Multiprofessional Digital Learning Environments

Michelle Möhring, Nadine Elstrodt-Wefing, Noemi Altendeitering, Matthias Schäfer

Problem-based learning (PBL) aims to foster understanding and application of knowledge by solving real or simulated problems. While the physically presented form of PBL is well researched, little is known about the role of learning technologies in PBL (tPBL) and its application in virtual classrooms and online learning. In this paper two methodological approaches of case development for tPBL environments are presented. It is exemplified how to derive evidence-based digital cases and digital learning environments and the significance of a comprehensive needs assessment that includes all stakeholders is illustrated. Additionally, a critical examination of the methodological approaches will be provided and it is discussed to what extent they can be tailored to the needs of students and teachers.

Enhancing Learning Through 360-Degree Images Using Signaling and Segmenting Principles

Kerstin Huber, Bernhard Ertl

Virtual reality has become a common feature in educational settings, with considerable research exploring its positive impact on learning. This study examines the effects of 360-degree images on learning outcomes and associated cognitive processes. Utilizing a VR learning environment, we employed signaling and segmenting principles to manage information processing. The content, focused on digital twins and sensor-equipped bridges, was organized into segmented learning units featuring 360-degree images. A 2x2 between-subject design will explore the impact of signaling and segmenting on learning outcomes alongside assessments of motivation, situational interest, cognitive load, and presence. Additionally, electrodermal activity will be analyzed to understand the learning process. Currently, the learning environment is being finalized, and knowledge tests are being developed. This study contributes to understanding the efficacy of 360-degree learning environments and offers insights into creating personalized virtual learning experiences.

From reflection into action: Does collaborative reflection afford regulation of interaction quality?

Sebastian Strauß, Ahsen Çini, Isis Tunnigkeit, Sanna Järvelä, Nikol Rummel

Poor collaborative learning outcomes may occur because learners lack knowledge of regulation strategies or the skills to monitor and implement them successfully in their groups. To co-construct knowledge during collaborative learning, individuals need to be (metacognitively) aware of their interaction quality overcoming teamwork obstacles. This paper investigates how 11 triads (n = 33 participants) assessed their collaborative processes, leveraged insights from a collaborative reflection to adapt their interactions, and how this impacted their interaction quality subsequently. Employing a mixed-method approach that included a detailed process analysis, we scrutinize groups' abilities to perceive and evaluate the quality of their collaboration, to devise and implement strategies addressing perceived challenges, and the resultant changes in interaction quality. A cluster analysis revealed distinct

patterns of perceptions of interaction quality, engagement in reflective practices, and subsequent changes in interaction quality. The research highlights three distinct clusters, demonstrating varied levels of success in improving interaction quality based on the reflective insights and strategies formulated. Groups in Cluster 1 appeared to lack monitoring accuracy which eventually hampered improving their interaction quality. Groups in Cluster 3 were more accurate but struggled to implement their plans effectively. Only groups in Cluster 2 showcased a visible improvement in interaction quality which was associated with identifying several deficits in their interaction and targeting these deficits with plans. These insights underscore the importance of promoting groups' accurate self-assessment and equipping them with effective strategies for collaboration regulation.

ICT Related Competences, Attitudes, and Experiences in Primary School Mathematics Teachers

Caroline Marx, Stephanie Roesch, Korbinian Moeller, Christiane Benz

Teachers' information and communication technology (ICT) competences are considered key to better integrate ICT in their teaching and learning approaches. Accordingly, several national and international studies aimed at evaluating teachers' ICT competences. However, most previous studies focused on secondary school teachers and also hardly differentiate between different school subjects. Therefore, we aim to gain specific insights into primary school mathematics teachers' i) ICT self-efficacy, ii) their attitude towards ICT for teaching and learning, iii) their experiences with ICT equipment in schools, iv) their conceptual idea of learning in general (constructivist vs. receptive view) and v) the frequency of ICT use during class. In particular, we are interested in whether positive attitude towards ICT and positive ICT self-efficacy predict primary school mathematics teachers' frequency of ICT use. Furthermore, we want to know whether attitudes towards ICT use in class are associated with age. Accordingly, we adapted the questionnaire used in the International Computer and Information Literacy Study (ICILS 2018) with the aim of collecting data from approximately 200 German primary school mathematics teachers. In our no-or-not-perfect-Data presentation, we will report early-stage analyses and discuss first results.

Single papers - Immersive Technologies II

Designing for Adaptivity: Systematic Design of Adaptive Learning Tasks for Immersive Virtual Reality

Gilles Obourdin, Piet Van den Bossche, Sven De Maeyer, Tine van Daal

This study presents a systematic approach to developing adaptive learning tasks within immersive virtual reality (IVR), addressing the challenge of creating a wide variation of tasks that accurately reflect the future work environment and provide actionable insights to guide appropriate task selection. Despite the recognized potential of adaptive learning to enhance IVR-supported instruction by tailoring experiences to individual learner needs, its application remains limited due to the significant effort required in designing and implementing such tasks. This research proposes a novel design process, inspired by McKenney & Reeves' (2019) educational design research framework, which efficiently bridges this gap by systematically creating relevant and actionable adaptive learning tasks. The process is articulated through two main paths: integrating variation and actionability, each going through four stages of analysis, conceptualization, operationalization and implementation. A practical application of this methodology was demonstrated in designing adaptive learning tasks for forklift operators within an IVR setting, showcasing the process's potential to generate adaptable learning scenarios that closely mirror real-world activities. By integrating adaptive strategies into IVR, this project not only advances our understanding of effective task design but also contributes valuable insights into personalizing learning pathways. The dual-path design process, with its emphasis on actionable data and relevant task variations, offers a scalable model for educators and researchers aiming to exploit IVR's full educational potential. This research underscores the importance of adaptability in creating immersive and engaging learning experiences, setting a precedent for future investigations in adaptive IVR education.

How do Learners Move when Grasping Derivatives?

Julia Chatain, Venera Gashaj, Bibin Muttappillil, Robert Sumner, Manu Kapur

While mathematics is conventionally viewed as an abstract discipline, contemporary perspectives on embodied cognition underscore the significance of integrating students' bodily experiences into the learning process. Specifically, students perform various bodily actions when making sense of mathematical concepts. First, they may perform directed bodily actions, meaning they move their bodies as requested per a certain learning activity or tool. Second, they may perform spontaneous bodily actions, meaning they spontaneously make use of their bodies to express mathematical meaning and understanding. In this work, we are interested in the design of digital interactive embodied learning activities for mathematics, and specifically the topic of derivatives. To gain understanding of the underlying design space, we conducted two exploratory studies to answer the following research question: How do students move when making sense of derivatives? Specifically, we are interested in identifying the key characteristics of students' bodily actions during the embodied learning process. We first performed a quantitative study with learners (n=130) interacting with an embodied learning activity on the topic of derivatives in Virtual Reality as well as on tablet and observed their directed bodily actions. We then performed a qualitative study of learners with different mathematical abilities and interest levels and observed their spontaneous bodily actions while solving tasks exploring derivatives in different contexts. Derived from both studies, we propose design recommendations, advocating for expanded embodied interaction design, consideration of

embodied metaphors, coarse gesturing for deep features identification, supporting of sense-making anchors, and in-VR learning assessments.

Learning in Immersive Virtual Reality: Relationship between Cognitive Load and Learning Gains

Dorian Thomsen, Alexander Georg Büssing

Several studies already investigated learning effects of modern technologies such as immersive virtual reality (IVR). However, there are still relatively limited studies on learning science in IVR that take a more coherent view. In particular, models such as the Cognitive Affective Model of immersive learning (CAMIL) propose several variables such as cognitive load and interest as predictors of learning outcomes, but does not outline possible interactions between these variables. The present paper utilizes empirical data from an experimental study in a pre- and post-test-design with 119 9thgrade biology students ($M = 14.77$ years, $SD = 0.54$ years, 48,12 % female) to compare three different representations of the human heart to close this research gap. While one group used a real model ($n = 30$), another group learned with an augmented reality (AR) model ($n = 30$) and the last one with IVR ($n = 30$). We investigated differences in cognitive load, interest, and cognitive learning outcomes (RQ1), connections between these variables (RQ2), and predictors of learning outcomes (RQ3). The results showed significant differences only for the reported interest in the learning situation, even when the distributions were in line with the hypotheses. While there were correlations with large effect sizes between interest and germane cognitive load, the regression results of the third research question showed how interest may explain similar variance in the cognitive learning outcomes as germane cognitive load. This could illustrate interactional effects between these variables, which will be further investigated and discussed at the conference.

Presence is Connected to Cognitive Activation: The Instructional Quality of Virtual Reality

Alexander Georg Büssing, Dorian Thomsen

The last years saw a further spread of several innovative digital technologies. One of these technologies is immersive virtual reality (IVR), which showed mixed results in prior studies. To broaden the evaluations, the present study utilizes a framework of instructional quality to understand learning effects of IVR compared to other representational media. Using data from 100 school students ($M_{age} = 15.69$ years, $SD_{age} = 1.43$ years, 61% male) from six classes of two German schools we investigated two hypotheses: (1) There is a significant difference between the groups concerning the cognitive activation and (2) presence is connected to cognitive activation. Students watched videos about the transformation of agriculture either with a tablet, HMD, or read a text with pictures and text from the videos. Even when there were no significant differences between the groups concerning the clarity, we found the IVR-condition (model 1) and presence (model 2) as predictors in two regression models. Even if a "real" connection to learning outcomes such as knowledge is still missing, the results point to a new aspect of evaluation for immersive learning, which connects traditional pedagogical variables such as instructional quality with psychological variables such as presence.

Single papers - Educational Technologies in Sec II

Inquiry Learning in Science Education with Real, Virtual and VR Experiments

Salome Flegr, Jochen Kuhn

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

Supporting Mastery Learning by Adapting Exercise Sequences to Working Memory and Learner Performance

Martí Quixal, Björn Rudzewitz, Tanja Heck, Yao Xiong, Caterina Gawrilow, Detmar Meurers

Individual learners benefit from adaptive teaching in teacher-orchestrated instruction settings. Thus, adaptive teaching is more effective if carried out at the individual level and more practical when supported by technology (Valle Torre et al., 2023; van de Pol et al., 2015). This paper presents a study that assesses a newly developed activity sequencing module in an Intelligent Language Tutoring System (ITS) for English as a foreign language (EFL). Through this module learning sequences can be individualized based on momentary cognitive status (i.e., working memory), previous knowledge, and ongoing performance. A total of 25 secondary school classes (Nstudents = 440) used the system to practice four different language constructs commonly taught in 7th grade in EFL courses in Germany: present simple, contrast between simple past and present perfect, relative clauses, and conditionals. Initial analyses show that (a) students in the control condition completed their assigned work but not always reached mastery in the target learning goals, while (b) students in the intervention condition worked through paths of different lengths and nature to reach mastery in the target learning goals. A regression analysis underway with a pre-posttest study design will evaluate if there is a significant difference in terms of learning gain.

Teachers' Digital Technology Integration Practices and Their Predictors

Doris Kristina Raave, Margus Pedaste, Eric Roldan Roa

This research investigates how digital technology is integrated into K-9 education, utilizing the SAMR, TEL, and ICAP models to explore teachers' technology integration practice. Moreover, it delves into how specific teacher characteristics—namely self-efficacy, agency, digital attitudes, and digital readiness—predict these practices employing a mixed-methods approach involving 93 teachers. Four distinct profiles of digital technology integration practices were identified: Interactive Facilitators, Constructive Deepeners, Active Engagers, and Passive Facilitators, with each group demonstrating unique approaches to integration technology. Our findings show agency for using ICT in teaching and learning as a significant predictor of these practice profiles, alongside influences from digital attitudes and self-efficacy, while agency for planning teaching and learning showed some effect. Interestingly, digital readiness did not directly predict technology integration practices but did so indirectly through digital attitudes, challenging assumptions about the direct impact of readiness on integration. These findings suggest that teacher-specific characteristics account for around 20% of the variance in technology integration practices, highlighting the necessity for a holistic approach that includes both individual and systemic factors for enhancing digital technology integration in education. This study contributes to understanding how teacher characteristics collectively shape the integration of digital technologies, offering insights for targeted professional development and policy formulation.

14:00 - 15:20/ 15:30 - Session K

Symposium IX - Problem-Solving before Instruction: Investigating Mechanisms and new Application Areas

Organizer: Inga Glogger-Frey

Discussant: Tamara Van Gog

The project on Problem-Solving before Instruction (PS-I) aims to promote discussion and research on mechanisms of this instructional design and its applicability to other content areas. PS-I is a composite instructional design that combines problem-solving approaches in a preparation phase with expository instruction in a subsequent phase (Loibl et al., in press). Theoretically postulated, but empirically understudied mechanisms of the design include: (1) prior knowledge activation which is not a mechanism specific to problem solving (cf. Ausubel, 1968), but is postulated to be especially broad and effective with complex preparation problems (Sinha & Kapur, 2021); (2) knowledge gap awareness, associated with open problem solving as learners experience impasses and feel they lack sufficient knowledge to solve the problem; (3) deep feature recognition, associated with special design features of the composite design (e.g., contrasting cases). This symposium will provide insights into prior knowledge activation as a mechanism (Paper 1), knowledge gap awareness (Paper 2), and deep feature recognition (analyses ongoing, Paper 2). These two studies on mechanisms use classical, well-comparable material (targeting the concept: variance). However, to understand the conditions for the effectiveness of PS-I and its mechanisms, research needs to expand its application to various content domains and learning groups (Fiorella & Mayer, 2016). This symposium also aims to provide insights into the applicability of PS-I in learning domain-general skills, namely secure emailing behavior (Paper 3) where achieving knowledge gap awareness may be difficult due to learners' overconfidence, as well as the complex skill of scientific reasoning (Paper 4).

Prior Knowledge Activation as Mechanism in PS-I: The Role of Goal Formulations

Charleen Brand, Katharina Loibl, Nikol Rummel

Generating solution attempts to an unknown problem prior to an instruction (i.e., problem solving prior to instruction, PS-I) has been found to prepare students for subsequent conceptual learning (Loibl et al., 2017). Prior studies suggest that students need to activate prior knowledge in a broad manner while generating solution attempts in order to be prepared. However, these findings are correlational, as experimental manipulations of students' prior knowledge activation are methodologically challenging. One way to manipulate students' activation and problem-solving approach is to provide them with different goal formulations of the task that vary in terms of goal type (i.e., problem solving vs. learning) and goal specificity (specified vs. unspecified). By means of the goal formulations, we aim to manipulate students' breadth of prior knowledge activation. We expected learning goals to lead to a broader activation than problem-solving goals, and specified goals to lead to a more relevant activation than unspecified goals, both

facilitating preparation for subsequent learning. In a 2x2-design (N = 213), participants were randomly assigned to one of four conditions: specified learning goal, unspecified learning goal, specified problem-solving goal, and unspecified problem-solving goal. Preliminary analyses (N = 180) indicated that learning goals could help students process their solution attempts more deeply, leading to better preparation of subsequent instruction. A broad or relevant activation alone did not appear to prepare students for learning. In combination, however, specified learning goals prepared students best for subsequent learning.

Exploring Cognitive Mechanisms in PS-I: Problem Solving Versus Self-Explaining Problem Solutions

Katharina Ockl, Inga Glogger-Frey

Open problem-solving or self-explaining a worked-out solution can prepare learners for a subsequent instruction through different mechanisms. That is, they can foster learning-relevant cognitive processes that can facilitate learning from subsequent instruction. Open problem-solving can make learners more aware of knowledge gaps to be filled, self-explaining a worked-out solution can guide learners towards recognition of deep features. The present study aims to explore these differences very close to behavior by analyzing think-aloud data and investigating the influence of the preparation activity on learning outcomes. Undergraduate students (N = 65) either invented a solution (inventing) or self-explained a worked-out solution (worked example) as preparation for an instructional video while thinking aloud. Preliminary analyses show significantly better far transfer after the worked example than after inventing, but no difference in near transfer. Learners who invented reported significantly more knowledge gaps in a questionnaire, but this measure did not mediate the effect of preparation activity on learning outcomes. Further analyses will show whether "thought-out loud" knowledge gaps and deep feature recognition during preparation will differ between groups and mediate the effect on learning outcomes.

Applying PS-I in the Context of Addressing People's Knowledge Gaps about Email Threats

Ann-Kathrin Mertineit, Valentina Nachtigall, Nikol Rummel

Productive Failure (PF) can be an effective approach for fostering learners' understanding of a targeted learning concept. By being asked to generate (often incorrect) solution attempts for a problem prior to instruction, it is assumed that learners activate relevant prior knowledge and identify knowledge gaps and, in turn, are prepared to learn the targeted concept in the subsequent instruction. To date, these mechanisms and effects of PF have especially been investigated for acquiring discipline-specific knowledge in STEM domains. There is still a need for more research that examines the effectiveness of PF for learning in non-STEM domains and for acquiring domain-general skills. The present study addresses this need by investigating whether PF can enhance people's knowledge about secure emailing behavior. It has been found that people tend to have incomplete and even incorrect knowledge about email threats. Due to the mechanisms hypothesized to underlie its effectiveness, PF might be an effective approach to addressing these knowledge gaps. To test this assumption, we conducted an experimental study comparing problem solving prior to instruction (PF), to instruction followed by problem solving, i.e. Direct Instruction (DI). The results show no beneficial effect of PF on participants' knowledge about secure emailing behavior. Further analyses suggest that potential reasons for this finding may relate to participants' overconfidence in their ability to identify email threats.

Applying PS-I in the Context of Promoting Multivariable Causality Reasoning via Simulations

Janan Saba, Manu Kapur, Ido Roll

Studying complex interactions between variables to understand and reason about phenomena can be a challenging task for students of all ages. Simulations are commonly used to promote exploratory learning of complex phenomena. However, students often struggle to reason about interactive relationships between factors. This study explores the effectiveness of Problem-Solving before Instruction (PS-I) approach in this context. It entails providing students with complex tasks aiming for sense-making of the domain before receiving instruction on the target concepts. While PS-I is mainly effective in teaching knowledge of diverse topics such as mathematics and physics, it has not yet shown any evidence of improving the ability to learn general inquiry skills. This study examines the impact of exploring with simulations before instruction (as opposed to after) on the development of Multivariable Causality (MVC) reasoning. 71 undergraduate students completed virus transmission exploration tasks using simulation, completing Task 1 before (Exploration-first condition) or after (Instruction-first condition) instruction related to MVC, and Task 2 at the end of the intervention, followed by transfer Task 3 on predator-prey relationships. Results showed both approaches had a similar impact on MVC reasoning development in the learning context. However, in a transfer context, exploratory learning (exploration before instruction) significantly promoted the transferability of MVC reasoning. This study is the first to demonstrate that an exploratory learning approach can improve scientific reasoning by incorporating interactive simulation.

Symposium X - Interleaved practice and meaningful learning: Its variety and application across domains

Organizers: Roman Abel, Erdem Onan

Discussant: Veronica Yan

The sequence, in which to-be-learned materials are presented, plays an important role in knowledge acquisition. Typically, study sequences, in which students alternate between to-be-learned materials (i.e., interleaved practice) lead to better learning than

those, where students study one topic at a time (i.e., blocked practice). A critical gap, however, exists in the literature since prior studies are largely confined to controlled laboratory studies, wherein students engaged in educationally less relevant tasks. This limitation, in turn, poses a substantial challenge to instructional recommendations, since the true value of interleaved practice in meaningful learning situations remains highly underexplored. In this symposium, we showcase several practical application arenas, in which interleaved practice can prove an effective instructional method to enhance learning. Contribution 1 and 2 embrace perceptual learning with visual and auditory materials. Contribution 1 supports the discrimination process by applying adaptive interleaving – providing additional opportunities for contrast between hard-to-differentiate categories. Contribution 2 shows that interleaving improves the auditory detection of (ab)normal respiratory sounds in the healthcare domain. Contributions 3 and 4 embrace learning with textual materials for second language acquisition and source evaluation skills. Contribution 3 shows an interleaving benefit for grammar learning – a robust effect across languages and grammatical abilities. Contribution 4 shows that upper, but not lower, secondary students benefited from interleaving in terms of distinguishing trustworthy and untrustworthy social media sources. The discussion will revolve around the authenticity of learning environments, educational relevance, and task requirements (induction versus practice).

Tailoring Interleaved Practice: Adaptive Interleaving in Visual Category Learning

Lea Nemeth, Johannes Osterberg, Frank Lipowsky

Research has shown that interleaving visual categories boosts inductive learning. The discriminative-contrast hypothesis suggests that this benefit stems from enhanced discrimination processes. Consequently, tailoring interleaving to address categories that an individual finds confusing should amplify learning effectiveness by sharpening the focus on distinguishing between these for an individual hard-to-differentiate categories. Although interleaved practice is beneficial for learning, it tends to result in lower category learning judgments (CLJ) compared to blocked practice. The effect of individualized interleaving on CLJ remains unexamined. Therefore, this study explores whether adaptive interleaving surpasses the efficiency of random interleaved and blocked practice and how it influences CLJ. A minimum of 159 participants will be randomly assigned to blocked, interleaved, or adaptive interleaved practice. Participants in all conditions will study the same 36 landscape paintings by 6 different artists blocked by artist, interleaved, or adaptively interleaved based on an on-task performance. Contrary to former studies, participants will not see the artist's name alongside the painting. Instead, they are asked to identify the artist from a list, receiving corrective feedback on their selections. This approach allows to track on-task performance and a real-time adaptive interleaving schedule. Immediately after the study phase, as well as one week later, participants' classification performance will be assessed with 3 new paintings per artist. CLJ will be measured twice during the study phase as well as at both posttests. Results will be presented, and theoretical as well as practical implications will be discussed.

Improving Diagnostic Accuracy of Lung Auscultation Through Interleaved Practice

Erdem Onan, Arif Onan, Semra Gundogdu, Hicran Bektas, Anique de Bruin

Health professions educators are increasingly encouraged to implement desirably difficult instructional methods, such as interleaved practice, in their teaching. However, despite this encouragement, there is a shortage of empirical evidence regarding the cognitive and metacognitive advantages of interleaved practice, particularly within the health professions education domain. This lack of evidence presents a challenge to theoretical assumptions. Therefore, in this pre-registered field experiment, we investigated the effectiveness of interleaved practice in auscultation training for nursing students, focusing on their learning outcomes and monitoring accuracy. The participants were second-year nursing students who were taught to identify (ab)normal respiratory sounds during a whole class lecture. Over a three-week period, we assessed the participants' immediate and delayed-test scores, monitoring accuracy, and metacognitive knowledge of learning strategies, as well as their perceptions of effort during blocked and interleaved practice sessions. The preliminary results showed that interleaved practice led to better auscultation performance compared to blocked practice; this learning benefit remained over a week. Our preliminary findings indicate that interleaved practice emerges as a viable learning technique suitable for teaching diverse and large groups of students in a classroom setting.

The Interleaving Effect for Language Learning Across Diverse Grammatical Tenses and Languages

Steven Pan, Sergio Rodríguez Flores, Michelle Kaku

To what extent does interleaved practice (or interleaving), wherein learners alternate between a series of to-be-learned topics, benefit the learning of diverse grammatical tenses and grammar skills from different Romance languages? In each of four experiments, adult participants learned to identify grammatical tense and conjugate verbs for two tenses in French or in Spanish (Experiments 1-3), or the same tense in French and in Spanish (Experiment 4). Across experiments, the two tenses learned varied in defining characteristics and degree of similarity with one another in terms of usage, meaning, and/or the spelling of verb suffixes used. Learning occurred across two weekly sessions and in either of two practice schedules: a conventional schedule wherein one tense was learned per session (i.e., blocked practice), or an alternative schedule that involved alternating between two tenses during and across each session (interleaving). On a delayed test, benefits of interleaving were observed for (a) tense identification ability, (b) verb conjugation skills, or both, and in the final experiment, (c) the ability to identify the language that best fit a sentence written in a specific tense. These results reveal that the benefits of interleaving for grammar learning do indeed generalize to at least seven grammatical tenses and three grammatical skills, and moreover, are not limited to grammatical tenses that are highly

susceptible to being confused for each other. From a practical standpoint, this study highlights the utility and generalizability of interleaved practice schedules to enhance second language grammar learning.

Fostering Source Evaluation Skills by Mixed Presentation of (Un)Trustworthy Social Media Sources

Roman Abel, Julian Roelle, Marc Stadler

In today's digital age, the ability to evaluate online sources is of utmost importance. Trustworthy and untrustworthy social media sources can be deceptively similar, with the key distinctions of expertise (based on professional qualifications) and benevolence (based on professional affiliations creating conflict of interest) being subtle. We investigated how the presentation sequence of social media sources in unsupervised inductive learning setting supports upper and lower secondary students' acquisition of source evaluation skills. 63 upper and 59 lower secondary students were prompted to identify key characteristics of trustworthiness while studying sources labelled as trustworthy and untrustworthy either interleaved (alternating sequence) or blocked (without alternation). We assessed learners' pace of recognizing the key characteristics of trustworthiness and perceived learning during the study phase, and their subsequent ability to discern trustworthy sources from the untrustworthy ones in terms of trust and use intention. Interleaving fostered upper secondary students' ability to recognize benevolence and elevated their trust and use intention for trustworthy sources, which was reflected in higher perceived learning scores. For lower secondary students, however, an unsupervised inductive learning approach resulted in low discrimination between trustworthy and untrustworthy sources, irrespective of the sequence. To support younger students with low social media experience, an important follow-up direction involves top-down learning approaches. The key distinctions of expertise and especially benevolence should be explained, illustrating how these can be discerned from source information, followed by interleaved (vs. blocked) presentation of (un)trustworthy sources for practicing.

Single papers - Pre- and In-Service Teachers x Technologies

Conceptual Change Among pre-Service Teachers - Unveiling Learning Styles Using Podcasts and Texts

Julia Götzfried, Lea Nemeth, Victoria Bleck, Frank Lipowsky

The learning styles myth is highly prevalent among (pre-service) teachers. Research has demonstrated that texts and podcasts, in which misconceptions are refuted and explicitly contrasted with scientific concepts, can effectively dissolve such misconceptions. By contrasting misconceptions and scientific concepts, cognitive conflicts are evoked, encouraging the reflection of one's beliefs. However, there is a lack of research on whether texts and podcasts differ in refuting pre-service teachers' misconceptions. Accordingly, this study investigated if conceptual change texts and podcasts have different potential for inducing conceptual change among pre-service teachers regarding their belief in the learning styles myth, compared to an expository information presentation. The experimental study used a 2 x 2 x 4 mixed-design (manner of information presentation: conceptual change vs expository; medium: podcast vs text; time: immediately before and after the treatment as well as four and eight weeks later). 105 pre-service teachers were randomly assigned to one of four conditions. Students' belief in the learning styles myth was measured immediately before and after the intervention and four as well as eight weeks later. As expected, the conceptual change conditions led to a stronger decrease in students' belief than the expository conditions ($p = .04$, $\eta^2 = .03$). Both media (text and podcast) were equally effective ($p = .56$, $\eta^2 = .01$, $BF_{01} = 31.47$). This study shows that podcasts and texts using conceptual change strategies can effectively dispel misconceptions about teaching and learning among pre-service teachers.

More Than a Feeling? – Insights Into how Teachers Select Explainer Videos

Felicitas Licht, Marie-Christin Krebs, Alexander Eitel

Videos are an increasingly popular instructional tool. Nevertheless, teachers should adhere to evidence-based video-design principles to select the (likely) most effective videos to ensure their successful implementation in class. Therefore, we investigated teachers' knowledge about effective video-design according to multimedia and emotional design principles, and whether they use this knowledge to select videos for their classroom during an online study with 161 in-service teachers ($M=16.39$ years teaching experience). When first asked about their usual selection criteria for videos, 60% reported using their own criteria, while 18% reported relying on their gut feeling only. Afterwards, they were presented with two learning scenarios as well as two videos each that either adhered to cognitive design principles, motivational design principles, or to neither of the two. When asked to select, 63% preferred a motivationally well-designed video over a cognitively well-designed one. In comparison to a video infringing design principles, 82% preferred a cognitively well-designed video and 57% a motivationally well-designed one. Regarding their selection rationale, 20% of teachers solely relied on their gut feeling. Overall, our findings suggest that evidence-based principles for effective video design are not sufficiently known and applied in educational practice. Consequently, a stronger focus should be placed on this in teacher education and training.

Opportunities and Hurdles of Video Usage in Flipped Mathematical Modelling Seminars

Mustafa Cevikbas, Gabriele Kaiser

This qualitative study explores the potential application of the flipped classroom (FC) paradigm, incorporating instructional videos, in a university seminar for pre-service mathematics teachers (PSTs) focusing on mathematical modelling. The research focused on the opportunities and hurdles of video usage in flipped modelling instruction. The study centers on the perspectives and experiences of 44 PSTs enrolled in master's programs at a German university. Employing instructional videos within a technology-enhanced FC framework, this qualitative case study adopts a multifaceted approach to data collection, including interviews, questionnaires with open-ended questions, and analysis of written documents from collaborative group activities. Findings suggest that videos used in FC show promise in mathematical modelling instruction, enhancing PSTs' understanding of the content and pedagogical approaches. Furthermore, PSTs enhanced their skills in creating instructional videos on modelling and evaluating video quality in terms of structure, content, and focus. Challenges identified include time-intensive content development, technical obstacles, and the need for motivation and training. Despite these challenges, the benefits of incorporating videos in FCs outweigh the drawbacks, offering potential for innovative enhancement of mathematical modelling instruction.

Willed and Skilled to Teach Mathematics with Technology? Relating Teacher Profiles to Technology Use

Timo Kosiol, Stefan Ufer

Teacher characteristics have been proposed as relevant factors for technology integration in educational settings (Knezek & Christensen, 2016). Meta-analyses support the important role of teachers for the effectiveness of technology use in classrooms (Hillmayr et al., 2020). The need to jointly analyze motivational and cognitive teacher characteristics has been emphasized (Holzberger, et al., 2021). Nevertheless, previous research focuses primarily on motivational characteristics as test instruments for actual technology-related knowledge as scarce (Petko, 2020). Person-centered analyses have been proposed to identify typical configurations of teacher characteristics, yet they mostly result in profiles that vary consistently over all included motivational indicators. Using a sample of $N = 234$ in- and pre-service teachers for secondary school mathematics, we investigate the added value of also considering actual technology-and-content-related knowledge for identifying typical configurations of teacher characteristics in a latent profile analysis. Results indicate that measures of actual knowledge contribute to the characterization of profiles allowing to differentiate profiles of low and average value beliefs according to different levels of knowledge. Based on a subsample of $N = 77$ in-service teachers, we find that profile membership is significantly related to the use of mathematics-specific tools, but not to the use of technology more generally for student-centered learning. Furthermore, profiles do not differ regarding the perceived availability of ICT resources at their schools. Implications for further research and professional development of teachers are discussed.