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Thematic Speech, Sub-Conference C2: Computer-Supported Collaborative Learning (CSCL)

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How to Better Understand the Collaborative Component in Computer-Supported Collaborative Learning:

Current Landscape, Challenges and Future Prospects

Dr., Docent Johanna Pöysä-Tarhonen
Finnish Institute for Educational Research
University of Jyväskylä, Finland

EDUCA
Education for the Future

Research Council of Finland

Finnish Institute for Educational Research | FIER

- A national centre for educational research, established in 1968.
- A multidisciplinary research institute based at the University of Jyväskylä; closely connected to the Faculty of Education and Psychology of JYU through teaching and research.
- Research areas:
  - **Learning Environments and Assessment of Learning Outcomes**
  - Higher Education as Pedagogical and Societal Phenomenon
  - Education, Working Life, and Lifelong Guidance
  - Education, Inclusion, and Sustainable Society

Overview of the speech

I. **Computer-Supported Collaborative Learning CSCL:**
   - Its origins and ‘three pillars’
   - Collaboration as the substance in CSCL research
   - Contemporary challenges in CSCL research
     - Focus on educational dialogues

II. **Collaboration as the substance: Case examples from collaborative problem solving (CPS)**
   - Joint attention behaviour in CPS
   - Commitment to collaboration during CPS

III. **Collaboration with AI**

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Part I: Computer-supported collaborative learning | CSCL

Origins and configurations of CSCL

- **Threefold integrated object of study:**
  - **Collaboration** concerning a **shared task**, involving the use of **technology.**
- **Theory diversity, reflecting interdisciplinary roots:**
  - No single theory dominates, multidisciplinary methods prevail.
- **Influence of elements:**
  - Changes in one element impact the others.

📖 e.g. Baker & Reimann, 2023, Stahl & Hakkarainen, 2021, Wise & Schwartz, 2017.

Three pillars of CSCL

Technology

Technological advancements redefine the role of computers in supporting and analysing collaborative learning.

Learning

Conceptualised from individual knowledge acquisition to collective knowledge co-construction, with emphasis from learning outcomes to learning processes.

Collaboration

Informed by multiple disciplines, collaboration spanning small group interactions, social networks, and communities including non-human agents, like AI.

Collaboration as the substance of study in CSCL

- Along the technological transformations, the question of **what qualifies as collaboration** remains central:
  - Collaboration involves individuals or groups working together to achieve shared goals and contribute towards a common purpose. While forms and contexts vary, effective collaboration remains active, intentional, and shared, relying on clear communication and meaningful participation from all members.
- **Continuous reconsideration of the concept of collaboration:**
  - Evolving definitions need to align with varying contexts and timescales.

📖 e.g. Dillenbourg, 1999, Järvelä & Rosé, 2023.

Contemporary challenges in CSCL

- Despite extensive research, what underlies successful collaboration remains a challenge:

a) **Widening gap between theories** and **data:**
   - Advanced tools now capture collaboration with unprecedented scope, scale, and granularity.
   - Data also becomes 'big' when interactions between a small number of participants captured in detail, across multiple modalities.
   - Many existing theories not designed for this type of data.

b) **How can such data inform theories of collaboration and learning?**
   - Danger of overlooking the **situated nature of cognition**.
   - The need to **integrate automated analyses with human analyses**.

📖 e.g. Baker & Reimann, 2023.

How to overcome challenges?
The quality of educational dialogues in the limelight

- **Educational dialogues** are at the core of understanding collaboration:
  - In evolving collaborative situations without common ground, dialogue becomes essential for joint work and learning.
- **CSCL context well-suited to study educational dialogues:**
  - diverse levels of data and capacity for observations.
- **Key question:**
  - How can diverse datasets, spanning multiple timescales and integrating automated and human analyses, be meaningfully combined?
- Calls for more broader **theorisation of educational dialogues in CSCL.**

📖 e.g. Baker et al. 2023.

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What would a broader focus on educational dialogues entail?

Educational dialogue seen as **empirical communicative exchange** (rooted on the present moment), or as **aspirational goal, an abstract ideal to be pursued**.

Focus of analysis on **development of collective thinking in and by dialogue.**

The smallest unit of analysis **exchange**.

📖 e.g. Baker et al. 2023

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II Case examples

How to better understand collaborative component during collaborative problem solving?

Case 1: Joint attention (JA) behaviour in CPS

Case 2: Joint action: Commitment to collaboration during CPS

📖 e.g. Pöysä-Tarhonen & Awwal, 2022, Pöysä-Tarhonen et al. 2020, 2021.

CoPSOI: Collaborative problem solving and online inquiry: Skills, processes and neural basis

- Aimed to provide new knowledge and explain differences in **CPS** and **online inquiry skills** as well as their **underlying processes.**
- Applied **research methods at multiple levels of explanation**: large-scale assessment study at classroom level, dual eye-tracking and neurocognitive studies.

Consortium project | Research Council of Finland

Research Council of Finland

Department of Psychology, JYU, PI Prof. Paavo Leppänen and Finnish Institute for Educational Research, JYU, PI Prof. Päivi Häkkinen

Collaborative problem solving | CPS

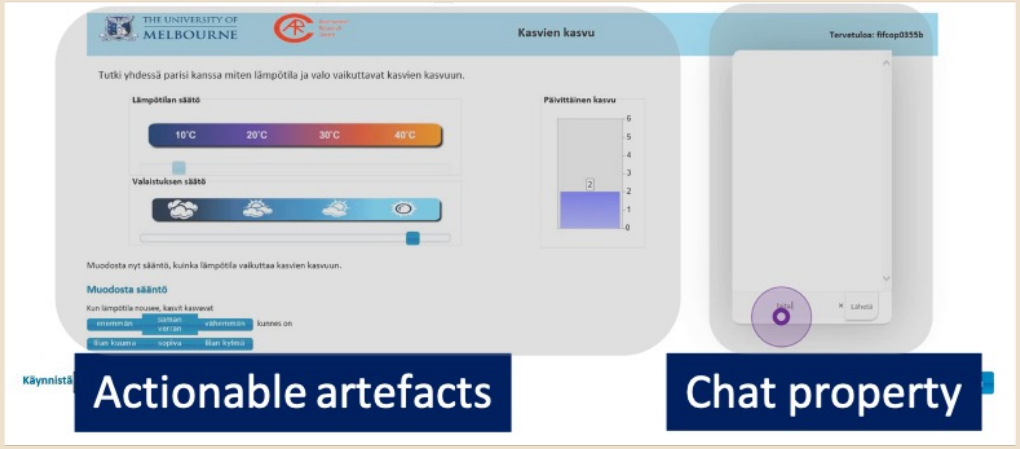
- Definitions of CPS emphasise that there is **a group goal to be accomplished through problem solving** and that **a single individual cannot solve the problem alone** or is much less prepared to do so.
- While cognitive domain, rooted in individual problem-solving approaches, well-understood, **dynamic nature of social domain, manifested in social interactions, remains a challenge**, especially in remote interaction contexts.

➢ How to unveil the complex social domain of CPS?

📖 e.g. Hesse et al., 2015, Graesser et al., 2020.

The context of case studies

- Digital CPS environment (ATC21S), based on **human-to-human approaches** for teaching and assessing CPS.
- Students work in dyads, **interacting remotely** (via free-form chat interface) to solve **open-ended problems** with **impersonal goals**.
- Tasks implement an overall structure of **asymmetry of resources**:
  - → Imposes need for collaboration.
  - → Requires participants to pool their knowledge, information, and resources.



e.g. Care et al., 2015, Pöysä-Tarhonen et al., 2017, 2018.

Case 1: Joint attention behaviour in CPS

Promising theoretical lens for revealing social aspects of CPS

- **JA foundational position of any social interaction.**
- **Closely associated with productive CPS**:
  - If joint attention is not achieved, it is less likely for the partners to establish common ground, take the partner's perspective, and build on ideas to solve problems together.

📖 e.g. Clark & Brennan, 1991, O'Madagain & Tomasello, 2019, Schneider & Pea, 2013, Tomasello, 1995.

What do we mean with joint attention?

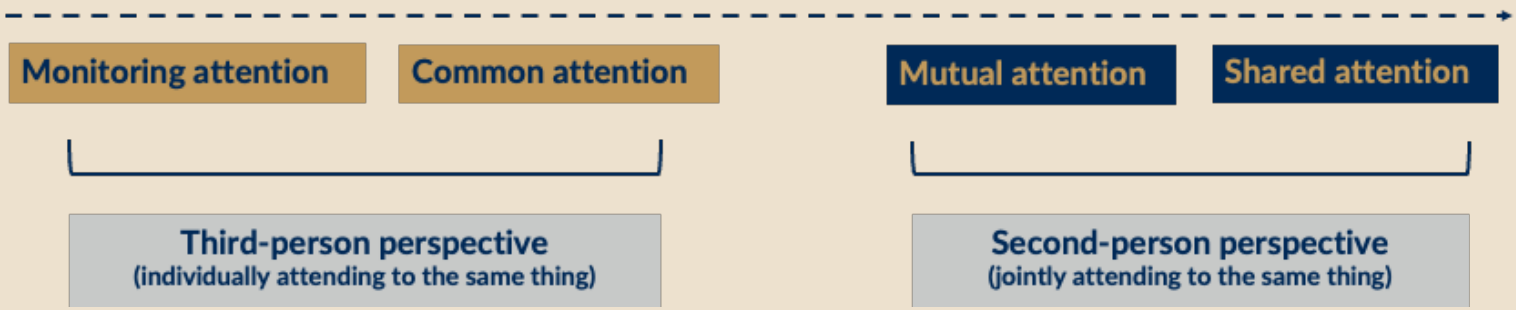
- A capacity to **focus together with another on an external source or object in the environment.**
- **The objects of attention can be observed at two levels**: as **external sources** or **events** or **mental, 'internal' contents**:

1) Diverse sensory inputs (visual, auditory)
2) Present, past, future events or mental states (ideas, plans)

📖 e.g. O'Madagain & Tomasello, 2019, Siposova & Carpenter, 2019.

Scale of jointness in joint attention

- Instead of a single state, **jointness** may come **in degrees**:
  - **A sliding scale connecting diverse 'intensities' of JA**, all of which are referred to as JA in the related literature.
  - Four levels of attention experiences: **monitoring, common, mutual, shared.**
  - All involve notion of **triadic relationship between self, other** and **object of attention**.



📖 Siposova & Carpenter, 2019.

What are the behavioural indicators of JA in this context and how to capture them?

- **Gaze following** promising **basis of JA**:
  - →The **coupling of eye gazing a proxy of lowe** and common), and possible **indicator** of **higher** shared attention) in dyadic interaction.
  - →To extract measures of **how partners focus on a** **on reference** while working on a shared CPS task.
- The significant **role of communication** in establishing jointness:
  - →Educational dialogues are analysed through **indicators of higher attentional levels.**

📖 e.g. Léon, 2022, Olsen et al., 2017, Siposova & Carpenter, 2019.

Can we make a meaningful link between eye-gaze data and and the specific higher-order construct of JA?

Objectives

Quantitative indicators of 'where-to-look'…

…for theory-driven qualitative analysis.

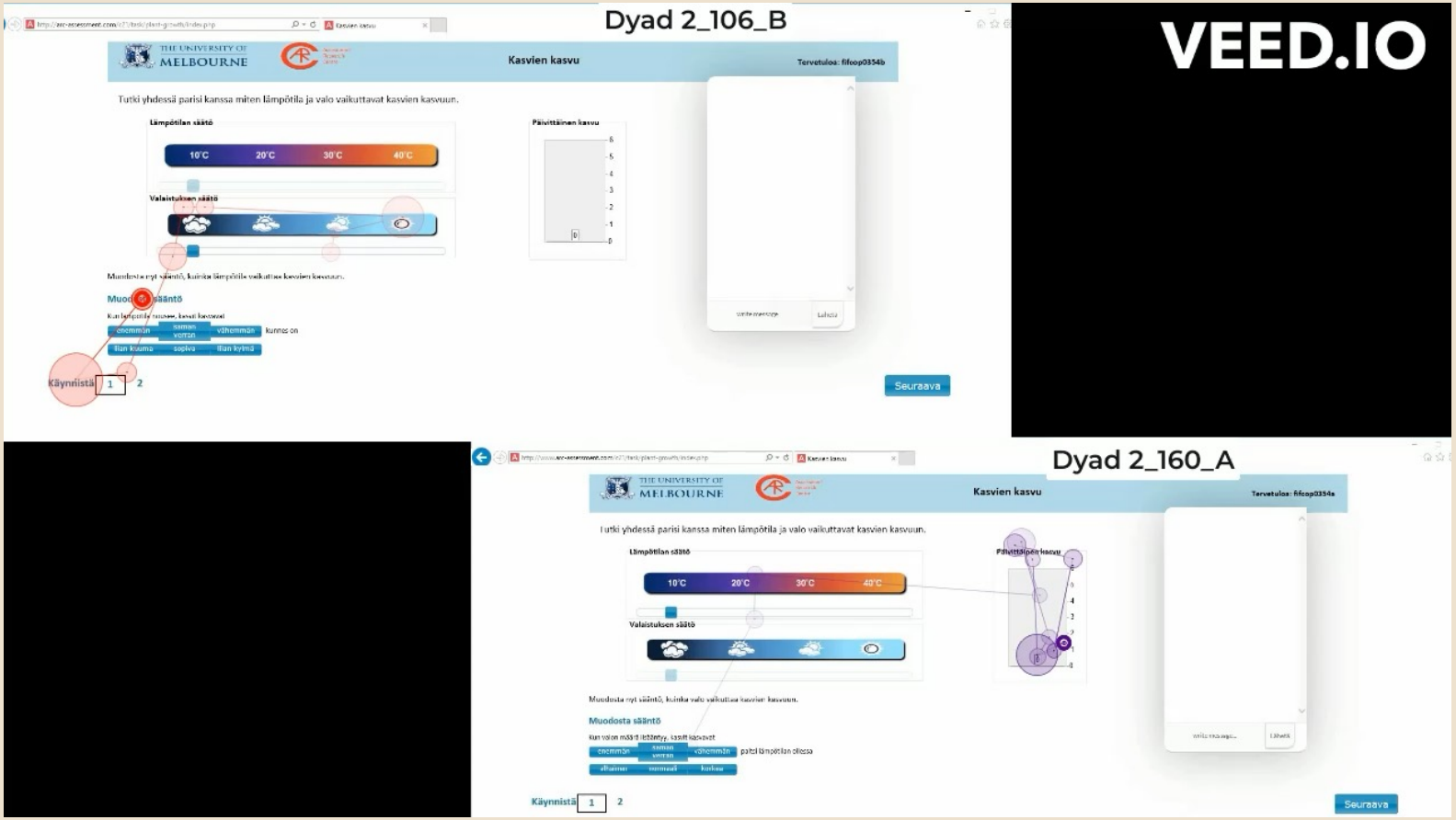
What is the **strength of the couplin** during the CPS task completion?

What is the **meaning** and **relevance of the measures of eye gazing** regarding the **actualised levels of JA behaviour** in dyadic interaction?

What kind of data was used?

- **Dual eye-tracking (ET) data** in remote CPS.
  - The dyads (students of 12–13-year-olds) solved problems in separate cognitive labs; **eye movements** were **recorded** with desktop eye trackers (screen-based).
- **The dataset:**
  - **Fixation data** (transformed into time series data, post-synchronised).
  - **Log files** (automatically generated time-stamped information of moving of artefacts as actions, verbal interactions via chat) (dyad level).
  - **Scan path video exports** (individual level).

Example of a scan path video export



The methods of analysis and how were they combined?

1) **Strength of eye-gaze coupling?**
   - **Cross-recurrence quantification analysis (CRQA)**, Recurrenc
     - ➢ General measure that quantifies the strength of coupling
2) **Meaning** and **relevance of these measures** regardin **actualised levels of IA behaviour**?
   - **Qualitative analysis of interaction** (logfiles, eye-event video **focus on students' communicational exchanges** during CPS

Cross-recurrence rate served as a basis…

…for selecting dyads for qualitative analysis of interaction.

📖 e.g. Wallot & Leonardi, 2018.

Results | The strenght of eye gaze coupling

Cross-recurrence rate (RR) the central measure (i.e. the percentage of cross-recurrence fixations)

Dyad	RR (%)	DET (%)	Lmax	L	ENTR	LAM (%)	TT	Time (s)
2	33.93	79.80	27	4.07	1.91	86.73	5.22	569
4	20.91							60
5	29.78							
6	25.24							
7	28.27							
8	34.34							
9	22.52							0
10	23.21							
11	29.02							
12	31.39							
13	32.10							8
14	19.02	58.96			1.46	73.19	3.96	262
Mean	27.48	72.26	21.92	3.87	1.77	83.62	5.43	449.00
SD	5.19	8.83	7.42	0.54	0.23	7.24	1.05	334.80
High	32.67	81.09	29.34	4.41	2	90.86	6.48	
Low	22.29	63.43	14.5	3.33	1.54	76.38	4.38	

The relation between theory and data:
What level of understanding is sufficient here?

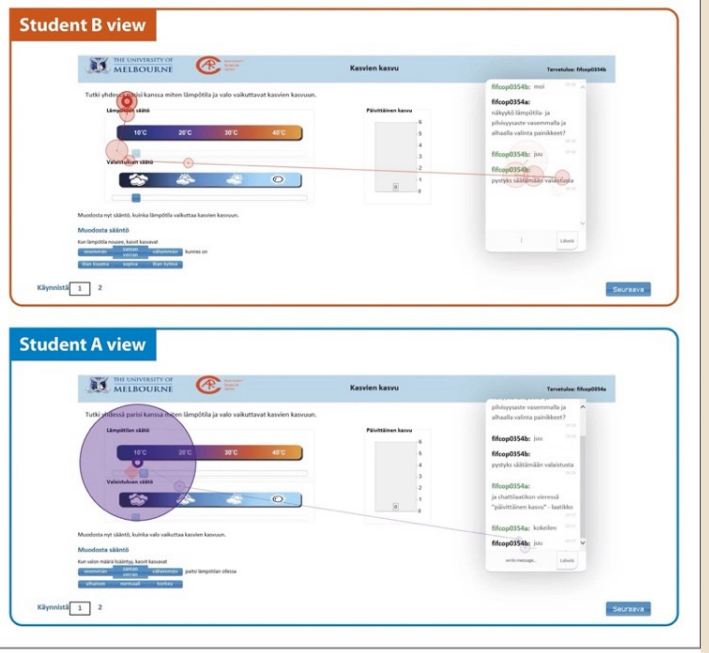
Dyad	RR % Means (Levels 1 and 2)
2	39.445
5	37.590
8	38.835

Results| Example of shared attention experience

Based on the highest RR measures, high-quality JA behaviour identified in all the selected dyads:

Sliding from mutual to shared attention experience during CPS.

Time	Role	Event	Verbal	Eye gazing (AOI)	Eye gazing (scan path view)
18.36	B	Chat	*Hi*	2	
18.36	A	Chat	*Can you see temperature– and cloudiness rate on the left and at the bottom selection buttons?*	2, 3a, 3b, 5	
18.36	B	Move-resource	*Brightness [as a response discovers the lightning control]*	2, 3b, 5, 2	
18.36	B	Chat	*Yep*	2	
18.36	B	Chat	*Can you adjust lightning?*	2, 3b, 3a	
18.37	A	Chat	*and next to the chat box the "daily growth" -box*	2, 4	
18.37	A	Chat	*I'll try*	2, 3a	
18.37	B	Chat	*Yep*	2	
18.37	A	Move-resource	*Temperature*	3a	
18.37	A	Chat	*I can adjust light*	2, 3b	
18.37	A	Chat	*No I can't*	2, 3b, 3a	
18.37	A	Chat	*Just temperature*	2, 3a, 3b, 2	
18.38	B	Chat	*Yes, I have it just the other way around*	3a, 3b, 2	



Takeaway from the case

Was there a meaningful link between different types of data and methods of analysis?

Quantitative measures made possible to zoom into complex phenomena of JA: Qualitative phase significant for contextualising quantitative findings.

- **JA behaviour** a **promising conceptual lens** through which to better understand the social domain of CPS.
  → To further **distinguish between different levels of JA behaviour critical** to understand the **actual quality of CPS.**
- **The CRQA measures prominent to identify productive social behaviour during remote CPS processes.**
  → All the selected dyads, with high RR values, showed **second-person relations during CPS task completion** (as mutual and shared attention).
  → Gaze data clarified understanding of CPS by affording additional evidence 'beyond' the actual interactional events visible in the log files:
  → **Made invisible moments visible** during CPS.

Case 2: Commitment to collaboration in CPS

- In CPS, to be successful:
  - →Participants need to **intentionally organise** themselves to a **coordinated activity.**
  - →CPS requires not only to share and process information to solve the joint task but also show **responsiveness** and **commitment** to their partner(s).

📖 e.g. Avry et al., 2020, Barron, 2000, Graesser et al., 2020.

Commitment as explict and implicit

- **Explicit** commitments:

→Arising via **speech acts** of **promising** or **making agreements.**

'If one social partner intentionally communicates to another that he intends to do X, and the other acknowledges this, then they have common knowledge about this interaction, and the first partner is committed to do X'.

- **Implicit** commitments:

→Arising via **expectations** and **motivations**, **slight nuances** of **verbal communication,** or **nonverbally**.

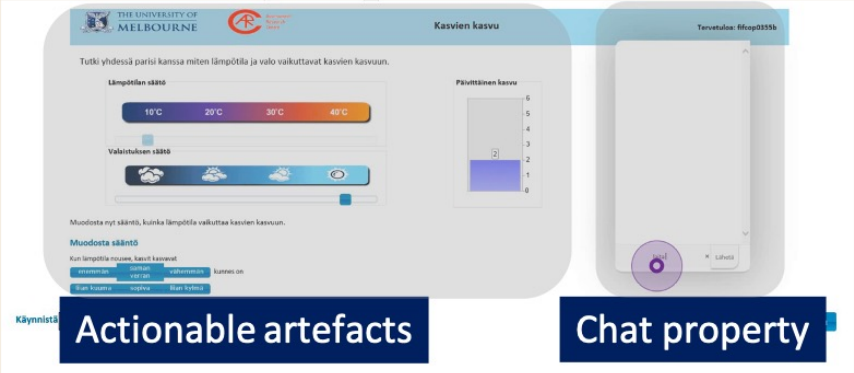
📖 Siposova et al., 2018, Michael et al., 2015, 2016, Michael & Salice, 2017.

A conceptual vantage point: A minimal structure of commitment

- A situation where exists **an outcome** or **goal of action** that an actor needs to achieve.
- The **external contribution of** a **second actor** is **crucial** to **bringing about the goal**.
- This **situation** may **elicit** a **sense of commitment** on the part of one or two actors, or when both actors desire to reach the goal, the commitment is **mutual**.
- Critical for commitments to arise is that the **goal** of action **defined** primarily in an **agent-neutral manner**.

📖 e.g. Michael et al., 2016, Michael & Salice, 2017.

How does the digital CPS environment fulfil the conditions for a minimal structure of commitment?



- Dyads interact remotely to solve **shared, open-ended problems** with **impersonal goals**.
- Tasks implement an overall structure of **asymmetry of resources:**
  - imposes need for collaboration and requires participants to pool their knowledge, information, and resources.
- Each individual action is only effective if the other action is also performed.
- To successfully solve a task requires both the participants' **commitment to the task** and **commitment to their partner.**

Objectives

- How **commitments** and **successful CPS processes come together in remote dyadic interaction?**
  - →How **interactional events of the log files are related to each other in terms of the speech acts of promising or making agreements?**
  - →**Appearance** of the **task-specific CPS elements** in these events?
  - →**Significance of CPS events** in this regard?

What kind of data was used?

- Student dyads were solving problems in separate cognitive labs; **eye movements** were **recorded** with desktop eye trackers.

- **Objective measures** based on the information embedded in automatically generated log files from the CPS environment.
- **Subjective measures** via **cued retrospective reporting** (CRR) **interviews** of individuals, cued with a stimulus video (**eye gaze video exports).**

How were the methods of analysis combined?

Preliminary phase:	
Quantitative summaries (log files).	Number of dyadic activities, total time in task.
Phase 1:	
Identification of **explicit commitments in students' exchanges.**	Verbal references, **promising** and **making agreements as exchanges** (log files)
Phase 2:	
Process qualities regarding CPS.	a. Detecting **behavioural indicators of CPS** (specific to the task) (log files). b. Analysing exchanges based on their **significance or insignificance** to task completion.
Phase 3:	
Identification of explicit or implicit commitments in students' experiences.	Verbal references (**verbalised motivations**, **expectations**, **expressions of trust**) CRR interview data

Episodes of the CPS processes, building on the log file data, notated with evidence from different phases of analysis and different perspectives (i.e. dyad and individual levels)

Results | Case: Two contrasting solution paths

- Quality of the various aspects came together in **two diverse, contrasting solution paths**, named ‘Low coordination condition of CPS’ and ‘High coordination condition of CPS’.
  - Substantial differences regarding **quality** of **actualisation** of **CPS processes** concerning **all the aspects of analysis**.
  - Comparison nicely underscores diverse dynamics and quality that can emerge in open collaborative problem solving scenarios.

Low coordination condition of CPS | Dyad 1

Logfile data:

Line	Student	Activity		Time	R… H… (…		…ant
193	**A**	**Type message**	**But try still those other points**	23.52.37	i…		
194	**A**	**Type message**	**Set that 2**	23.52.40			
195	B	Light input	temp: "20 degrees"; light: "quite dark"; growth: 2mm	23.52.43	r…		3-195
196	A	Temperature input	temp: "10 degrees"; light: "quite dark"; growth: 1mm	23.52.43	i…		
197	A	Temperature input	temp: "20 degrees"; light: "quite dark"; growth: 2mm	23.52.45			95, 197
198	B	Light input	temp: "20 degrees"; light: "quite bright"; growth: 3mm	23.52.46	i…		
199	A	Temperature input	temp: "10 degrees"; light: "quite bright"; growth: 1mm	23.52.49	initiating	Action	
200	B	Light input	temp: "10 degrees"; light: "quite dark"; growth: 1mm	23.52.50	initiating	Action	Insignificant: 196, 200
201	A	Temperature input	temp: "20 degrees"; light: "quite dark"; growth: 2mm	23.52.51	initiating	Action	Insignificant: 195, 197,201
202	A	Temperature input	temp: "30 degrees"; light: "quite dark"; growth: 3mm	23.52.53		Action	

Explicit/implicit commitments rare or missing

Cued Retrospective Reporting (CRR) Interviews:

Student A:
'Then **I** at least **had fully forgot at this point that we might have the different things** there although **there might just be some discussion about it in the beginning**, or in a way so that there can be same or different stuff, so then the **initial assumption was that the same things are actually displayed to both**, the same things. Or one somehow thought that also the question is the same at this point when we were still starting to solve this.'

Student B:
'Er, so that I **didn't realise it at first that it's sort of different, for both of us**. So we noticed it together only at some point, we had proceeded quite far already with this and then **we realised that (oops) I cannot do like it**. That we have a different question. So we realised this fairly quickly that we have different controls. But **we discovered then only later that we didn't have the same question**, after all, what we were looking for. So that we **needed to collaborate differently** from the first one.'

- Dyad 1 **set out plans** for solving the task, but **did not systematically coordinate** their **actions** in accordance with the plans: **explicit commitments** (promises and agreements) **not made.**
- Dyad 1 did more trials than Dyad 2, spent more time on the task, **repeating similar, insignificant activities without acknowledging solution path.**
- CRR interview data suggests that Dyad 1 commenced the task **without** a **comprehensive picture of the problem or a plan on how to collaborate.**

High coordination condition of CPS | Dyad 2

- Dyad 2 constantly interacting by **sharing information** to **build** a **mutual understanding** of the **problem space**:
  - Set out a plan and proceeded systematically with the trials.
- Made **explicit, mutual commitments** to **coordinate** their **actions**.
- Even though spent less time on task, with fewer trials than Dyad 1, activities consisted of larger number of **significant activities** regarding **efficient solution paths.**
- CRR interviews shed more light on the **agreements made between partners** and how they **expressed trust** in their partners.

Logfile data:

Line	Student	Activity				ignificant activities
519	**B**	**Type message**	**30**			nt: 519-523
520	**A**	**Type message**	**Shall we put 30c**			nt: 520-529
521	A	Temperature input	temp: "30 degrees"; light: "very growth: 1mm			nt: 521
522	**B**	**Type message**	**Yes**			
523	B	Light input	temp: "30 degrees"; light: "quite growth: 3mm			cant: 523, 526
524	**A**	**Type message**	**Show the temps**			nt: 524-530
525	B	Light input	temp: "30 degrees"; light: "very growth: 1mm			cant: 525
526	B	Light input	temp: "30 degrees"; light: "quite growth: 3mm			
527	B	Light input	temp: "30 degrees"; light: "quite bright"; growth: 4mm			
528	B	Light input	temp: "30 degrees"; light: "very bright"; growth: 6mm	01.08.59		Action
529	**B**	**Type message**	**30: 1,3,4,6**	01.09.07	initiating	Collecting info: B

Dyads demonstrated predominantly explicit commitments to their partner

Cued Retrospective Reporting (CRR) Interviews:

Student A:

'Well but then we started to study what we can see there**. I noticed that there are two such slide controls** there and here I might just read those also the instruction quickly and about observing what's the daily growth here and I tried to get it adjusted [pause] the **lower slide control even several times I tried, it didn't work**. I wondered that if there is now some fault here. Well, **[the partner] then commented there that you apparently put it to 30 Celsius there and I replied that yes that's right**. [pause] And soon we did find out that – we have this kind of situation that **we can adjust them contrastedly, or we can't adjust both at the same time**.'

Student B:

'And started to investigate and there then, the partner already adjusted those temperatures onwards. And I asked that you apparently like changed them. And then **we noticed really quickly that like [pause] he has the other control and I have the other control what the partner then hadn't then**. But like the same screenview **– there in the upper section of the page anyway**. And then **I asked the partner to keep it stable**, to set it back to 30 there, so that **we reach a certain systematic approach there.** And then well we increased them one by one. This amount of light, or I increased then and well, listed them then – **we noted there on chat that it's better to leave a kind of clear memory trace to which we can return when needed** and what was like working well so we wrote there that.'

Takeaway from the study

The connection between theory and data?

Problems with sensitivity of different data sources in understanding theoretical construct.

Intra-individual measures needed

- When performing joint actions together that require long-term thinking and communication about the joint activity, **role of language, intentionality**, and **commitment** become crucial.
  - Critical when participants not aware of the details of other participants' actions, or they are separated in time or space from their partners.
- Processes essential to successful CPS such as conjoined effort towards elaborating 'joint problem space' and expressions of shared intensions **vulnerable** and **uncertain**:
  - Can endanger mutual predictability in efficient coordination of joint actions, required in successful CPS.
- **Commitments**, if credible, can **reduce the uncertainties related to the fulfilment of joint goals,** facilitating the planning and coordination of joint actions.

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Part III: Collaboration with Artificial Intelligence AI

Potentials and challenges of collaboration with AI:

- Actual need for tailored support by AI agents due to challenges in teachers' individualised support in large classrooms.
- **How generative AI tools can be utilised by users for knowledge co-construction, to inspire a collective endeavour in developing new insights?**
- It is expected that argumentative dialogues between humans and AI tools, with appropriate prompts, can foster emergent processes of joint knowledge construction:
  - **A need to better understand the contributions of both human and AI (non-human) participants in collaboration.**

📖 e.g. Cress & Kimmerle, 2023.

Current understanding and research gap

Cognitive benefits of conversational AI in learning situations (whether as peers or teachers) well documented.

A deeper understanding of social dimensions needed (e.g. in dyadic interaction).

Inspired by Human-Computer Interaction (HCI) and usability studies.

Human-AI collaboration: 'Decentring' the human

- Focus on **human–non-human collaboration** (e.g. with chatbot, simulated conversation agents) in collaborative learning.
- **What does collaboration mean in this context?**
  - Dynamic interplay between human (learners) and non-human actors to co-create understanding and collaboratively solve problems.
  - Human actors influence these processes, but so do the non-human actors by providing e.g. interactive feedback.

📖 e.g. Vasconcelos et al. 2023.

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Posthuman lens

📖 e.g. Giaccardi, 2020, Nicenboim et al. 2023

Move beyond traditional focus on 'users' and 'products'.

Emphasis on 'relations' and 'ecologies' of human–non-human interactions.

Recognise entangled agency of human and non-human actors.

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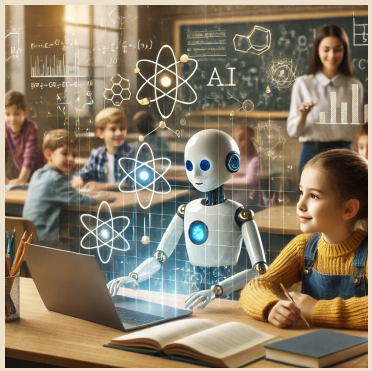
Challenges in design

Bridging theory and practice



📖 e.g. Nicenboim et al. 2023.

How to include non-human agency in design processes?

How to recognise multiple 'voices' and contributions from AI agents?

Challenges in bridging theory and practice: Application in STEM learning?

References:

Thank you for your attention !

johanna.poysa-tarhonen@jyu.fi

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ