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CSCL has come of age

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Origins and orientations

We would like to use this opportunity to thank the previous Editors-in-Chief of the journal, Carolyn Rosé and Sanna Järvelä, once again for their service and for shepherding our journal through some challenging times. We are particularly grateful that both of them have joined the Executive Editors team, helping us learn the ropes and provide strategic advice. We would also like to thank two other past editors-in-chief, Sten Ludvigsen and Gerry Stahl, who have generously given us their time and advice. It will certainly be challenging to uphold the very high academic standards of the journal, but also its sheer intellectual vitality, that were firmly established by our predecessors.

We take over the co-editorship of this journal at a juncture when CSCL research has come of age. If we accept, as Tim Koschmann suggested in the mid-1990s (Koschmann, 1996) that CSCL was an "emerging paradigm", then — not least thanks to the efforts of the founding editor of ijCSCL, Gerry Stahl — almost thirty years later the field could be said to have matured into what Kuhn (1962) termed "normal science". This would mean that researchers in this field are now like worker bees, feeding a hive of established problems, methods, theories and results. Note that those last four terms are plural: there is not, nor do we think there should be, one theory (nor method) to rule them all (cf. Wise & Schwarz, 2017; Rummel, 2018). CSCL research is characterised by the three-fold nature of its integrated object of study: *collaboration*, with respect to a more or less shared *task*, involving use of *technology*. CSCL studies the elements of this object, and relations between them; a change in one has repercussions for the others. Our object of study changes with society and its technologies, and it is common knowledge that such changes have accelerated, involving qualitative shifts, over the past thirty years. None of the three key terms is neutral, each of

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them being highly theory-laden — for example, 'task' can be conceptualised as a problem solving goal, a learning object, the object of activity, etc. (see Stahl & Hakkarainen, 2021). We shall dwell briefly on each of the three elements, from their beginnings, in order to see what is currently emerging in CSCL research.

As the swansong of the two previous editors of this journal maintains (Järvelä & Rosé, 2023), the question as to what counts as collaboration is still a vital one. Ways of characterising it — as quasi-synchronous joint agency directed towards elaborating a shared representation of a problem — were proposed during the 1990s (Roschelle & Teasley, 1995; Dillenbourg, 1999). Today, we are in a situation where the concept of collaboration needs to be continually rethought, for a number of reasons. Alternative theoretical approaches to cognition and action (distributed, situated, embodied, mediated, …) either reformulate or else recuse the concept of representation and what it means for representations to be shared. Collaborative learning across sites, varied timescales (Ludvigsen et al., 2011), as well as mass collective activities in online education, also require new conceptual realignments. CSCL enables the collaborative interaction to become a 'substance', to be moulded by scripting, to be reflected upon and analysed by the various social actors concerned. Turning to the task around which collaboration is put in place, it must be said that early work in CSCL was dominated by STEM, Science, Technology, Engineering and Mathematics. It makes a difference all round to have extended the collaborative learning situations under study to more open-ended domains, where creativity is required, as well as to tasks involving complex manipulations (see the article by Keune, in this issue) and reflection on the very nature of social relations in society. The task can also be collaboration itself. It might be said that these are the types of activities to which collaboration is most adapted.

Finally, technological change has rightfully revolutionised the field of CSCL, and such changes have not yet been completely played out (if they ever will be). To state matters simply, at the outset of CSCL research in the mid-1990s, the technologies under study were mostly hand-crafted laboratory network tools, being used during a period when the Internet had not reached most areas of society. Just to put things in perspective, it may be useful to recall that "TheFacebook" was launched in 2004, then "Facebook" one year later. Computers, mobile phones, tablets, wearables, VR, and so on are now an ordinary part of everyday life, and to some extent our learners under study have co-evolved with these technologies. Although, according to the culture involved, changes in society may be more or less far reaching, education can not ignore this. Therefore, not only does a greater amount of communication and interaction take place via these technologies, giving us a broader field of study, but the way that they mediate, shape collaboration raises new questions (see, for example, Silseth et al., this issue, on collaboration mediated by Virtual Reality). And technology can be turned back on itself: a growing proportion of CSCL research is concerned not only with studying technology as a mediator of collaboration, but also with how it can be used as a means for analysing it automatically. Natural language processing research has made such significant advances (see the work of the previous editor of this journal, C. Rosé, and her colleagues) such that automatic real-time analysis of collaboration, to provide feedback for learners and teachers, becomes a realistic possibility.

CSCL has come of age. Its foundations in terms of the triadic object of study 'collaboration—task—technology' are firmly established, yet in constant evolution. Given the complexity of this research object, it is necessary to reaffirm and reinforce the multidisciplinary and interdisciplinary nature of the field that studies it (cf. Hmelo-Silver & Jeong, 2021).

Theory, method and experimental field are connected by an underlying epistemology, a theory of what counts as scientific knowledge and how it can be acquired in a reliable manner. This must be plural here too, going beyond description/explanation-oriented research to include design science and, in order to avoid redundancy, establishing links with 'sister' fields, such as those concerned with small group research, collaborative work, design, creativity and even areas of pragmatics such as argumentation studies. We need also to be vigilant about the possible dilution of research approaches that become 'lost in interdisciplinary space', by maintaining an equilibrium between the rigour of analyses of technology-mediated collaboration on an epistemic level, and their capacity to approach data and human experience as closely as possible.

Below we sketch out three more specific tendencies that we would like to nurture, described in terms of three 'Cs', for 'Connections'.

Three connections

Connecting theory with design

A characteristic of the Learning Sciences, including CSCL, is the orientation towards design-based research (DBR; Barab & Squire, 2004; McKenney & Reeves, 2019). In an influential paper, Collins (1992) argued that educational research should adopt the methods of design sciences rather than analytical sciences, that it is more like aeronautics than psychology. The idea behind DBR was that designed interventions allow rigorous (read: experimental) research to be conducted in authentic settings while acknowledging the situated nature of learning and cognition: "Design-based research (…) was introduced with the expectation that researchers would systemically adjust various aspects of the designed context so that each adjustment served as a type of experimentation that allowed the researchers to test and generate theory in naturalistic contexts." (Barab & Squire, 2004, p. 3). Despite the methodological critique as a weak experimental method (e.g., Kelly, 2004), DBR has rapidly been taken up and to this day serves as the methodology for many, if not most, empirical studies in the Learning Sciences. But the question remains as to how such a putatively poor experimental method can serve as the methodological foundation for advancing learning theories and be more than a convenient method for formative evaluation ("A/B testing"). A related question is what constitutes a theory in the Learning Sciences and CSCL.

The Learning Sciences are not the only discipline that has debated the role of design(ing) for producing scholarly knowledge. Deserving specific attention is the development of Design Science Research (DSR) in the Information Systems community. This work is communicated in high-impact journals (such as MIS Quarterly), conferences (such as DESRIST), textbooks (e.g., Johannesson & Perjons, 2021), and guidelines (Van Der Merwe et al., 2020, for instance). Foundational to DSR are: (i) artefact design and (ii) the creation of abstract knowledge in the form of design theories (Hevner et al., 2004). Design theories are typically mid-range theories that account for why the artefact works, under which circumstances and for whom (Gregor & Jones, 2007). These two forms of knowledge stand in a productive relationship to each other: abstract theoretical knowledge contributes to design practice; the enacted design process along with the created artefact and observations on its use provide empirical data for informing theory.

While DBR has mainly been conceptualised in the tradition of natural and behavioural sciences as a variant of descriptive-explanatory research, DSR aligns itself with pragmatism (Garrison, 1994): it explores a world to-be, starting from an analysis of the world as-is (Goldkuhl, 2012). As such, DSR creates knowledge about the possible (prospective knowledge). The prospective knowledge orientation goes hand in hand with a normative concern: the world to-be is not only a possible world but also a desirable one. In other words, the epistemic concern for truthfulness is joined by the normative concerns for utility and usefulness. Rescher (2000) puts it this way: "a pragmatism…that cares not just for the efficiency of means but for their appropriateness, which is a matter of combining a whole range of evaluative factors: not efficiency and effectiveness alone but also their broader normative nature" (2000, p. 175). Importantly, it is not only the designed artefacts that should create utility and be useful to those who grapple with the problem addressed; abstract knowledge — the design theories — should also have value, ideally beyond local practice (Gregor & Jones, 2007).

We propose that the epistemic position put forward by DSR — that knowledge is possible and valuable not only in abstract form but also in the form of artefacts — could be productive for CSCL research as well. Of particular relevance to CSCL are computational artefacts, with the instantiations taking the form of implementations. Other forms of artefacts developed in CSCL research are design documents and models (e.g., wireframes), collaboration scripts, teacher manuals, worksheets, protocols for (reproducible) data analysis, etc. But not all artefacts are equally valuable; good designs need to be motivated by a deep understanding of the problem they address, the needs and concerns of the stakeholders, and a rigorous analysis of existing solutions, including where they fall short (Hevner et al., 2004; Peffers et al., 2007). Furthermore, designers should follow an established design method and document all steps, providing reasons for deviating from established methods. Design methods suggested in DSR are iterative, with a strong focus on demonstration (prototyping) and formative evaluation (Venable et al., 2016). While this bears similarities with design-based research as conducted in the Learning Sciences — in particular, co-design (Roschelle et al., 2006) — it needs to be stressed that an artefact is more than an 'experimental condition' or 'intervention'; artefacts should be useful tools in the service of authentic practices and thus part of the socio-technical infrastructure affecting people's lives.

Analytical sciences such as psychology and sociology, continue to be relevant for CSCL, as their mid-range and 'grand' theories inform problem analysis and design, and as data produced in the course of designing and using artefacts are being used to revise and advance the theoretical knowledge base. The DSR methodology provides CSCL with a model for conducting design-based research that connects Computer and Information Science with the Learning Sciences and that, through its foundation in philosophical pragmatism, extends concerns for truthfulness and effectiveness with a normative-ethical dimension (utility, usefulness, appropriateness, equity). Consequently, we invite papers that employ a design science stance to address problems of collaborative learning. Authors may consider using a Short Paper format, soon to be made available in ijCSCL, in cases where a design project is not yet comprehensively evaluated but includes innovative and useful design ideas and artefacts.

Connecting theory with data through models

We observe a widening gap in CSCL — as in other behavioural research — between theories and data. Progress in instrumentation has enabled the capture of collaboration of unprecedented width (duration, number of participants), breadth (multi-level and -modal), and depth (granularity) (Reimann, 2019). The availability of multimodal data with high temporal granularity leads to the question of how this can inform theories of collaboration and learning. The problem is that most of the (psychological, for instance) theories we use in CSCL have not been conceived of with this kind of data in mind. They do not predict/explain unaggregated behavioural data such as event sequences, only changes in aggregated variables. They do not account for the situatedness of cognition and interaction, but abstract away from context. They are (meant to be) tested with statistical models for linear relations that cannot account for feedback relations in dynamic and complex systems.

Whilst qualitative methodology suffers less from these consequences of 'variable-ism', it is as much affected by the granularity gap. Data does not only get "big" in the sense of a large number of participants; data also gets big when interactions between a small number of participants are recorded in detail in multiple modalities (e.g., Nguyen et al., 2023). This is not new to researchers who have been conducting conversation and interaction analysis, building on data with high temporal resolution. Using sophisticated data analysis tools and methods has always been part of the answer (see for instance software such as Elan - https://archive.mpi.nl/tla/elan - for audio- and video analysis). The quantitative analysis of sequential data has also been tackled early on in CSCL, with advanced stochastic methods such as Hidden Markov Modelling (Soller, 2004; for an overview see Chiu & Reimann, 2021). Recently, we have seen the rise of dedicated data mining methods ("collaboration analytics", Martinez-Maldonado et al., 2021) targeting the challenges of big data in (not only, but also computer-mediated) collaboration.

IJCSCL will continue to provide a forum for methodological papers. Indeed, we would like to see *more* papers on computational methods for the analysis of technology-mediated collaborative learning! For instance, we welcome submissions using theory-guided computational modelling. Modelling as the epistemic strategy for linking more or less general and abstract theories to high-resolution data has been extremely successful; arguably, all modern sciences are modelling sciences (Magnani & Bertolotti, 2017). This is because theories cannot do all the explanatory work on their own. Theories can and should provide key concepts and mechanisms, but theoretical *models* are needed to explore the implications of theoretical assumptions for (interaction) behaviour and for making contact with (behavioural) data eventually (Ylikoski & Aydinonat, 2014). Examples of the use of computational models in social science can be found in journals such as JASSS (Journal of Artificial Societies and Social Simulation).

Methodological advancement can also contribute to reducing the divide between the quantitative and qualitative approaches to learning (technology) research. The analysis of interactions, dialogues, and discussions produced in collaborative learning situations, involving learners, teachers and other social actors (e.g. parents, experts) is at the heart of CSCL. And yet our field still suffers somewhat from a false dichotomy between "experimental research" versus "qualitative analysis", where rigour is only seen to apply to the former, not the latter ("analyses" of interactions often lack systematicity, being reduced to simple 'accounts' of what was said). We shall be especially vigilant, therefore, with respect

to the rigour of analyses of social interactions presented in papers. In particular, an area of work to be encouraged concerns the definition of the unit of cognitive analysis of social interactions (see Baker et al., 2021).

Connecting CSCL research with educational practice

How can CSCL research be conducted and communicated so that it is useful to educators, amongst which teachers, trainers, instructional and learning designers, e-learning specialists, and technology developers? More ambitiously: how can research knowledge contribute to transforming educational practices? Given how widespread collaborative learning has become, a huge number of practitioners could benefit from CSCL research.

Publication of research syntheses and literature reviews is helpful but only part of the answer, as research on knowledge brokering and knowledge mobilisation in education (related terms in other disciplines are knowledge translation, knowledge transfer, and research utilisation) has shown (Rycroft-Smith, 2022). Referring to "the multiple ways in which stronger connections can be made between research, policy and practice" (Levin, 2011, p. 15), knowledge brokering has been conceptualised using linear models (e.g., research synthesis read by practitioners), relationship models (such as networks and partnerships), and systems models (co-creation of knowledge, co-design of learning resources). Linear knowledge transfer (such as research publications tailored to practitioners) has proven successful only for bounded problems with relatively clear solutions. More successful for mobilising knowledge are forms of "collaborative entanglement" (Mosher et al., 2014), such as research with a design science stance (co-design). Whatever strategy is chosen, knowledge brokering needs to be grounded in an analysis of the specific barriers to research use.

It is challenging for a journal to go beyond the linear transfer model; 'publishing research knowledge' is by necessity a one-directional form of communicating with practitioners. What we can do is encourage submissions that report research on knowledge brokering/mobilisation of CSCL research: studies on how CSCL research knowledge is communicated to inform policy and practice. We also invite studies where computer-mediated collaboration is used as an *instrument* for knowledge brokering in an educational context to support "collaborative entanglement". Here also, the (soon to be made available) Short Paper format is intended to provide a publication avenue for work that can report on design and formative evaluation, whilst the normal paper format might be more suited for more comprehensively evaluated projects.

As we see it, the three connections reinforce each other: as more useful CSCL designs get used more often in real educational settings, their use produces more rich and dense interaction data. This in turn requires more powerful analytical methods, making the findings more relevant for practitioners and for researchers alike, the latter being provided with the means to advance learning theories and models.

Highlighting the research articles in this edition

The four articles in this issue contribute on one hand, to our understanding of how specific technologies and materials that are the focus of learning, are integrated into collaborative processes. Silseth et al. describe how immersive Virtual Reality can become a resource for collaborative meaning making. Keune analyses computational collaborative learning with fibre crafts (weaving) from a posthumanist perspective, where such materials are seen as active agents.

On the other hand, the articles by Park et al. and by Chen et al. contribute to the body of research on approaches to analysing collaborative interactions. The first article in this group proposes "stance" as a unit of analysis that integrates participants' relations to the discursive object and to each other. The second explores the phenomenon of group awareness.

New mediating objects and technologies

In their article, Silseth, Steier and Arnseth address the question of how students' immersive experiences in Virtual Reality (VR) technologies become resources for collaborative meaning making and learning. An authentic classroom situation was designed in collaboration with teachers, integrated into the Norwegian curriculum for secondary school students (17–18 years old) on "Health and life skills", and the specific topics of inequity, prejudice, respect and tolerance. The study centred on the VR film "Travelling While Black" (TWB), that narrates how African Americans experienced racism. After a whole class lecture, students watched the film individually, using Head-Mounted Displays, then engaged in small group, teacher facilitated, reflective dialogues. Analysis focused on students' references to features of TWB and their general immersive experiences, drawing on the theories of situated and embodied learning (e.g. Danish et al., 2020). Students described their experience of 'being there' together with the people they encountered in the film, of feeling part of the ongoing situations. They evoked their own bodily responses (such as having "a knot in [the] stomach"), as well as those of people in the VR film. Teachers adapted the type of guidance that they gave with respect to the emotional responses mentioned by the students. This research makes an important contribution to research in CSCL by showing how VR can provide important resources for shared meaning-making and learning, by a process of "emancipatory immersion" (Enyedy & Yoon, 2021).

The paper by A. Keune, on learning with fibre-crafted algorithms, delves into the intersection of fibre crafts and computational learning through a posthumanist lens, emphasising the role of materials as active agents in collaborative processes. By analysing video data of youth engaging in fibre crafts, the study uncovers how human-material interactions produce algorithmic outcomes and evolve over time. The research highlights the significance of recognising materials as collaborative actors in computational production, shifting the focus from individual mistakes to productive variations. Through fine-grained video analysis, the study captures the dynamic relationships between humans and materials, showcasing how algorithmic ideas are physically manifested through craft projects. The findings underscore the importance of considering human-material collaborations in computational collaborative learning, offering insights into how technologies and techniques emerge through these interactions.

Theorising the collaborative interaction

In the article entitled "Taking a stance in the process of learning: Developing perspectival understandings through knowledge co-construction during synchronous computer-mediated classroom discussion", Park, Schallert, Williams, Gaines, Lee and Choi present an innovative approach to addressing a foundational issue in CSCL research, that of analysing knowledge co-construction and meaning-making processes in online discussions. A strong point of this research resides in its theoretical and methodological integration. Firstly, of the psychological construct of "perspectival understanding" (e.g. Greeno & van de Sande, 2007) with the sociolinguistic concept of "stance" (du Bois (2007). Secondly, the concept of "stance" itself integrates in a single unit of analysis both interlocutors' positionings with respect to referential 'objects' and their alignments with each other's positionings, along epistemic, affective and evaluative dimensions. The evolutions of such stances are analysed in a corpus of online (CHAT) and classroom discussions involving graduate students enrolled on a learning theory course. Students most frequently expressed themselves within an epistemic stance, sometimes in combination with affective and evaluative stances. Signs of learning were manifest in the evolving shifts of main stance objects, where the conversation moved to a deeper level. The integrated analysis approach presented here reinforces the interdisciplinary nature of the field of CSCL research.

The paper "Effects of Group Awareness Support in CSCL on Students' Learning Performance" reports a meta-analysis for evaluating the impact of group awareness (GA) support on students' learning performance in computer-supported collaborative learning (CSCL) environments. The study included 45 articles reporting on 58 independent studies with 96 effect sizes. The results showed a moderate significant effect of GA support on students' learning performance, with a greater influence on cognitive development. Significant moderating factors identified were GA support type (behavioural, cognitive, social awareness) and group size. Behavioural GA support had the largest effect on behavioural participation, while cognitive GA support showed a higher impact on cognitive development. Larger groups benefited more from GA support compared to smaller groups. The study also found no significant differences in effect sizes across disciplinary domains, intervention durations, and educational levels. Overall, the meta-analysis provided valuable insights into the conditions under which GA support most effectively enhances collaborative learning outcomes in CSCL settings.

Concluding remarks

We proposed that CSCL research has come of age. As the impressive body of research assembled in the *International Handbook of Computer-Supported Collaborative Learning* (Cress et al., 2021) shows, a body of foundational theories, problems and methods has been established. And yet, it seems that the CSCL universe is still expanding, with new theoretical and methodological approaches being brought regularly into the field from others. Like educational sciences, CSCL is a 'science of synthesis'; and the process of integration seems unlimited. Beyond such interdisciplinary expansions, the specificity and unity of the field endure, given its focus on something that is perhaps obvious or even old-fashioned: we are concerned with technology-mediated collaboration, certainly; but with respect to the pro-

cesses of emergence of *meaning*, *knowledge*, *learning*. And there would be much to be said about change over the past thirty years in our visions of what counts as learning. We have sketched out a few additional possible directions in which the field could or perhaps should go, but we are no more able to predict which, if any, will be followed than we are able to predict the evolution of human societies and their technologies.

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