Forming social systems by coupling minds at different levels of cognition: Design, tools, and research methods

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Since its inception, the main interest in CSCL has been in describing and supporting the fine-grained processes that make collaboration and joint actions happen. CSCL asks how digital tools can be designed in order to support learners' cognition and activities in such a way that they mutually influence each other. How can tools and settings enhance interpersonal exchange and help learners to maximally benefit from each other? How can individual minds be linked in a way that they altogether from a social system?

In ijCSCL, researchers have presented several concepts and theoretical frameworks that aim at describing this synergetic process in more detail, e.g. the concept of *conceptual convergence* (Roschelle 1992), the idea of *group cognition* (Stahl 2016), the *co-evolution model of individuals and social systems* (Cress and Kimmerle 2008), the description of *socially shared regulation* of learning (Järvelä et al. (2016), or the role that visual representations play in collaborative and interactive meaning making (Furberg et al. 2013; Suthers and Hundhausen 2003). All of this work aims at describing and explaining the complex process of coupling individual minds.

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With regard to this coupling process, CSCL research delivers three strands of research topics: 24

- First of all, CSCL describes the **processes for coupling minds**: Here, CSCL asks on a 25
  more conceptual and theoretical basis how tasks can be designed and learning situations 26
  can be orchestrated in ways that lead to joint and co-regulated activities and collaboration. 27
  In a nutshell: Which processes facilitate the coupling of individual minds in order to enable 28
  shared and collective processes? 29
- Based on these theoretical considerations, a concrete aim of CSCL is to design **tools for** 30
  coupling minds. Based on its theories and frameworks, CSCL has been developing a 31
  variety of tools for collaborative learning. Such tools can be full learning environments like 32
  WISE or Knowledge Forum©, but also elements like visualizations, scripts, or prompts. 33
  CSCL develops these tools and also aims at providing empirical evidence for their efficacy. 34
- In order to empirically test the efficacy of CSCL tools, the third interest of CSCL lies in 35
  using and establishing methods of **analysing the process and outcome of coupling:** CSCL 36
  develops and makes use of adequate methods for capturing data of interacting individuals, 37
  and it aims at analysing relevant data on individual and group levels (Cress 2008). 38

The coupling processes themselves can take place at different stages of information 39
processing: 40

- At the early stage of **attention**, where tools and tasks serve to direct the attention of 41
  individuals. This could even be at an unconscious level. 42
- At the core of the information processing, where the central cognitive processes of 43
  thinking and problem solving take place. 44
- At the **metacognitive** level here planning and co-regulation happen. 45
- And - last but not least – at the level of social activities. They may be individual or social. 46

Research focusing on these different stages needs different tools and methods of analysis. In 47
this issue of ijCSCL we present four papers, each of which addresses one of these four stages 48
of collaborative information processing: The paper of Schneider and colleagues uses eye- 49
tracking methods and focuses on joint visual attention, the earliest stages of information 50
processing. With its focus on argumentation thinking and the integration of knowledge, the 51
paper of Matuk and Linn addresses the core level of information processing: cognition and 52
thinking. The paper of Hadwin, Bakhjtiar, and Miller deals with meta-cognition, and the paper 53
of Heimbuch, Ollesch, and Bodemer considers writing activities. For addressing these four 54
different levels of coupling minds, each paper makes use of specific theoretical concepts. Each 55
of them designs or uses specific tools that serve to couple minds at a specific level. Finally, 56
each paper applies different methods of data capturing and data analysis as well. 57

Paper 1: Schneider, Sharma, Cuendet, Zufferey, Dillenbourg, & Pea: 58
Leveraging mobile eye-trackers to capture joint visual attention 59
in co-located collaborative learning groups 60

Joint attention provides a fundamental basis for social interactions. It is so fundamental that 61
collective patterns of visual attention can be observed in babies or animals. So, it is not surprising 62
that joint visual attention is an important basis for social learning. It has been shown that it is also 63

relevant for the acquisition in complex domains. For instance, Jarodzka et al. (2013) showed that novices can learn from experts if they are forced to follow their gazes. The study of Schneider et al. describes a more spontaneous form of coupling visual attention. It uses a rich co-located collaboration task offering the use of tangibles, speech and gestures. In the so-called TinkerLamp task, dyads of learners interact with a tangible interface. They have to define design principles for optimizing a warehouse layout by moving small-scale shelves and finding an optimal position for the shelves. During the task, a camera detects the location of the shelves and a projector enhances the physical layout with an augmented-reality layer. The authors use mobile eye trackers to measure eye-movements of both learners. Based on this data, they propose the use of a *cross-recurrence graph* augmented with spatial information about the eye movement of both persons. They use this to detect which warehouse the two students were jointly looking at.

The study shows that this indicator for joint visual interaction correlates with collaboration quality. They additionally found a negative correlation between dyads' learning gains and an unbalanced level of participation. So, joint visual attention may be high also in highly coordinated – but ultimately ineffective groups – where one person takes on a visual leadership, and the other just follows and behaves like a free-rider. They conclude that a balanced level of visual leadership is a precondition for successful cooperation. With a visualization of the augmented cross-recurrence graphs, the authors propose a method to distinguish between dyads with a balanced and with an unbalanced level of participation.

In sum, the paper shows that in a complex collaboration task, the very basic level of information processing – namely visual attention – is linked to collaboration quality. Referring to the concept of joint visual attention, using the TinkerLamp task and applying the cross-recurrence graph as a visualization tool, the authors took a promising and exciting step for "looking into individual's minds" and detecting that coupling processes can be identified at a very basic level. In CSCL we do not have many studies that focus on these fine-grained processes of coupling minds!

Paper 2: Matuk & Linn: Why and how do middle school students exchange ideas during science inquiry?

The second paper deals with the core level of information processing: the level of thinking. Much previous research has shown that the coupling of thinking processes needs interpersonal exchange of knowledge. This requires processes of externalization, internationalization and integration for all the people involved in cooperation, as for example described in the knowledge-integration framework (Linn and Eylon 2011).

Consequently, the study of Matuk and Linn investigates how students in a collaborative setting generate, collect, contribute and integrate ideas, and it measures as an outcome variable how this integration impacts the explanations the students ultimately produce.

For a learning and collaboration tool the study uses the idea manager, which is a tool integrated into the Web-based Inquiry Science Environments (WISE, Slotta and Linn 2009). The idea manager offers each learner two baskets for saving ideas regarding a WISE task: one for private use, which offers only individual access and one as a shared tool, where all other learners also have access. A learner can copy ideas from the private to the shared basket and vice versa. So, this tool makes processes of externalization, internationalization, and integration through the development and modification of ideas observable. The study measures the influence of explicit instruction, where students are asked to sort ideas, share at least one of their ideas, and copy at least one of the ideas of others into their own basket. With this

instruction, the coupling of minds is supported by an explicit rule that prescribes how often 108
learners have to use both baskets at least. As expected, the results show, that there is a 109
relationship between the diversity of students' ideas, the sources of those ideas (i.e., whether 110
they came from the students themselves or from their peers), and the quality of students' 111
scientific explanations. However, the direction of this relationship is interesting and perhaps 112
surprising: Students who collected more ideas that were not already represented in their private 113
idea collections tended to write poorer explanations, whereas students who generated their 114
own redundant ideas tended to write better explanations. This result shows that just getting to 115
know and dealing with the ideas of others is not enough for the coupling of minds. It is the 116
individual's writing and re-formulation of ideas that primarily enhances idea integration. So, 117
this study seems to propose that for the core cognitive level of thinking and integration of 118
ideas, actions are highly relevant. This is also a main issue in CSCL: Cognition and action are 119
not separated. Action forms cognition, and tools that are developed to stimulate actions deepen 120
the processes of thinking and understanding. This is the case for individual minds, but it might 121
be even more necessary for coupled minds. 122

Paper 3: Hadwin, Bakhtiar, & Miller: Challenges in online collaboration: Effects of scripting shared task perception
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The third paper deals with another level of information processing: metacognition. This 125
includes processes of planning, monitoring, and reflecting. These processes are important for 126
individual learning, but even more so for collaborative learning. Tools and processes that 127
support team planning and co-regulation of team members are an essential part of many 128
collaborative environments. 129

One important aspect of collaborative learning is a self-referential one: Collaborating needs 130
negotiating beliefs and perceptions regarding the collaborative goals and plans about how to 131
achieve the task. This is a complex process of co-construction of goals and plans, where meta- 132
cognition and regulation processes of collaborating individuals need to be exchanged, 133
negotiated, and aligned to achieve shared or joint regulation (Jarvela and Hadwin 2013). 134

Analogous to the co-construction of knowledge, the co-construction of meta-cognitive 135
knowledge can be supported by scripts. Scripts help the members to focus on the common 136
task, they facilitate externalizing individual perceptions, thoughts, and plans, and they support 137
the exchange and negotiation of these individual cognitions and enable their alignment. The 138
script used in the paper of Hadwin et al. provides questions about the individual perception of 139
task requirements, and about the challenges a learner anticipates during the task. The learners 140
have to provide their answers in a highly standardized way, which makes all answers 141
comparable. They are accessible in a so called "awareness visualization". This visualization 142
shows individual planning perceptions summarized across group members, so each group 143
member gets to know about the perception of the others, and they can reflect on that. 144

The study showed that without these kinds of visualizations, individuals rated planning as 145
more problematic, and they encountered more challenges. Consequently, they saw a high need 146
for planning strategies and expected them to be more effective than teamwork strategies. This 147
was different for the groups with visualizations. This group reported higher levels of success 148
with their strategies and it expected both planning and teamwork strategies to be equally 149
effective. So, the awareness visualization seemed to be an efficient tool for the coupling of 150
minds with regard to meta-cognition. It did not only induce reflection processes, but also 151

influenced activities and outcomes. The authors used pathways analysis to show this differ- 152
ences between the groups. These decision paths provide transition probability measures from 153
(1) encountering the challenge to (2) selecting a specific strategy and (3) enacting the strategy. 154
With this method, they could consider the relevant processes (that range from perception to 155
action) on the individual level as well as on the group level. 156

Paper 4: Heimbuch, Ollesch, & Bodemer: Comparing effects of two 157
collaboration scripts on learning activities for wiki-based environments 158

The fourth paper explicitly deals with the level of activities: Specifically, it considers activities in 159
collaborative writing. Collaborative writing is a topic that has become more and more relevant 160
through social media, and especially through the widespread use of wikis. Accordingly, the paper 161
deals with a script that is proposed in Wikipedia, the largest and most-used collaborative writing 162
environment we have. This script promotes a high frequency of individual article edits. It 163
encourages content creators to be bold and perform an edit of an existing article or to create an 164
entirely new article. It encompasses guidelines on how to continue if an edit gets reverted, and it 165
suggests accepting at least three revisions before a discussion becomes required. These different 166
steps are not necessarily designed to be followed in an invariant order, although flow chart 167
representations as used in Wikipedia and the like might suggest a specific order of events. The 168
proposed script practiced by Wikipedians, but is not informed by any theoretical consideration 169
about collaboration. Consequently, Helimbuch et al. propose an alternative script that aims at 170
providing a more collaborative focus: It promotes participants to discuss any planned article edit 171
and revision upfront, before they make any change to a document. In a first step, the editors have 172
to take planned article edits to the corresponding discussion space. In the second step, they have to 173
start a deliberation process where the community can comment on the proposed wiki edits. Only 174
then can the article revision be performed in the third step. So the alternative collaboration script 175
encourages students to take part in the whole negotiation process where people consider different 176
perspectives and then need to integrate them. The results show that the Wikipedia script leads to a 177
lower quality of article, even if the effect was not as large as the authors may have expected. 178

Looking across the four papers we find not only differences in the level of information 179
processing they consider, but also in the tools they use and the research methods they propose: 180
All four papers were successful in relating the processes on the level of their focus to some 181
output variables, (e.g., individual learning results or the quality of a shared artifact). Summarized 182
across all four studies we find correlations for all four levels of coupling with task performance: 183
Early steps of information processing like visual attention, central steps of knowledge integra- 184
tion, and meta-cognitive processes of co-planning and performing activities – all can support 185
combining individual systems to a social system, and the coupling of minds can be effectively 186
facilitated at all four levels. 187

Regarding the tools that enable these coupling processes, three of the four papers focus on 188
scripts. The high efficacy of scripts as coupling means is not surprising, as they force the 189
individuals to consider the actions and perspectives of their partners. The provision of visualiza- 190
tions is more implicit. As many other CSCL studies show, this implicit support – just the provision 191
of visualization – can be effective for supporting cooperation by fostering awareness. 192

When we consider the papers in this issue, it may also be of interest to note that 193
visualizations play not only an important role as tools for coupling, but also as research 194
methods for data analysis. They seem to also be effective awareness tools for researchers. 195

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