Methodological Advances in

Research on Learning and Instruction and in the Learning Sciences

Frank Fischer[a], Sanna Järvelä[b]

[a] University of Munich, Germany

[b] University of Oulu, Finland

Recent years have seen a dynamic growth of research communities addressing conditions, processes and outcomes of learning in formal and informal environments. Two of them have markedly advanced the field: The community on research on learning and instruction that has been organized in the European Association for Research on Learning and Instruction (EARLI), and the learning sciences community, including the computer-supported collaborative learning community, organised in the International Society of the Learning Sciences (ISLS). In this special issue we bring together excellent young researchers from these two communities who are currently contributing to advancing the methodology. We are convinced that the methodological developments in these two communities have a lot of commonalities as the core phenomena under investigation and the core questions are related to conditions, processes and outcomes of learning. Common for both of these communities is that they have strong roots in cognitive science. However, we also assume that there are substantial differences in these methodological developments, as the foci of the two communities differ in important respects. Most importantly, the learning sciences have strong theoretical roots in situative cognition and socio-cultural approaches focusing on learning activities in authentic contexts. The main assumption underlying this focus is that knowledge is represented in activity structures rather than solely in the head (Greeno, 2006). Therefore, removing the activities of their social and physical contexts into which they belong will change their nature and, hence, research would lead to invalid results, because only a part of the knowledge that is relevant for effectively participating in a practice can be investigated. Given these assumptions, it comes as no surprise that learning sciences research focuses on learning in authentic activities in contexts rather than settings stripped off the context for reasons of control in the experimental studies. Besides experiments and mixed-method approaches a core methodology that originated in the clear need for alternatives to deductive-experimental methods for early phases of such field research is Design-Based Research with a cyclic process and the goal to improve a practice and to develop a modest and local theory. DBR has its origins in seminal papers by Ann Brown (1992) and by Allan Collins

(1992) as well as in influences coming from computer science (see Hoadley & Van Haneghan, 2011). As knowledge is seen to be tied to activities in practices rather than to a single individual, units of analysis beyond the individual (e.g., network, or activity) are rather the rule than the exception in learning sciences research. Explorations of different units of analysis are happening in both communities, of course, but they are more pronounced in the learning sciences community. Due to the theoretical roots in socio-cultural thinking and situative cognition the relation of the social and material environment to individual cognition is at the core of theorizing in the learning sciences. This is perhaps most obvious in research on computer-supported collaborative learning (see Dillenbourg, Järvelä & Fischer, 2009).

As the activities or practices are seen as the core medium of knowing, and the practices differ a lot between communities, domains and disciplines, research in the learning sciences has an important focus on disciplinary practices (e.g. Herrenkohl & Cornelius, 2013). As the use of tools is a key feature of any community, tool appropriation and use are important foci in learning sciences research. In the learning sciences, the concept of tool is often very broadly defined ranging from tools like scientific concepts to digital technologies.

Research in the learning and instruction community is characterized by a strong connection of basic research to applied field studies. The field has deeper roots into experimental psychology and general psychology of learning and motivation. Traditionally, research on learning and instruction has focused on basic processes of cognition and learning and then applied these principles to teaching and learning practices. For example, understanding metacognitive processes in human learning (Flavell, 1979) has led many research groups to making effective interventions to the classroom contexts (Azevedo & Hadwin, 2005). Also research on self-regulated learning has tried to integrate empirical evidence on basic processes of cognition, motivation and emotion into broader applications and interventions in the classrooms, where teacher's role, students' activities and features of the learning environment have been synchronized to serve learning (e.g., Dignath, Buettner & Langfeld, 2008).

In recent years, basic research on learning and instruction has been helpful for designing powerful learning environments, where knowledge about student's cognitive, motivational and emotional processes and their individual differences has been applied to instructional design. For example, knowledge on scientific reasoning and on worked-out examples has been applied in developing guidance for inquiry learning (Mulder, Lazonder & De Jong, 2014) and collaborative learning (Kollar, Ufer, Reichersdorfer, Vogel, Fischer & Reiss, 2014).

In the learning and instruction community one of the current strong emphases is on methodological orientations linking learning research to natural science brain research. The educational neuroscience movement seems to be more pronounced in research on learning and instruction than in the learning sciences. This is consistent with the deeper roots of learning and instruction research in general and experimental psychology, which has developed a strong neuroscience orientation over the last years.

In addition, methodologies are being developed addressing the temporal characteristics of learning. In both communities, quantitative approaches to the analysis of temporal aspects of the learning process have been developed over the last years. It is argued that the explanatory power and the validity of the analyses can be improved dramatically by including the time information that has typically been neglected in many studies on individual and collaborative learning. In research on learning and instruction, this new focus has originated as a consequence of a conceptual shift, as Molenaar (this volume, p. XX) puts it: "Constructs formerly viewed as personal traits, such as self-regulated learning and motivation, are now conceptualized as a series of events that unfold over time". There are several arguments in support for this point also in recent publications in the learning sciences (e.g., Reimann, 2009).

There are *four main potentials for innovation* resulting from these developments for learning research, no matter if situated in research on learning and instruction or in learning sciences research.

Potential #1: *Increased gain in scientific understanding through more "messy studies" when investigating "real" learning in new fields*. It seems inadequate to presume a purely deductive experimental approach in fields where the set of potentially influential variables is unknown. Learning research is not an exception here, the same applies to other fields like, e.g. physics, where pioneering research at the edges of current scientific knowledge is more "messy" as well (Wieman, 2014). DBR approaches, although still in their infancies, might well develop into a standard methodology for pioneering research on "real learning" in authentic settings, also in research on learning and instruction. In this special issue, Svihla (this volume) reports on recent developments in DBR that address the issues of scalability and generalizability: Design-based implementation research (DBIR). This might be a promising alternative approach to randomized trial approaches to implementation research in fields where the set of influential and to-be-controlled variables in real formal and informal learning environments is far from clear. Because of its design focus, DBR and DBIR might contribute to advancing learning research beyond generating new scientific knowledge: They might have the potential to build bridges into practice and increase the credibility and trustworthiness of learning research. An alternative approach is suggested by Stegmann (this volume), who addresses the issue of control in studies of complex, collaborative learning environments. He argues for a more systematic use of nomological networks on the conceptual level in connection with as-controlled-as-possible empirical studies that include measures of learning processes as their methodological core.

Potential #2: *More comprehensive understanding of learning phenomena through the use of methodologies that can handle multiple units of analysis and include process analyses.* Units like the activity, the group or the collective could become standard for questions that transcend the individual's learning. It will be a challenge how to conceptually deal with this paradigm shift: talking about "learning" also with respect to super-individual units. For example, should team learning be considered as a whole, or should the term "learning" be reserved for the individual and different concepts should be used to describe what is happening in activities or collectives? An even more far reaching question is to what extent phenomena on super-individual levels should be traced back (or be reduced as some would prefer to say) to the individual contribution, i.e. social phenomena are treated as a result of interacting individuals, and the phenomena can be fully explained by the individual contributions and reactions. Increasingly there is research arguing that some social phenomena in contexts of learning cannot be reasonably reduced to the individuals involved (Cress, Held & Kimmerle, 2013; Eberle, Stegmann & Fischer, 2014; Stahl, 2006). In this special issue, Stegmann's (this volume) work is additionally addressing this aspect. He describes measures of individual cognition and argumentative discourse in computer-supported small groups and exemplifies approaches to a synchronized analysis of individual cognition and group discourse to address the mutual impact. We argue that systematically employing other units of analysis in learning research than the individual would not only advance research on learning in context, but also help to build bridges into other social sciences that are sometimes hesitating because of the exclusivity of the individual-centric perspective of some learning researchers.

Potential #3: *Overcoming overreliance on self-reports: From personal constructs to series of interactions unfolding over time.* Many learning researchers are currently working on developing alternative conceptualisations of well-established psychological constructs such as self-regulation or motivation. There are shortcomings of relying solely on self-reports in questionnaires (e.g. Zimmerman, 2008) to measure personal constructs, such as low predictive value for behaviour in real problem-solving situations. Learning researchers have therefore begun to develop methodological approaches that use behaviour or interaction in problem-solving situations as indicators for these constructs. An example from research in the learning

sciences is Dan Hickeys work on disciplinary engagement in a discussion (Filsecker & Hickey, 2014) as a complementary measure of motivation. In this special issue, Inge Molenaar's work is representing this broader issue. She focuses on the temporal characteristics of learning processes that are typically missed when only self-report measures are used or observational data is aggregated into frequencies over the whole learning process under consideration. Also recent advances in the use of computer-generated trace data for understanding patterns and processes of students' learning (Malmberg, Järvenoja & Järvelä, 2013) have advanced the instructional design field for developing scaffolding and prompts for computer supported learning (Järvelä & Hadwin, 2013).

Potential # 4: *Building bridges between research on learning and cognitive neuroscience.* There have been discussions if the gap between education and neuroscience might require a bridge too far. However, recent advances in cognitive neuroscience are encouraging. Research on learning and instruction and in the learning sciences are increasingly interested in the biological basis of the learning phenomena under investigation and some of these ideas have already been applied e.g. to mathematics learning (Hannula, Lepola & Lehtinen, 2010). In the learning sciences and the learning and instruction community there is increasing awareness of the possibilities to analyse processes that are not readily accessible for behavioural research. One can hope that in the future, researchers on learning and instruction and in the learning sciences will be able to successfully point out interesting learning phenomena to neuroscientists (Varma, McCandliss & Schwartz, 2008). These often complex and dynamic phenomena are typically highly challenging for contemporary neuroscientists. At the same time one can hope that researchers in learning and instruction as well as in the learning sciences would become more receptive for stimulations coming from unexplained phenomena in neuroimaging studies on cognition and learning. De Smedt (this volume) addresses these questions and elaborates on some convincing examples from mathematics learning that give evidence for a productive interaction between research on learning and instruction and cognitive neuroscience. He argues that the successful interaction crucially depends on finding the right level of resolution or granularity when involving neuroscience methods. We argue that it is now a good point in time to start exploring this interaction from both research on learning and instruction and in the learning sciences more systematically. This would enhance the interface of learning research to the natural sciences. At this interface there is a considerable potential for innovation.

Conclusion

Research on learning and instruction and research in the learning sciences have seen considerable methodological advancements in recent years. Although a certain specialisation can be seen due to differences in some of the basic assumptions we see good reasons for transferring these innovations between the research communities. We see four potentials for innovation for learning research resulting from these methodological developments: (1) Increased gain in scientific understanding through more "messy studies" when investigating "real" learning in new fields, (2) more comprehensive understanding of learning phenomena through the use of methodologies that can handle multiple units of analysis and entail processes analyses, (3) overcoming overreliance on self-reports: From personal constructs of learning and motivation to series of interactions unfolding over time, and (4) building bridges between research on learning and cognitive neuroscience.

The contributions to this special issue are each addressing one of these potentials.

References

Azevedo, R. & Hadwin, A. F. (2005). Scaffolding self-regulated learning and metacognition – Implications for the design of computer-based scaffolds. *Instructional Science*, *33*(5), 367–379. **DOI:**10.1007/s11251-005-1272-9

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences, 2(2),* 141-178. **DOI:**10.1207/s15327809jls0202_2

Collins, A. (1992). Toward a design science of education. In E. Scanlon & T. O'Shea (Eds.), *New directions in educational technology* (pp. 15-22). New York: Springer. **DOI:**10.1007/978-3-642-77750-9_2

Cress, U., Held, C., & Kimmerle, J. (2013). The collective knowledge of social tags: Direct and indirect influences on navigation, learning, and information processing. *Computers & Education, 60(1),* 59-73. **DOI:**10.1016/j.compedu.2012.06.015

Dignath, C.**,** Büttner, G. & Langfeldt, H.-P. (2008). How can primary school students acquire self-regulated learning most efficiently? A meta-analysis on interventions that aim at fostering self-regulation. *Educational Research Review, 3*, 101-129. **DOI:**10.1016/j.edurev.2008.02.003

Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). The evolution of research on computer-supported collaborative learning. In N. Balacheff et al. (Eds). *Technology-enhanced learning (pp. 3-19).* Springer, The Netherlands. **DOI:**10.1007/978-1-4020-9827-7_1

Eberle, J., Stegmann, K., & Fischer, F. (2014). Legitimate Peripheral Participation in Communities of Practice: Participation Support Structures for Newcomers in Faculty Student Councils. *Journal of the Learning Sciences*, 23(2), 1-29. **DOI:**10.1080/10508406.2014.883978

Greeno, J. G. (2006). Learning in activity. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 79-96). New York: Cambridge University Press.

Filsecker, M., & Hickey, D. T. (2014). A multilevel analysis of the effects of external rewards on elementary students' motivation, engagement and learning in an educational game. *Computers & Education, 75,* 136-148. **DOI:**10.1016/j.compedu.2014.02.008

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist, 34,* 906-911. **DOI:**10.1037/0003-066X.34.10.906

Hannula, M., Lepola, J. & Lehtinen, E. (2010). Spontaneous focusing on numerosity as a domain-specific predictor of arithmetical skills. *Journal for Experimental Child Psychology, 107*, 394-406. **DOI:**10.1016/j.jecp.2010.06.004

Herrenkohl, L. R. & Cornelius, L. (2013). Investigating Elementary Students' Scientific and Historical Argumentation. *Journal of the Learning Sciences, 22*(3), 413-461. **DOI:**10.1080/10508406.2013.799475

Hoadley, C. & Van Haneghan, J. (2011). The Learning Sciences: Where they came from and what it means for instructional designers. In R. A. Reiser & J. V. Dempsey (Eds.), *Trends and Issues in Instructional Design and Technology* (3rd ed., pp. 53-63). New York: Pearson.

Järvelä, S. & Hadwin, A. (2013). New Frontiers: Regulating learning in CSCL. *Educational Psychologist, 48(1), 25-39.* **DOI:**10.1080/00461520.2012.748006

Kollar, I., Ufer, S., Reichersdorfer, E., Vogel, F., Fischer, F., & Reiss, K. (2014). Effects of collaboration scripts and heuristic worked examples on the acquisition of mathematical argumentation skills of teacher students with different levels of prior achievement. *Learning and Instruction, 32*, 22-36. **DOI:**10.1016/j.learninstruc.2014.01.003

Malmberg, J., Järvenoja, H. & Järvelä, S. (2013). Patterns in elementary school students' strategic actions in varying learning situations. *Instructional Science*, *41*, 933–954. **DOI:**10.1007/s11251-012-9262-1

Mulder, Y. G., Lazonder, A. W., De Jong, T. (2014). Using heuristic worked examples to promote inquiry-based learning. *Learning and Instruction, 29,* 56-64. **DOI:**10.1016/j.learninstruc.2013.08.001

Reimann, P. (2009). Time is precious: Variable-and event-centred approaches to process analysis in CSCL research. *International Journal of Computer-Supported Collaborative Learning, 4(3),* 239-257. **DOI:**10.1007/s11412-009-9070-z

Stahl, G. (2006). *Group cognition*. Cambridge, MA: MIT Press.

Varma, S., McCandliss, B. D., & Schwartz, D. L. (2008). Scientific and pragmatic challenges for bridging education and neuroscience. *Educational Researcher, 37,* 140-152. **DOI:**10.3102/0013189X08317687

Wieman, C. E. (2014). The similarities between research in education and research in the hard sciences. *Educational Researcher, 43(1)*, 12-14. **DOI:**10.3102/0013189X13520294

Zimmerman, B. J. (2008). Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. *American Educational Research Journal, 45(1),* 166-183. **DOI:**10.3102/0002831207312909