Understanding CSCL through the lens of research syntheses

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Abstract: Computer-supported collaborative learning (CSCL) forms a diverse field with researchers from different backgrounds using a variety of learning theories and research methods to design and analyze CSCL learning environments. The dynamic and active features of the field can lead to confusion about its identity and conclusions that can be drawn from the outcomes of CSCL research. Syntheses of CSCL research can help to answer questions about the prevalent topics and outcomes in the field. There are a number of synthesis methods to choose depending on the methods used in the primary studies as well as goals of the synthesis. Meta-synthesis is also available to better integrate findings obtained using different research methods. This symposium showcases a spectrum of different synthesis methods used in CSCL. Benefits and disadvantages of the synthesis methods will be discussed along with the question of how different synthesis methods can be used to inform each other.

The field of computer-supported collaborative learning (CSCL) brings together researchers from diverse disciplines (Computer Science, Psychology, Education, Linguistics, etc.) with diverse learning theories. A broad spectrum of different research methods is used in the field of CSCL depending on considerations such as the specific research goals, the maturity of the theories, the complexity of the problems and the researcher's epistemological orientation. Thus, CSCL is a dynamic and active research community and a wealth of CSCL research has been conducted to reveal the mechanisms of successful CSCL (King, 2007; Scardamalia & Bereiter, 1994). In order to achieve a more comprehensive and precise conclusion about CSCL mechanism, structured research synthesis are needed that integrate the rich amount of primary studies about specific topics in CSCL However it also became of a source of confusion and disagreement about integrative conclusions that can be drawn from CSCL research (see also Wise & Schwarz, 2017).. Goals and motivations of the synthesis may dictate the use of quantitative or qualitative synthesis methods, which, in turn, limit the type and scope of conclusions that can be drawn from them. These goals might be the generation of innovation, the building of theories, finding evidence for specific hypotheses, or informing policy and practice in education. However, even when the most adequate synthesis method might have been selected to integrate primary research done in a specific area of CSCL, challenges still remain. For instance, deciding for meta-analysis means the exclusion of a part of primary studies. Qualitative syntheses, in spite its depth and insights, lack the precision of meta-analyses. This means that even the most adequate synthesis method may lead to biased conclusions about CSCL research.

This symposium showcases a spectrum of syntheses used in the field of CSCL which all have the common goal to integrate CSCL research and to contribute to the understanding of the CSCL community and its research outcomes. Firstly, three papers will be presented that depict a bibliometric analysis, a qualitative systematic review and a quantitative meta-analysis all conducted in the field of CSCL. Secondly, the fourth paper will introduce meta-synthesis as a method to integrate quantitative and qualitative research outcomes and a way to overcome the disadvantages of using only one particular synthesis method.

More specifically, the first paper by Håklev et al. used bibliometric analysis to get a better understanding of the CSCL researcher community. In this paper, ICLS and CSCL proceedings are analyzed to uncover and portray patterns in co-authorship, authors' field of research, geographical location and commitment to the community. While qualitative analyses are quite common in CSCL research, few qualitative syntheses exist. In the second paper, Wan and Wan instead present a qualitative systematic review to uncover how phenomenography, a specific qualitative research method, is used in the field of CSCL. This paper presents how

a novel qualitative research method is adopted by the field of CSCL, the depth of explanation of qualitative syntheses, and makes suggestions how phenomenography could be utilized to synthesize CSCL research. The third paper by Radkowitsch et al. represents the use of quantitative meta-analysis in the field of CSCL. Their choice of synthesis method was justified by the substantial amount of quantitative experimental studies already available. More specifically they synthesized experimental studies about the effects of CSCL scripts as a scaffold to enhance collaborative learning. Their findings provide a strong empirical argument for the effectiveness of CSCL scripts against the critic – raised in the controversial debate within the CSCL field – that CSCL scripts may be too constraining and thus ineffective. In the fourth paper, Hmelo-Silver and Jeong showcase a way to synthesize qualitative and quantitative primary studies in evaluating the outcomes of STEM CSCL. The study provides one model of meta-synthesis that takes into account both quantitative and qualitative outcomes. It aims to integrate CSCL research outcomes both from quantitative and qualitative studies and thus overcome some of the existing synthesis methods that solely uses either quantitative or qualitative outcomes. Continued efforts are needed to synthesize CSCL research outcomes across different theoretical and methodological boundaries.. Taken together, the current symposium will showcase available synthesis techniques and provide a forum to reflect on their advantages and limitations. It can help us better understand which synthesis method might be adequate for the different research goals and motivations and how the various syntheses can inform each other and the field in general.

A bibliographic analysis of our community through the lens of ICLS and CSCL proceedings

Stian Håklev, Léonore Valentine Guillain, and Nour Ghalia Abassi

The CSCL community has over time developed a shared set of theories and concepts which are constantly being referenced and built-upon. However, as a community that both draws from multiple disciplines (such as computer science, psychology, and education), and that interacts with rapidly changing technological affordances, it needs to constantly reposition and reframe itself relative to other communities and disciplines. CSCL community members act as bridges, bringing new ideas, concepts and methods into the CSCL community, by co-authoring with authors that would not consider members of the CSCL community, or citing research from other communities. One way to better understand the development of our community is through a bibliometric analysis of conference proceedings.

Using bibliometric and social network analysis approaches to analyze the growth and structure of academic disciplines and communities have a long history. Descriptive statistics of authors lets us understand who contributes to a given conference, which universities and groups they represent, which geographical locations are represented, and how this changes over time. Co-authorships and citations can be seen as indicators of how well members of a field are connected (Kienle & Wessner, 2006), and let us detect links and bridges with other communities (Kärki, 1996). Applying text analytics methods to the article contents can be used to detect semantic clusters within the community, but also to track the appearance of new topics of interest over time (Ding, Chowdhury, & Foo, 2001).

Bibliometric signals alone do not tell the whole story. They can be enhanced by other data, such as an early analysis by Kienle and Wessner (2006) which included both conference proceedings, lists of participants and Program Chairs, as well as e-mail surveys and an analysis of policy documents to understand how the community was developing. They describe a burgeoning international community at an early stage of growth, with few core members, and conference participation highly dependent on participation in large grants or shifting institutional policies. Later studies have tended to look at CSCL literature spread over a larger set of journals and conferences. For example, Jeong, Hmelo-Silver, and Yu (2014) manually coded empirical CSCL studies according to research designs, settings, data, and analyses, and identified four distinct theory-method clusters. Tang, Tsai, and Lin (2014) used co-citation analysis of CSCL literature to automatically extract intellectual sub-fields, and pivotal papers that served as bridges between sub-fields. Others have used completely different data sources, such as Sommerhoff, et al. (2015), which analyzed the curricula from 75 learning science programs.

We propose to narrow our focus to the two bi-annual conferences as the flagship events of our society – the research that is published there reflects both what researchers in the community choose to work on, and what kind of research is selected by the peer-review process. We propose the following Research Questions: a) How can we describe the CSCL conference authors in terms of fields, geographical location and commitment to the community, b) How is CSCL as a knowledge field structured in terms of collaboration with local and international partners from within and outside the community, c) What is the relationship between CSCL and ICLS, the two conferences that are hosted by the same society?

We have analyzed 446 papers (including full, short, posters, and symposia) from CSCL 2015, ICLS 2016, CSCL 2017, and ICLS 2018. From each paper, we extract authors, use e-mails to determine institutional affiliation, and parse citations. The five countries with the most author contributions (counting each co-authored paper separately) are United States, Germany, Canada, Israel and Singapore. The number of US authors had a large spike in 2018 (2015: 8%, 2016: 20%, 2017: 16%, 2018: 57%). That year, ICLS was co-located with Learning at Scale, and Artificial Intelligence in Education, and this probably led to a number of people who would not otherwise have attended the conference submitting papers. Perhaps these other two conferences are traditionally more US-centric, and this led to the large growth in US contributions. This large growth mainly came from universities that had not presented during the previous three years' conferences. Analyzing the data from CSCL in 2019 and ICLS in 2020 will help us understand whether 2018 was an aberration, or the beginning of a trend.

To investigate the extent to which researchers think of themselves as members of the ISLS, and attend both conferences (CSCL and ICLS), or primarily identify with one of the two communities, we look at research groups that have been present at all four conferences (36), or all CSCL/no ICLS (12), or all ICLS/no CSCL (58). This indicates that there is a large number of research groups that identify with ICLS and not CSCL. In future work, we will extend the number of years analyzed, and also look at differences in citation patterns and semantic content between authors that are identified as mainly-ICLS, mainly-CSCL, or both.

We were able to extract 13,047 unique authors from the citations in the papers analyzed. Of these, 1009 authors have published at one of the four conference proceedings. To understand which external disciplinary communities that ISLS researchers connect with, we wanted to identify the most commonly cited authors from outside of the CSCL/ICLS communities. To do this, we excluded all authors that had published at one of the four conferences, or that had any cited work in CSCL, ICLS, International Journal of CSCL, or Journal of the Learning Sciences. We further split this into works written before 2010, and after 2010, to get one list of historical influences, and another with currently active researchers who are highly cited by CSCL/ICLS researchers, but do not attend our conferences. The five most highly cited researchers before 2010 was E. Wenger, L. S. Vygotsky, S. Papert, C. Goodwin and B. Rogoff. The most highly cited authors of publications published after 2010 were C. Goodwin, J. P. Gee, J. S. Krajcik, B. J. Fishman, and M. Windschitl.

By continuing to add data from past proceedings, and extending our analysis, we will be able to say more about the difference research published at CSCL and ICLS, the structure of research group collaborations, the emergency and popularity of certain topics over time, and the links between the CSCL/ICLS literature and other fields/conferences, and how that might be changing over time. We might also connect the bibliometric analysis to other sources, such as the data on Learning Science programs by Sommerhoff et al (2015) – how do course curricula affect future graduates' research topics? Because of the public nature of publications, we will make our full dataset of parsed metadata available, as well as all the code used to generate our findings. We hope that this will encourage other groups to extend or question our analysis.

Systematic review about the use of phenomenography in educational technology studies

Sally Wai-Yan Wan and Sancia Wai-San Wan

There has been a rise in the demands of looking for 'appropriate' research methodology to investigate how educational technology is used so as to search for 'better' ways for sustainable development in the field. Some scholars described the potentials of phenomenography as 'opening a new territory' (Bruce, 1999) that explores the understandings of a phenomenon in the use of computer-supported collaborative learning (CSCL) for informing educational practice from a second-order perspective, rather than a first-order perspective that cannot reveal the phenomena as it is understood (Rovio-Johansson & Ingerman, 2016, p. 261). Phenomenographic research helps 'to bridge the gap between research and practice' that puts an emphasis on collective meaning and identification of conceptions in an empirical manner (Johnston & Salaz, 2017).

Phenomenography is 'a research method for mapping the qualitatively different ways in which people experience, conceptualize, perceive, and understand various aspects of, and various phenomena in, the world around them' (Marton, 1986, p.31). The essential facets of phenomenography include categories of description (different ways of understanding), structural aspect (combinations of features discerned and focused upon by the subject), referential aspects (a particular meaning of an object), outcome space (logical relations of categories of description). Phenomenography is not only a research approach but also serves for the purpose of informing curriculum and pedagogical design in CSCL practices (Åkerlind, 2012), which potentially offers theoretical and methodological advantages for explaining difference and change in individuals' conceptions, keeping aware of such contradictions in understanding of learning experiences, and allowing for opportunities for self-reflection.

To find out how this relatively novel method is applied in CSCL research, in this study we chose systematic review for assessing how previous phenomenographic studies in CSCL were conducted. Two research questions guided the study: (1) How is phenomenography applied in studying CSCL? and (2) What are the key limitations and possible future development in the use of phenomenography in CSCL studies?

Data collection and analysis

We initially identified the relevant papers from the Social Science Citation Index (SSCI) journals with keyword search (e.g. phenomenographic study) in the journal websites. We did a quantitative content analysis according to the origin of study, year of publication, targeted groups, essential facets of phenomenography, data collection method, research trustworthiness, targeted groups in the study, research questions, objectives of the study, and limitations of study. We then conducted a qualitative thematic analysis in identifying patterns.

Findings

A total of 32 papers were reviewed and most were conducted in Australia, Taiwan and UK respectively. Most of them were found in higher education. 'What' and 'how' questions were commonly found in the research questions, where more focus was on studying students' conceptions, experiences and learning approaches whilst fewer studies were done to explore that of teachers. The basic facets of phenomenography such as referential and structural aspects of conceptions and experiences of the use of CSCL pedagogies were addressed. However, 'outcome space' was not presented in nearly half of the reviewed studies. The paper by Limbu and Markauskaite (2015) demonstrated a good example about the key facets of phenomenography, in which their study revealed the outcome space of the students' conceptions of online collaborative writing (OCW) with four categories of descriptions (referential aspect), namely (A) Division of work to complete the task; (B) Combination of expertise to produce a good end product; (C) Fusion of ideas and insights to enable deeper understanding; and (D) Development of new skills and attitudes for collaborative work, whilst dimensions of variations (structural aspect) involved five aspects: the outcome of OCW, learning from each other, the nature of the OCW process, the intensity of interaction and the values and commitment of participants. This review explored how the phenomenography as a research method in primary studies can inform the field of CSCL, where the reviewed papers revealed the usefulness of phenomenography in understanding of learning and teaching, informing pedagogical design and helping evaluating the learning outcomes, as well as providing information for teacher professional development. On the other hand, this review further led us to reflect how qualitative syntheses can help explore the phenomenographic method in studying CSCL. Limitations were commonly identified and addressed in these studies: (1) Small sample size may restrict understandings of the phenomena; (2) Diversity in study participants' backgrounds and experiences that could not be captured in the different contexts within the study and could not be classified into single categories of descriptions; and (3) Ineffective application of research methods and techniques affecting the findings of the study.

Our reflection

The systematic review study guides us in future research by filling in research gap by comparing students and teachers' conceptions and experiences in CSCL and exploring their conceptions and experiences of CSCL in primary and secondary education. Attention should be paid to the data analytical procedures including trustworthiness and the creation of outcome space. More significantly, there can be possibilities of applying phenomenography as a tool to synthesize qualitative research in CSCL with reference to structural and referential aspects of the past CSCL studies so as to generate a new understanding of what learning conceptions and experiences in the previous CSCL studies and inform future CSCL development. There are still limitations in this systematic review. Due to that only SSCI papers were selected for this review, other papers using phenomenography were not covered. The study relied on those papers addressing limitations and contributions of the study for analysis and this thus restricted the deliberations of insights as gained from the papers. This study depends on the analysis of qualitative aspect of the papers and this may cause the 'bias' in the synthesis of the results of this study.

Good for learning, bad for motivation? A meta-analytic counter-argument on a widespread position regarding CSCL scripts

Anika Radkowitsch, Freydis Vogel, and Frank Fischer

In collaborative learning, learners often have difficulties to use expedient activities which are expected to induce cognitive elaboration, such as explaining or negotiating cognitive conflicts. CSCL scripts were designed as

scaffold to guide learners through collaborative practices that are beneficial for learning collaboration skills as well as domain learning by inducing learners to engage in specific collaborative practices repeatedly (Fischer, Kollar, Stegmann, & Wecker, 2013). To explain why studies about CSCL scripts show heterogeneous results, the risk of overscripting learners by too coercive guidance undermining learners' self-determination and motivation is most prominently quoted. In a recently published qualitative approach collecting widespread views of experts in the field, Wise and Schwarz (2017) conclude with this overscripting explanation. They emphasize that rare positive effects of CSCL scripts are restricted to learn collaboration skills only at the expense of learners' agency and motivation. Other positive effects of CSCL scripts are mostly neglected while negative effects are emphasized. Interestingly, the very idea of overscripting came from a contribution by Dillenbourg (2002) to Paul Kirschner's inauguration event at the Open University of the Netherlands. The idea, however plausible it may have appeared then was not backed up by empirical findings. We argue that a scientific community should develop strategies of evidence generation and accumulation that go beyond re-stating an opinion for 15 years. It seems to be a questionable practice to base the knowledge of a scientific community on the aggregation of repeated opinions. Since many experimental studies have been conducted on the effect of CSCL scripts on learning quantitatively synthesizing the effects by conducting a meta-analysis seems to offer better evidence. In contrast to narrative reviews and intuitive summaries of widespread opinions, meta-analyses allow to weigh the individual effects based on their precision giving more weight to the more precise studies. A recent quantitative meta-analysis about CSCL scripts partially contradict the qualitatively drawn conclusion showing overall positive effects of CSCL scripts on learning (Vogel, Wecker, Kollar, & Fischer, 2017). However, the widely proposed negative influence of CSCL scripts on motivation was not analyzed and a great amount of new studies about CSCL scripts have been conducted since then. Thus, the research question of this study is: What is the overall effect of collaborative learning with CSCL scripts compared to collaborative learning without CSCL scripts on domain learning, collaboration skills, and motivation?

Method

A comprehensive literature search was conducted on ERIC and ISI Web of Science using the search terms "(scaffold* OR script*) AND (learn* OR know*) AND (collaborat* OR cooperat*) AND (computer* OR CSCL OR techno*)" resulting in N = 624 articles. The criteria-oriented coding for inclusion (e.g., experimental variation of the factor CSCL script) led to a final sample of 41 articles reporting 43 studies involving 4,414 participants. The data for the calculation of effect sizes was extracted. Using the effect size Hedge's *g*, the standardized mean difference between groups was calculated. All analyses were based on the random-effects model.

Results and conclusions

The overall effects show that in general collaborative learners who are scaffolded by CSCL scripts outperform learners who are not scaffolded by CSCL scripts with respect to their domain learning ($g = 0.29$, $p < .01$, $k = 45$) and their collaboration skills ($g = 0.73$, $p < .01$, $k = 18$). No significant effect on motivation was found ($g = 0.07$, $p = .57$, $k = 6$). All tests for publication bias were not significant. In line with prior findings, the results show that the positive effects of CSCL scripts on domain learning and collaboration skills stay robustly constant when including the outcomes of more recent studies about learning with CSCL scripts. Our results do not support the criticism that CSCL scripts negatively influence the learners' motivation and hence lead to either no learning or learning only on the expense of learners' motivation. This indicates that learners might not feel less autonomous when interacting with CSCL scripts. However, the reduction in autonomy might be compensated through a gain in the feeling of competence. The small number of primary studies analyzing learners' motivation is a major concern and, given the persistent criticism of overscripting, future research about CSCL scripts should by default include the measurement of different dimensions of motivation.

With respect to the question of the symposium our findings support the position that meta-analyses can substantially contribute to the accumulation of scientific knowledge. Using meta-analysis as a method was not only useful to synthesize existing findings, to assess the robustness of effects and to test hypotheses. It also helped to substantiate a counter-argument against the summarizing position about the malfunction of CSCL scripts recently published by Wise and Schwarz (2017). According to our meta-analytic integration of primary studies, there is a positive effect of CSCL scripts on domain learning which is basically ignored by Wise and Schwarz. Moreover, the meta-analytic integration found no evidence at all for a negative scripting effect on motivation where Wise and Schwarz concluded that overscripting in this very sense (i.e., scripts reduce motivation) is one of the main issues for CSCL scripts. The learning sciences are a field of empirical research (Hoadley, 2018; Sommerhoff et al., 2018). We are hence convinced that meta-analyses of quantitative or qualitative studies are useful and needed to disqualify or support widespread opinions.

Connecting the diversity of CSCL research through meta-synthesis

Cindy E. Hmelo-Silver and Heisawn Jeong

There has been little systematic review of CSCL in STEM that has integrated across qualitative and quantitative research. Our motivation for this research was in particular to better understand the compound resources that comprise CSCL (Roschelle, Bakia, Toyama, & Patton, 2011): collaboration, technology, and pedagogies used (Hmelo-Silver & Jeong, 2016; Kirschner & Erkens, 2013). We wanted to address the questions of 1) How do different combinations of CSCL technologies, pedagogies, and collaboration modes co-vary in CSCL and 2) For these different combinations, is CSCL effective, broadly construed and what factors support or impede the effectiveness of CSCL. This task requires synthesizing diverse CSCL research outcomes while paying attention to factors that support and impede different approaches to CSCL.

Our review uses meta-synthesis as a way to address these questions. Meta-synthesis is a methodology that uses both qualitative and quantitative studies as sources of data and allows for the integration of research across qualitative and quantitative studies (Suri & Clark, 2009; Bair, 1999). Our initial rationale was that any review of CSCL would need to take into account the diversity of methodological approaches in the CSCL community (Jeong, Hmelo-Silver, & Yu, 2014) and thus was well suited for this approach. Another key rationale for choosing this method was that the CSCL community considers a broad range of outcomes from traditional individual pre-post test measures to artifacts to engaged participation (McKeown, Hmelo-Silver, Jeong, Hartley, Faulkner, & Emmanuel, 2017). Meta-synthesis is an interpretive approach concerned with understanding and describing key points and themes across multiple kinds of studies and thus well suited for achieving our goal.

To guide our systematic review of CSCL literature in STEM domains, we defined CSCL as two or more people using technology to work together toward a shared learning goal, and used this definition while searching and screening papers. We searched through two databases, ERIC and Web of Science, in addition to seven key journals regarded by experts to be major outlets for publishing CSCL research (Jeong et al., 2014). Over 1,500 qualitative and quantitative papers focusing on various education levels published between 2005-2014 were screened to ensure each paper met the following criteria: (a) STEM education, (b) empirical research. Out of these papers, 708 papers met our criteria and were then coded for a range of study characteristics; educational level, collaboration type, pedagogy, and technology (e.g., Jeong et al., 2014). Earlier synthesis in which we had coded the study characteristics of the dataset in Jeong, Hmelo-Silver and Yu (2014) confirmed that CSCL used a diversity of qualitative and quantitative methods, and thus was ideally suited for this approach.

We used Latent Class Analysis (LCA) to examine how these three characteristics of CSCL designs covaried to help address research question 1 and to form a framework for sampling from the large number of papers to address question 2 (Hagenaars & McCutcheon, 2002). The LCA identified six thematic clusters ranging in size from 38- 246 papers of which the four largest were interpretable. Cluster one (n=246), Face-to-Face Collaborative Inquiry with Dynamic Feedback (F2FCI), emphasizes papers using face-to-face collaboration, inquiry and exploration pedagogies, and dynamic or other tools. Cluster two (n=74), Synchronous Collaboration (SC), emphasizes papers using synchronous collaboration and communication technologies. Cluster five (n=154), Asynchronous Teacher-Structured Discussion (ATD), emphasizes papers using asynchronous collaboration, discussion or teacher-structured pedagogies, and asynchronous communication technologies. Finally, cluster six (n=145), Online Generative Inquiry (OGI), emphasizes papers using asynchronous or face-to-face collaboration, inquiry and exploration or teacher-structured pedagogies, and sharing and co-construction technology. Larger proportions for a particular code tend to dominate the cluster membership and, therefore, can be used to label and describe the cluster. There was still variability within clusters, which was used to identify an appropriate number of papers to for stratified random sampling, with adjustments to match the demographic characteristics and study designs of the overall cluster. Nonetheless, this synthesis has demonstrated that there are particular combinations of CSCL that vary based on technologies, pedagogies, and modes of collaboration.

For the meta-synthesis that focused on research question 2, we first synthesized findings in each cluster based on the outcomes and overarching theme(s) indicating under what circumstances CSCL may or may not be effective based on the papers sampled for each cluster. To make this process tractable we first annotated the articles sampled for each cluster and then proceeded to create outlines that emphasized what was effective, what was not effective, and any implications. Once we synthesized each cluster, we then looked for themes and patterns across the clusters and compared outcomes across technology, collaboration, and pedagogy. In particular, we looked for indicators of effectiveness broadly construed and patterns that suggested particular factors that supported or impeded effective CSCL.

Addressing the second research questions, our results show generally positive effects of CSCL on content, skills, and affective indicators. These indicators refer to either gains from pre to post intervention or qualitative demonstrations of improvement on these indicators. The strongest evidence comes from the clusters

that use CSCL with inquiry and exploration. These clusters tend to present results that include processes and outcomes more uniformly and provide more detail on their intervention. Although such outcomes are important, designers and researchers need to focus more on the functions that CSCL technologies provide in learning environments and how those are appropriated towards instructional goals. Across clusters, results demonstrate that scaffolding and feedback in different combinations were important for positive learning outcomes (McKeown et al., 2017). However, feedback that was poorly timed or excessive sometimes impeded learning. In addition, certain technologies lend themselves better to particular communication channels and/or pedagogical goals. Finally, we found that different learning environments are used for different learners. For example, simulations were often used in face-to-face inquiry learning environments with younger learners whereas asynchronous threaded discussions were commonly used with more mature learners.

Overall, our study helped us understand the workings of CSCL as a compound resource and how different components may interact with each other. Our approach to research synthesis met the goals of synthesizing research across qualitative and quantitative research methods, examining how technologies, pedagogies, and modes of collaboration cluster together. Using cluster analysis helped us to sample systematically from a literature that was too vast for an exhaustive narrative review. The qualitative and quantitative papers outcomes helped inform each other. Experimental, quasi-experimental, and pre-post test designs provide useful details about what was learned but may not represent the full range of what it means to learn, engage, collaborate productively or be motivated. Qualitative studies can help provide these alternate lenses that look directly at participation and collaborative activity. These different research designs and analytic methods can provide opportunities to triangulate findings as they did in Cluster 1 and highlight factors that might explain the findings (e.g., the kinds of feedback that are useful). This diversity in research also leads to some of the limitations of meta-synthesis. In trying to be open to a range of outcomes, we found that different clusters often used different types of research designs and indicators of effectiveness, making it hard to draw broader conclusions across clusters. Design-based and other mixed methods research are helpful in bridging this gap as is more research that considers the different stakeholders in CSCL. For example, there is little research on the role of teachers in CSCL though their role is clearly important. In addition, future research needs to consider the multiple outcomes that are valued in CSCL (e.g., knowledge, affective, collaboration skills). Although it is challenging to synthesize across such diverse set of studies, but continued efforts toward meta-synthesis are needed to understand CSCL in its full complexity.

References

Åkerlind, G. S. (2012). Variation and commonality in phenomenographic research methods. *Higher Education Research & Development, 31*(1), 115-127.

Bair, C. R. (1999, November). *Meta-synthesis.* Paper presented at Annual meeting of the Association for the Study of Higher Education, San Antonio, TX.

Bruce, C. S. (1999). Phenomenography: Opening a new territory for library and information science research. The New Review of Information and Library Research, 5(1), 31-48.

Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. P. Kirschner (Ed.), Three worlds of CSCL: Can we support CSCL? (pp. 61-91). Heerlen: Open University of the Netherlands

Ding, Y., Chowdhury, G. G., & Foo, S. (2001). Bibliometric cartography of information retrieval research by using co-word analysis. Information processing & management, 37(6), 817-842.

Fischer, F., Kollar, I., Stegmann, K., & Wecker, C. (2013). Toward a script theory of guidance in computer-supported collaborative learning. *Educational Psychologist*, *48* (1), 56–66.

Hagenaars, J. A., & McCutcheon, A. L. (2002). *Applied latent class analysis.* New York: Cambridge University Press.

Hoadley, C. (2018). A short history of the learning sciences. In International Handbook of the Learning Sciences (pp. 11-23). Taylor and Francis. https://doi.org/10.4324/9781315617572

Jeong, H., & Hmelo-Silver, C. E. (2016). Seven affordances of CSCL Technology: How can technology support collaborative learning. *Educational Psychologist, 51*, 247-265.

Jeong, H., Hmelo-Silver, C. E., & Yu (2014). An examination of CSCL methodological practices and the influence of theoretical frameworks 2005–2009. *International Journal of Computer-Supported Collaborative Learning*, *9*(3), 305-334.

Jeong, H., Hmelo-Silver, C. E., & Yu, Y. (2014). An examination of CSCL methodological practices and the influence of theoretical frameworks 2005–2009. *International Journal of Computer-Supported Collaborative Learning*, *9*(3), 305–334.

Johnston, N., & Salaz, A. M. (2017). Using phenomenography to bridge the gap between research and practice: a meta-analysis of three phenomenographic studies. *Information Research, 22*(4). Retrieved on November 15, 2018 from: http://InformationR.net/ir/22-4/rails/rails1614.html.

Kärki, R. (1996). Searching for bridges between disciplines: an author co-citation analysis on the research into scholarly communication. Journal of Information Science, 22(5), 323-334.

Kienle, A., & Wessner, M. (2006). The CSCL community in its first decade: development, continuity, connectivity. *International Journal of Computer-Supported Collaborative Learning*, *1*(1), 9–33.

King, A. (2007). Scripting collaborative learning processes: A cognitive perspective. In F. Fischer, I. Kollar, H. Mandl, & J. M. Haake (Eds.), *Scripting computer-supported collaborative learning - cognitive, computational, and educational perspectives* (pp. 13–37). New York, NY: Springer.

Kirschner, P. A., & Erkens, G. (2013). Toward a framework for CSCL research. *Educational Psychologist, 48*, 1-8.

Limbu, L., & Markauskaite, L. (2015). How do learners experience joint writing: University students' conceptions of online collaborative writing tasks and environments. *Computers & Education, 82,* 393-408.

Marton, F. (1986). Phenomenography: A research approach to investigating different understandings of reality. *Journal of Thought, 21*(3), 28-49.

McKeown, J. M., Hartley, K. A., Faulkner, R. T., Hmelo-Silver, C. E., Jeong, H., & Emmanuel N. (2017). A meta-synthesis of CSCL literature in STEM education. In B. K. Smith, M. Borge, E. Mercier, & K. Y. Lim. (Eds.) Proceedings CSCL 2017 Volume 1, (pp. 439-486). ISLS. Philadelphia PA.

Miyake, N. (2007). Computer supported collaborative learning. In R. Andrews & C. Haythornwaite (Eds.), Sage Handbook of E-learning Research (pp. 248-266). London UK: Sage.

Roschelle, J., Bakia, M., Toyama, Y., & Patton, C. (2011). Eight issues for learning scientists about education and the economy. *Journal of the Learning Sciences, 20*, 3-49.

Rovio-Johansson, A., & Ingerman, Å. (2016). Continuity and development in the phenomenography and variation theory tradition. *Scandinavian Journal of Educational Research, 60*(3), 257-271.

Scardamalia, M., & Bereiter, C. (1994). Computer Support for Knowledge-Building Communities. *The Journal of the Learning Sciences, 3*(3), 265–283. www.jstor.org/stable/1466822

Sommerhoff, D., Szameitat, A., Vogel, F., Chernikova, O., Loderer, K., & Fischer, F. (2018). What Do We Teach When We Teach the Learning Sciences? A Document Analysis of 75 Graduate Programs. *Journal of the Learning Sciences*, *27*(2), 319-351.

Sommerhoff, D., Szameitat, A., Vogel, F., Chernikova, O., Loderer, K., & Fischer, F. (2018). What Do We Teach When We Teach the Learning Sciences? A Document Analysis of 75 Graduate Programs. Journal of the Learning Sciences, 27(2), 319-351.

Suri, H., & Clarke, D. (2009). Advancements in research synthesis methods: From a methodologically inclusive perspective. *Review of Educational Research, 79*, 395-430.

Tang, K.-Y., Tsai, C.-C., & Lin, T.-C. (2014). Contemporary intellectual structure of CSCL research (2006–2013): a co-citation network analysis with an education focus. *International Journal of Computer-Supported Collaborative Learning*, *9*(3), 335–363.

Vogel, F., Wecker, C., Kollar, I., & Fischer, F. (2017). Socio-cognitive scaffolding with collaboration scripts: a meta-analysis. *Educational Psychology Review 29*(3), 477-511. doi: 10.1007/s10648-016-9361-7

Wise, A. F. & Schwarz, B. B. (2017). Visions of CSCL: eight provocations for the future of the field. *International Journal of Computer-Supported Collaborative Learning, 12*, 423-467.

Wise, A. F., & Schwarz, B. B. (2017). Visions of CSCL: eight provocations for the future of the field. *International Journal of Computer-Supported Collaborative Learning, 12*, 423–467. 10.1007/s11412-017-9267-5