International Society of the Learning Sciences

Outside-in, Inside-out, or Outside-out? Exploring the Flow of New Ideas and the Development of CSCL and ICLS Via Co-Authorship Networks From 1995 to 2020

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Abstract: This paper examines all conference papers published in the proceedings of the International Conference of Learning Sciences (ICLS) and the International Conference on Computer-Supported Collaborative Learning (CSCL) from 1995 to 2020 to explore the changes of research foci in the two research communities over the years. By conducting keyword analysis and social network analysis on the time-evolving co-authorship networks, we found three distinctive spreading patterns of keywords in the two communities: outside-in ascending pattern, inside-out ascending pattern, and outside-out descending pattern. Our analysis also reveals how different co-authorship cliques and core authors have influenced such patterns, and points to possible actions for both research communities.

Introduction

Since the first conferences in 1995 and 1996 respectively, the research communities of Computer-Supported Collaborative Learning and Learning Sciences have grown vastly in terms of their sizes and topics. Jeong et al. (2019) analyzed bibliographical clusters in educational research and examined their relationships with CSCL and ICLS communities, while Lund et al. (2020) used scientometric methods to connect educational research to social science and humanities research. Pea and Linn (2020) reviewed the growth of the learning sciences from a personal history perspective. Our work is based on frameworks we developed for an analysis of the Artificial Intelligence in Education community (Zheng et al., 2022), and adds to this ongoing conversation and responds to this year's theme of *building knowledge and sustaining our community* by analyzing the time-evolving co-authorship networks based on all conference papers published in the proceedings of the International Conference on Computer-Supported Collaborative Learning (CSCL) and the International Conference of Learning Sciences (ICLS) from 1995 to 2020. We identify distinctive patterns in research topics and reveal how co-authorship cliques and core authors have influenced these patterns.

Methods

To examine the change in research foci and collaboration patterns in CSCL and ICLS over time, we first collected the metadata of full conference publications (including long papers, short papers, and posters) from the ISLS repository (ISLS, 2022). For years of data that were not included in the repository, we then retrieved the data from archived websites, school repositories, and personal archives. In total, there are 5,091 papers and 8,225 authors in our dataset including both the CSCL and ICLS conferences from 1995 to 2020 with only ICLS 2002 data missing. The dataset includes article title, author names, publication year, and abstract. We collected background information on the published authors' Google Scholar profiles using SerpAPI. The author dataset includes author name, interest areas, institution, number of citations, and h-index. We created a unique author ID for each author and combined the two datasets based on the IDs. Then we built time-evolving co-authorship networks based on these data (Feng & Kirkley, 2020; Zheng et al., 2022).

Our data analysis was organized into three levels: the *(1) macro-level* analysis displaying the structural and topical comparisons of the two communities, the *(2) meso-level* analysis presenting the evolution of topics among cliques within each community, and the *(3) micro-level* analysis revealing the demographics of core authors in each community. At the macro-level, overall network measures and ascending and descending keywords (Pesta et al., 2018) were analyzed to identify major trends in the research communities over the years. At the meso-level, cliques were detected using the modularity-optimization method offered in the R package, *i*graph, which maximizes the proportion of edges within communities relative to the expected proportion of such if all edges were placed randomly (Csardi & Nepusz, 2006). At the micro-level, core members of each community were identified using degree centrality (Nieminen, 1974).

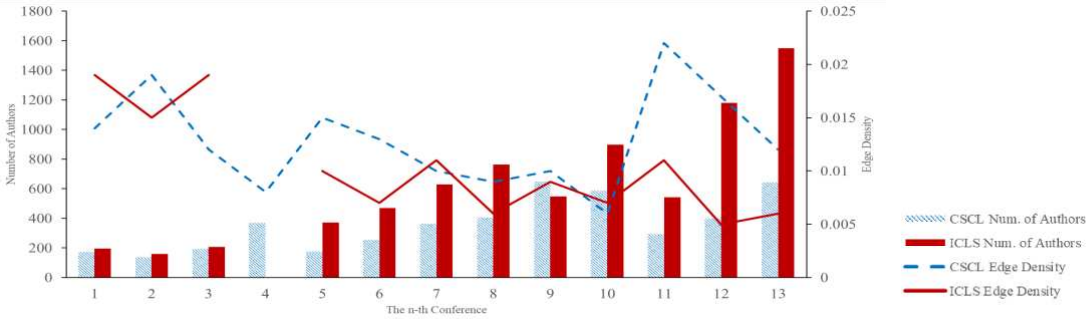
Findings

Macro-level analysis

We first compared CSCL and ICLS using network metrics at the conference level. In total, there were 3,347 authors and 5,370 authors who had contributed to the CSCL and ICLS conferences, respectively, from 1995 to 2020. The increase in the number of ICLS authors was greater than that of CSCL authors but at the cost of internal connectedness (Figure 1). As the size of the ICLS community increased almost eight-fold from 195 authors in 1996 to 1,549 authors in 2020, its connectedness measured by edge density dropped more than two-thirds from 0.019 to 0.006. In contrast, CSCL edge density showed more volatility but ultimately concluded the measurement period with a similar density as it displayed at the start (0.014 in 1995 and 0.012 in 2019) as CSCL authorship increased overall from 173 to 644.

Figure 1

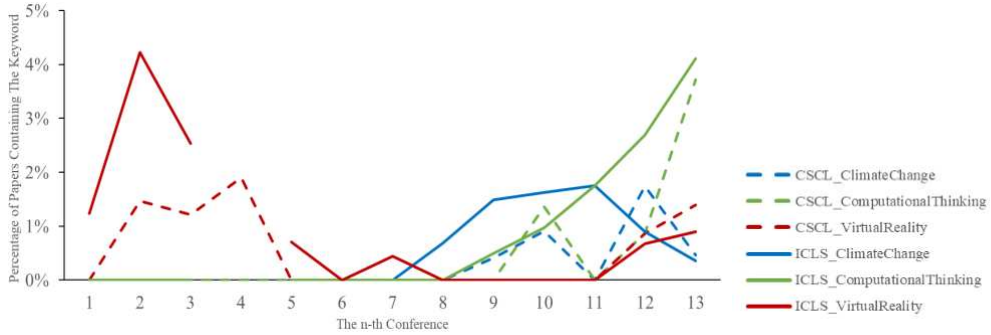
The number of authors and the edge density of CSCL and ICLS conferences from 1995 to 2020



To examine how research foci evolved over the years in ICLS and CSCL, we then analyzed changes in the most frequently-used keywords in both conferences over time. Ascending, descending, and fluctuating keywords were defined by the Pearson's correlation coefficient (> .5, < -.5, or in between) of their relative frequency in each conference against the sequence of the conference (Carroll, 1961; see Figure 2 for examples). Among the 500 most frequently-used keywords from 1995 to 2020, 16 keywords were ascending in both CSCL and ICLS: five related to specific domains (*climate change*, *computational thinking*, *computer science*, *the Next Generation Science Standard (NGSS)*, and *STEM learning*); three related to new learning media (*augmented reality (AR)*, *online course*, and *social media*); four related to processes of learning (*knowledge advancement*, *learning gap*, *meaning making*, and *online discourse*); and four related to research methods (*design-based research*, *epistemic network analysis*, *learning analytics*, and *qualitative analysis*). These keywords reveal rising research topics in both communities.

Figure 2

Relative frequency of "climate change" (ascending in both), "computational thinking" (ascending in both), and "virtual reality" (fluctuating in CSCL and descending in ICLS)



However, macro-level analysis did not explain why certain keywords ascended to the top while others fell out of favor. Was the rise of a keyword promoted by core authors of the community? Or was the rise a reflection of a shared focus across community members? To further investigate how different research ideas spread or declined in the communities, we zoomed in on cliques and core authors in co-authorship networks in meso- and micro-level analysis.

Meso-level analysis

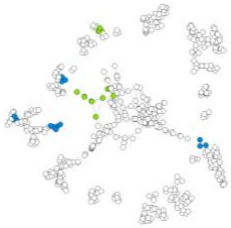
At the meso-level, we explored how the chronological change of keyword usage unfolded laterally on co-authorship networks throughout the years. We discovered three major types of patterns of spreading dynamics on the co-authorship network:

1. **Outside-in ascending pattern:** the ascending keyword was first brought up by cliques on the periphery of the network and then entered the central cliques (e.g., *climate change* in both CSCL and ICLS)
2. **Inside-out ascending pattern:** the ascending keyword was first mentioned by central cliques and then spread to the periphery (e.g., *computational thinking* in ICLS)
3. **Outside-out descending pattern:** the descending keyword was discussed by the periphery but never reached central cliques (e.g., *virtual reality* in ICLS).

The network graphs in Table 1 illustrate the spread of three keywords in ICLS from 2014 to 2020. Each keyword represents one pattern mentioned above. The ascending keyword, *climate change* (blue vertices in Table 1), represents the outside-in pattern, which suggests that the rise of its frequency originated from spontaneous concerns for climate change shared by various cliques in ICLS and spread to central cliques only later on. Another ascending keyword, *computational thinking* (green vertices in Table 1), represents the inside-out pattern, meaning a small group of authors in the central cliques studied and advocated for computational thinking first and the concept later spread outwards on the network along their co-author connections. The descending keyword, *virtual reality* (red vertices in Table 1), never reached the central cliques, representing an outside-out pattern. We did not observe an inside-in ascending pattern; ascending keywords taken up by central cliques were never confined only within the center but always spread to the rest of the network, exhibiting the inside-out ascending pattern.

Table 1

ICLS co-authorship networks from 2014 to 2020 with colored vertices showing cliques that used the keyword "climate change" in blue, "computational thinking" in green, and "virtual reality" in red

The 10th ICLS in 2014	The 11th ICLS in 2016	The 12th ICLS in 2018	The 13th ICLS in 2020
			

The contrast between the three patterns implies the importance of authors in the central cliques. On the one hand, the rise of keyword frequency is always associated with the involvement of core authors (i.e., core contributors who have high degree centrality in the co-authorship networks), whether the core authors are advocates from the beginning (i.e., the inside-out ascending pattern) or adopters at a later stage (i.e., the outside-in ascending pattern), although the former seems to boost the rise of keywords faster than the latter (see Figure 2 for growth trends of the three example keywords). On the other hand, descending keywords primarily followed the outside-out pattern without any involvement of core authors. *Thus, core authors in CSCL and ICLS seem to play critical roles in shaping the development of the community by carefully adopting certain keywords in their own research, bringing those keywords to the center of the research network.*

Micro-level analysis

Since the meso-level analysis revealed the importance of core authors, we further looked into this particular group of authors to examine any endogenous biases that could lead to their unconscious preference for certain research topics or keywords over others. We defined core authors as the top 1% of authors by degree centrality in the CSCL and ICLS communities. 31 CSCL core authors (overall d.cen >= 48) and 51 ICLS core authors (overall d.cen >= 62) were identified, and their Google Scholar profiles were fetched. Eight overlaps were found between the two sets.

Based on authors' self-identified interest areas in their Google Scholar profiles, we identify comprehensive research topics covered by the core authors from different subjects (e.g., *science*, *computer science*, *math*) and pedagogical approaches (e.g., *project-based learning*, *game-based learning*) to different

technologies and media (e.g., *tangible interfaces*, *intelligent systems*, *AR/VR*). However, it is worth noting that, while the core authors in CSCL exhibit geographic diversity, core authors in ICLS predominantly worked for North American institutions. In CSCL, 13 out of the 31 (42%) core authors are in North America (United States and Canada), nine in Europe (Germany, Finland, Swiss, and Spain), seven in Asia (Japan, Singapore, and China), and two authors in the Middle East (Israel). In contrast, 46 out of the 51 (84%) core authors in ICLS are in North America, with three in Germany and two in Israel. To investigate the change of core authors over time, we identified the top 1% of authors by degree centrality in the CSCL and ICLS communities every eight years. CSCL showed a steady decline of core authors in North America from 69% in 1995-2003 to 39% in 2013-2019 while this percentage remained almost the same for ICLS from 90% in 1996-2004 to 91% in 2014-2020. *The geographic concentration of ICLS core authors is concerning due to their influence on research community development, as shown in our meso-level analysis.*

Discussion

This paper is part of a larger project that investigates the dynamics of the CSCL and ICLS communities. These initial results are encouraging since they reveal some important aspects of these dynamics. First, they suggest that the CSCL community, although smaller, secured a high level of interconnectedness over the years *while* spreading internationally beyond Europe and the US. In contrast, ICLS grew much larger, possibly as separate subcommunities that are not as well connected to each other. This finding points to possible actions by the CSCL community to promote its own growth and by ICLS to increase collaboration and connectedness. A second and important finding relates to how topics gain popularity within the research communities. The inside-out and outside-in growth patterns indicate that the communities are accepting of peripheral members bringing new ideas and also of core members introducing new topics. However, in the case of the outside-out patterns, other topics are rejected by the community (outside-out) and disappear. We intend to more thoroughly research both processes to find out the normalized frequency of those event types and also to determine why and how some topics are rejected by CSCL/ICLS, perhaps due to issues of power, political capital, just a very high bar for new topics. A final key finding was the role of core authors. In both communities, these authors have a strong influence on which topics get accepted and, thus, the destinies of CSCL/ICLS. It was concerning, especially considering issues of equity and justice, that 84% of ICLS' core authors are located in the US. It was less concerning that CSCL members were more diverse, but in both communities core members are mostly located in developed, Global North countries.

We believe that this research project could shed light on how both communities could evolve, learning from each other, towards communities that, while experiencing "growing pains", remain more connected, more diverse, less hierarchical, and more accepting of new ideas.

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