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ABSTRACT

We use a co-authorship network analysis to describe and examine the social network of researchers studying physical education content knowledge worldwide. Co-authorship network analysis is a method for determining the scope, trend, and focus of research around a topic. It provides a way to evaluate both the growth of a field and to examine the extent of research collaboration. Our review consists of 101 articles that were examined in our network analysis. Our results show that the research on content knowledge occurs within and among 13 high-income economies. Research productivity in this area is on an upward trajectory since 1990. The research in physical education occurs in a distributed network with some authors serving as key hubs for research collaboration. From a global perspective, there is a need to create links to low-income economies to strengthen their research capacity.

KEYWORDS

Common content knowledge; specialized content knowledge; co-authorship analysis; research trends

Research on teaching took a decidedly different turn from previous efforts such as process-product research (Dunkin & Biddle, 1974) when Shulman (1986, 1987) argued that researchers should consider the content of a lesson as part of the context of teaching and learning. The importance of content knowledge for teaching is that if teachers do not know the content they are teaching then what are they teaching and how will their students learn? This has been empirically validated by a number of experimental studies that he measured teacher behavior and student learning in physical education (Iserbyt et al., 2017; Kim et al., 2018; Stefanou et al., 2021). This of course had significant implications in terms of creating outcomes for preservice teacher education such as the SHAPE America (2017) national standards for initial physical education teacher education (standard 1.1. and 1.2), and professional development that focuses on teacher knowledge of content (Darling-Hammond & Oakes, 2019).

While a number of researchers began to deconstruct the components of PCK, it was not until Ball et al. (2008) in their seminal paper *Content knowledge for teaching: What makes it special*, that researchers paid significantly more attention to unpacking what is meant by content knowledge. Ball et al. (2008) endeavored to map out the domains in teaching in a similar fashion to Shulman (1986, 1987) differentiating between content knowledge and

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PCK. Within content knowledge, which she referred to as subject matter knowledge, she and her coauthors included three domains. First, common content knowledge (CCK), which referred to knowledge that individuals need to perform an activity. Their focus was mathematics, and an example would be the knowledge to perform long division. Second, horizon content knowledge, which referred to knowledge of how the curriculum across grades relates to each other such as knowing how subtraction taught in early elementary school would be used in middle school. Third, specialized content knowledge (SCK) is knowledge that instructors, such as teachers and coaches, need to design instruction in terms of learning the content. For example, knowing the instructional tasks to teach long division. Within PCK, they proposed three domains: (a) Knowledge of content and students refers to knowledge of how students understand mathematics, (b) knowledge of content and teaching refers to the sequences of content tasks to teach mathematics, and (c) knowledge of content and curriculum is related to the organization of content in the curriculum.

Few of the domains of teaching proposed by Ball et al. (2008) have empirical evidence in support of them, but two components that do are CCK and SCK. In physical education, Ward (2009) proposed sub-domains of common content knowledge in movement (CCK-M) classifying them as knowledge of etiquette, how to play safely and the rules of a movement activity, knowledge of how to perform the activity technically, and where relevant knowledge of tactics. More recently, Tsuda et al. (2019) differentiated between knowledge measured on a test or obtained by questioning with actual performance as an indicator of CCK called CCK-P. There is also a substantive literature on health-related fitness (CCK-HRF; Santiago & Morrow, 2020).

Ward and colleagues (Ward et al., 2020; Ward, 2009) also defined the sub-domains of SCK as (a) knowledge of instructional tasks that can be used to teach CCK, (b) how to represent the instructional task to students, and (c) the errors that students might make in performing the task. Since then, research has been conducted worldwide, by different researchers often in research teams, who often draw on the work of each other to both systematically replicate and extend the research findings relative to content knowledge (e.g., Dervent et al., 2020; Hastie, 2021; Iserbyt et al., 2017; Kim et al., 2018; Stefanou et al., 2021). Studies have also been conducted that demonstrate the impact of CCK and SCK on a teacher's PCK and some in terms of student learning (e.g., Dervent et al., 2020; Iserbyt et al., 2017; Kim et al., 2018; Santiago & Morrow, 2020; Stefanou et al., 2021).

There are substantive summaries of the literature on CCK and SCK (see Hastie, 2021; Kim et al., 2018; Ward et al., 2022). In short, these findings provide strong evidence that content knowledge either as CCK or SCK is not well acquired by participating in K-12 schooling, nor extra-curricular activities such as sports, nor is it acquired well in teacher education programs. What is interesting about these findings is that for the most part, the studies show that worldwide the problems are more similar than different. There are some exceptions in CCK scores. In China where preservice teachers (PSTs) are taught to be specialists in 1–2 content areas, PSTs know their CCK well and are very competent at performing it (Ward et al., 2018). In contrast, this is not the case for other countries in the world such as Belgium, Japan, Korea, Turkey (Ministry of Education [MoNE], 2018a, 2018b), and the United States, where physical education teachers must teach multiple content areas including fitness and strength training, dance, court sports, racquet sports, and field invasion games. Recently, a number of experimental studies have shown how CCK and SCK can be improved in meaningful ways (Hastie, 2021; Hastie et al., 2022; Tsuda et al., 2019; Ward et al., 2018); but for the most part content knowledge has not been emphasized well in physical education research.

Content Knowledge is central to teaching because it represents an important knowledge domain in teaching in general (Ball et al., 2008; Shulman, 1986, 1987) and in physical education specifically (Siedentop, 2002; Ward, 2009). Given this importance and the similarities of challenges faced by PETE globally, we examine the extent of the research being conducted worldwide. It is increasingly commonplace for researchers to collaborate within and across countries (Ward et al., 2021). Yet researchers pursuing a line of inquiry may be unaware of the work being done elsewhere in the world, particularly if it is being reported in other languages. As such typical literature reviews may miss essential features of worldwide inquiry into a topic including if there is inquiry elsewhere. A first step is to recognize the scope of the research on the topic using indices that provide some indication of the interest and work on the topic, who is researching it, and what collaborative networks exist.

Doing this can facilitate the growth of collaborative networks when researchers share their findings, challenges, and foci before research is in print and in so doing move the research direction forward by keeping momentum. One way to document the scope of the research on a topic and collaborative networks is Social Network Analysis (SNA) (Fonseca et al., 2016). In the context of this study, a social network is defined in terms of researchers who study content knowledge and are represented as nodes (points) on a graph (Fonseca et al., 2016). Social network analysis examines the relationships (or links) between nodes as a function of the co-authorship of research papers and the content knowledge sub-domains (e.g., CCK or SCK). This relational information characterizes a social "research" network. SNA allows both a visual representation of the collaboration on publications and it also identifies hubs of researchers working collaboratively. SNA also uses several indices that indicate the strength of the network. An SNA analysis focuses not on the characteristics of the researchers, but on the connections among them. By quantifying these relationships as indices, it is possible to identify the most important nodes, the formation sub-groups, and the scope of the research.

Our primary purposes in this study are to describe and examine the social network of researchers studying content knowledge worldwide. In particular, how researchers are linked with each other through co-authorship; the network of research teams and smaller hubs as clusters of research collaboration; research hubs and the extent of the focus on content knowledge domains (CCK-M, CCK-HRF, CCK-P, and SCK). Our broad research question is to analyze and map the networks of collaboration (i.e., structure) among the researchers studying content knowledge worldwide. Our specific questions are: (a) What is the scope and trend of scholarship on content knowledge? (b) How distributed is the research in the network? and (c) What are the co-authorship relationships?

Method

This study was deemed exempt by the second author's institutional review board for human subject research. All of the data reported in this study were obtained from a systematic literature review where we searched the literature using predetermined procedures and predetermined inclusion and exclusion criteria and where we extracted the data and synthesized it. Systematic literature review allows the researchers to comprehend existing body of the focused subject-matter and describe gaps in literature. It also provides summarizing, analyzing, and synthesizing a group of related literature (Paré et al., 2015; Xiao & Watson, 2019). We describe this process below.

Selection process of databases

The online databases ERIC, Psych info, Web of science, and Scopus were searched. The first three were chosen because they comprehensively covered English language papers and some non-English language papers. Scopus was chosen because of its good coverage of non-English papers. Keywords were selected from key articles that were focused on content knowledge in PE and were searched as key words in titles, abstracts, and then full texts (Hastie, 2021; Kim et al., 2018; Santiago & Morrow, 2020; Stefanou et al., 2021; Tsuda et al., 2019; Ward et al., 2020). The inclusion criteria were defined before beginning the literature search. First, the paper must be published in a peer-reviewed journal. Second, the setting of the research must focus on physical education PSTs or physical education teachers or students following a physical education lesson in a school setting. Third, the research must have included the terms SCK, CCK-M, CCK-P, or CCK-HRF or the description of the independent or dependent variables must conform to the definitions of the four variables. The latter criterion was required because the search time frame was open, and many studies of content knowledge while able to be classified by us as SCK, CCK-M, CCK-P, or CCK-HRF did not use these terms because the terms have only been used since 2008. Figure 1 presents a diagram of the article search and screening steps taken to examine studies for exclusion and inclusion in the literature review (Huerta & Garza, 2019). Our search of the literature found 101 articles that met the criteria and they covered studies from 1990 (Note: none were found before that time that met the criteria) to the time of the submission in September 2022. There were also 16 review and conceptual papers where we examined the reference lists to see if there were studies included in their reviews that were not identified in our database search (i.e., snowballing; Greenhalgh & Peacock, 2005). We also used the snowball technique on all papers found in the database search.

Variables

In this study, we used an SNA, to analyze a finite set and relationship between people, nodes, actors, objects, and edges (Fonseca et al., 2016). Nodes represent researchers (both lead and coauthors) who published studies focused on the domains examined in our literature search. To determine the metrics for the analysis, SNA uses connections (i.e., links) among the nodes as a basic unit. These links are reported on a network map (See Figure 2). The lines between nodes are called *edges*, and represent the links among nodes. The thickness of the edges indicates the relationship among nodes and it is represented on the map by darker lines. We used three primary metrics in our analysis: degree centrality, network density, and betweenness centrality, and to analyze our publications in SNA. We consider each of these metrics of equal value in the analysis.

Degree centrality

Centrality represents a gross measure of the number of links one node (i.e., author) has with other nodes. It allows us to see who is the most connected in a network and who is on the

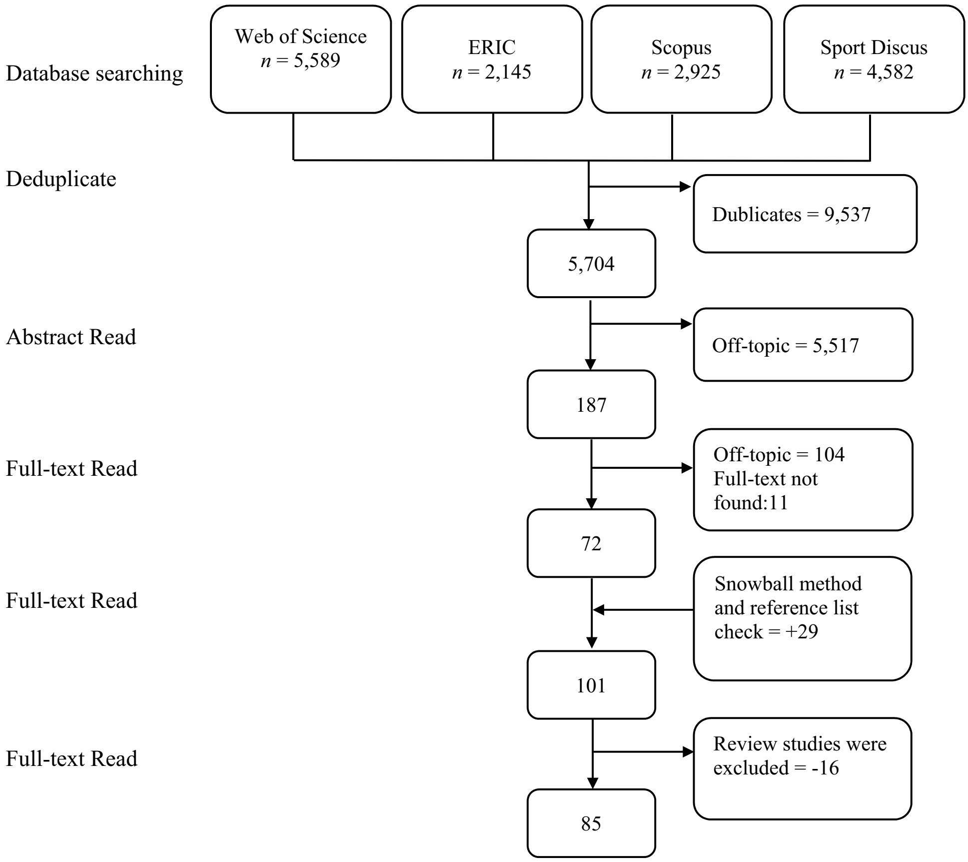


Figure 1. Diagram of article search and screening steps taken to examine studies for exclusion and inclusion in the literature review.

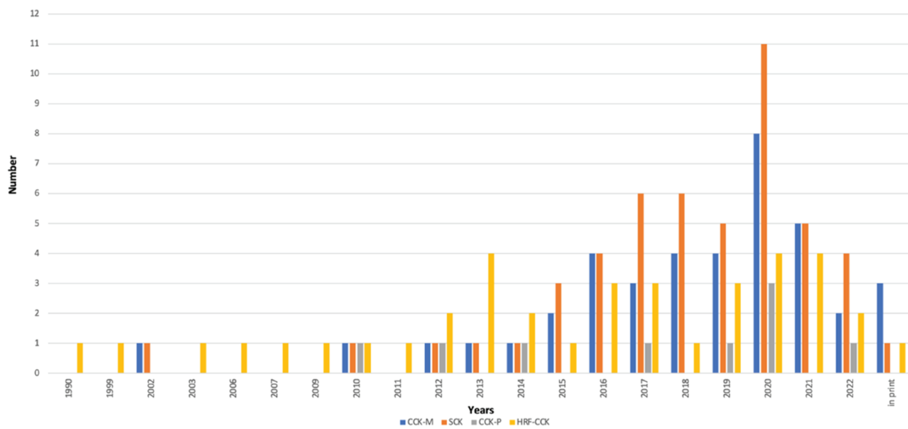
periphery of the network. Centrality scores range from 0 to 1. If a score is close to 1, this indicates a more centralized social network with the most nodes connected; if the score is close to 0, it is a more decentralized social network with more who publish more independently of other authors working on the same research topic. In our case, this is content knowledge.

Network density

Density is defined as a measure of the number of connections in a network divided by the number of potential connections. It provides a comparison between how connected the network is and how connected it could be. The density of the social network was calculated using percentages. Percentages close to 100% demonstrate strong links among network publications. If there are potentially 100 connections and the network has 10 connections, a density score will be 0.10 (10%) which would indicate a low connection among network authors.

Betweenness centrality

Betweenness centrality measures the number of times a node is located on the shortest path to other nodes. It reflects the connections authors have with other researchers in terms of



X axis= Years of the publications

Y axis= Number of the publications

Figure 2. Publication trends by domains 1990–2022.

a sub-network or hubs. A hub or sub-network, which is a node is the starting point for a number of links leading out of it. Authors with a high betweenness score act as a bridge to other authors and affect the flow, in this case, the flow of publications in a system. Authors with high betweenness scores are considered to occupy a strategic position in the network (Brandes, 2001). Authors with high betweenness scores are also critical for connection among groups, because no connections in the network would exist without them.

Results

What is the scope and trend of scholarship on content knowledge?

Our SNA reports studies for each of the four domains of content knowledge contained within the 85 studies we reviewed. A reference list of the studies can be found at https://contentknowledgere.wixsite.com/-sna. These domains were in order of investigation SCK ($n = 50$ foci), CCK ($n = 40$ foci), CCK-P ($n = 9$ foci), and CCK-HRF ($n = 39$ foci). We report on the focus of the studies rather than the number because many studies included multiple domains that were measured and collectively these foci add to the database in each domain separately. A majority of the studies 47% were descriptive, 31% were quasi-experimental or experimental, 7% were qualitative, and 15% were content knowledge instrument development studies.

Figure 2 reports the number of publications from 1990 to September 2022. There were no studies that met our criteria that were published before 1990. From 1990 to 2011 there was a low rate of publications approximately one every two years. The majority of these were CCK-HRF. Beginning in 2012 there is an increasing trend reaching a peak in 2020 for all domains, but particularly for CCK-M and SCK studies. The studies focusing on the domains in 2021–2022, while not as high as in 2020 still demonstrate a strong publication rate.

How distributed is the research in the network?

Based on the data retrieved, the global network for research on content knowledge is composed of 13 countries (See Figure 3). All 13 countries have within country connections among researchers. Germany, Greece, Ireland, Portugal, and the United Kingdom have only within country collaborations (See Figure 3). We calculated the network density as 0.3. The network density can be viewed at a low to moderate level (Yang et al., 2017) reflecting a distributed, yet somewhat collaborative international effort to examine content knowledge. The centralization score for the network is 0.08, which indicates that publications studied in the countries in our analysis represent a decentralized network connection. This can be seen in Figure 3 which shows that the content knowledge studies in the countries in our analysis are not dependent on only one or a few researchers in the countries. The betweenness score for the whole network is .25 or 25% indicating that many authors are not connected.

Table 1 presents network metrics by country. The countries with the most publications are in rank order, the United States of America (USA), Turkey, Belgium, and China. The degree centrality and density calculations understandably are affected by the smaller number of publications in countries with fewer publications which represents a majority

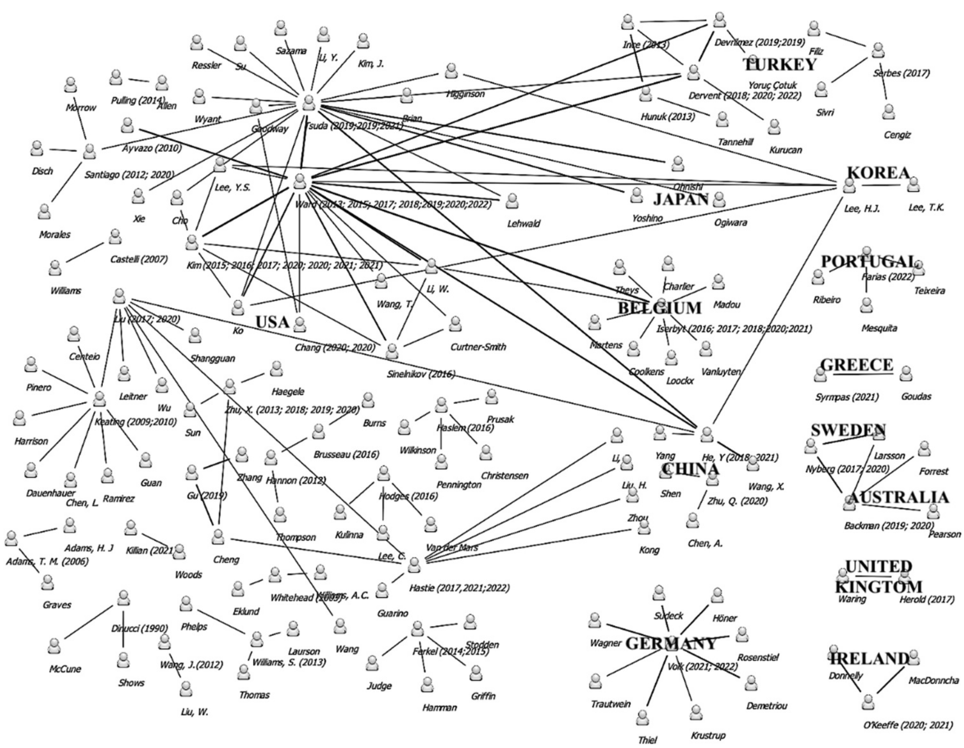


Figure 3. International collaborative networks: Authors and countries.

Table 1. Network metrics by country.

Country	Rank	Degree Centrality	Density	Number of Papers
USA	1	0.12	0.022	50
Turkey	2	0.09	0.181	10
Belgium	3	0.10	0.020	6
China	4	0.10	0.089	5
Sweden	5	0.33	0.330	3
Japan	6	0.25	0.500	2
Ireland	6	0.33	0.667	2
Germany	6	0.11	0.220	2
Australia	7	0.33	0.667	1
Greece	7	0.50	1.000	1
Korea	7	0.14	0.289	1
Portugal	7	0.25	0.500	1
United Kingdom	7	0.50	1.000	1

of the countries. Table 2 reports the collaborative researcher links in the network of the researchers with five or more connections ($n = 20$). A majority of lead authors of papers are located in the USA and Germany. Overall 28.24% of all collaborations are between two countries, 3.53% are between three countries, and 1.18% are between four countries.

What are the co-authorship relationships?

We answered this question with SNA. Figure 4 provides a visual representation of the relationship of the key scholars that have published in the network both within and across strands. There are 157 coauthors (i.e., nodes) connected by 375 edges (i.e., collaborations). Table 3 provides metrics on the network and influential nodes, and these are discussed below.

Figure 4 shows that the number of links among coauthors is at a moderate to a high level. The density score of content knowledge strands was 0.30 which shows a low to moderate relationship among content knowledge authors in the network (Yang et al., 2017). Indicating that while a substantive amount of research is occurring on the topic it is distributed among the authors with only 30% of the authors collaborating. The centralization of the content knowledge strands was 0.08. This score demonstrates that the researchers studying content knowledge do so in a decentralized network. Collaboration of group members has taken place among different researchers rather than depending on only one or a few group members. The greatest number of links (i.e., highest in degree) reported in Table 3 show that Ward, Tsuda, Kim, Dervent and He are the most connected researchers in the global network. Table 3 also indicates that Ward has the highest betweenness score followed by He, Tsuda, Iserbyt, and Liu suggesting that this these members exert the most control over the network.

Discussion

Our primary purposes in this study were to describe and examine the social network of researchers studying content knowledge worldwide. Understanding the scope of a network allows researchers to determine the extent of investigations into a topic which in turn provides an understanding of how an investigation into a topic emerges, grows to maturity, and declines. Studies of this kind also identify how researchers are linked with each other

Table 2. International collaborative researcher linkages.

Name	Country	Number of Connected Researchers
Ward, P.	USA	39
Tsuda, E.	USA	21
He, Y.	China	18
Kim, I.	USA	16
Ko. B.	USA	16
Liu, H.	USA	15
Dervent, F.	Turkey	13
Santiago, J.	USA	13
Iserbyt, P.	Belgium	12
Lee, Y.S.	Korea	12
Lee, W.	USA	11
Wang, X.	China	10
Lee, H.J.	Korea	8
Demetriou, Y.	Germany	7
Devrilmez, E.	Turkey	7
Höner, O.	Germany	7
Krustrup, P.	Denmark/UK	7
Loockx, J.	Belgium	7
Rosenstiel, S.	Germany	7
Sudeck, G.	Germany	7
Thiel, A.	Germany	7
Trautwein, U.	Germany	7
Volk, C	Germany	7
Wagner, W.	Germany	7
Theys, L.	Belgium	6
Xie, X.	USA	6
Castro-Piñero, J.	Spain	5
Centeio, E.	USA	5
Chen, L.	USA	5
Cribbs, J.	USA	5
Doan, R.	USA	5
Harrison Jr, L.,	USA	5
Ince, M.L.	Turkey	5
Keating, X. D.	USA	5
Lineberger, M. B.	USA	5
Ramirez, T.	USA	5
Webster, C. A.	Australia	5
Webster, L.	USA	5
Wellborn, B.	USA	5

through co-authorship (i.e., collaboration), networks of research teams, and smaller hubs as clusters of research collaboration. These studies provide understanding into scientific research groups that direct inquiry into a topic through their collaborative efforts that oftentimes can extend beyond a single country (e.g., Ward et al., 2021). In this case, our focus is on studies investigating the content knowledge domains (CCK-M, CCK-HRF, CCK-P, and SCK) and those who conduct the investigation (i.e., collaboration networks).

Our first research question examined the scope and trend of scholarship on content knowledge. Our review consisted of 85 studies which is a substantive body of literature for a topic in our field. However, we also want to acknowledge 16 important review and conceptual papers that have addressed the topic and these can be found at https://contentknowledgere.wixsite.com/-sna .The study of content knowledge in physical education can be said to have begun in the early 1990s. Before then there were movement skills tests, but virtually no research assessing what PSTs and teachers knew about their content. Research on content knowledge was not substantive until the 2000s when it rapidly grew in all content knowledge domains (CCK-M, CCK-HRF, CCK-P, and SCK). Based on our

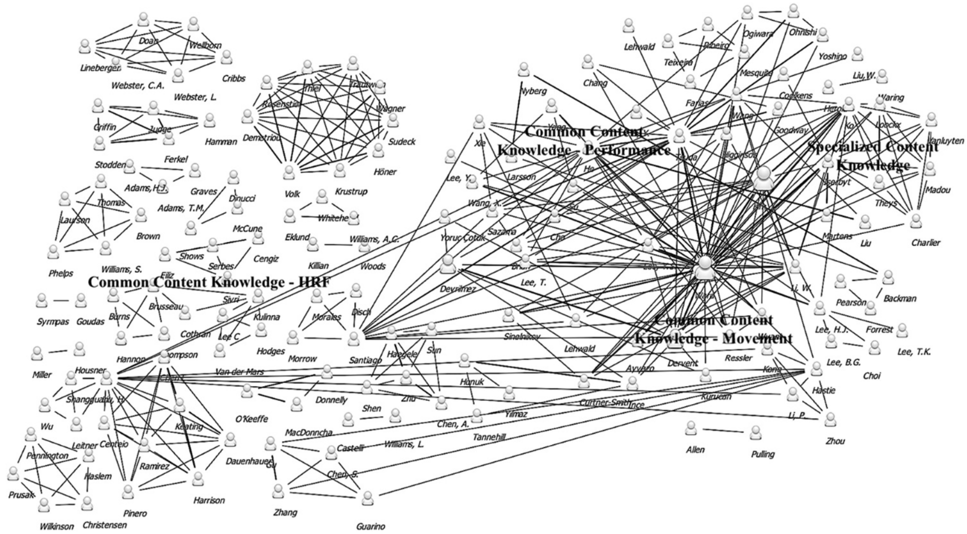


Figure 4. Social network analysis of domains and authors.

Table 3. Node-level metrics of top five faculty in the network.

Node-Level Metrics	Researcher	Value	Country
Highest in degree centrality	Ward	0.80	USA
	Tsuda	0.37	USA
	Kim	0.22	USA
	Dervent	0.22	Turkey
	He	0.21	China
Highest betweenness centrality	Ward	0.23	USA
	He	0.15	China
	Tsuda	0.13	USA
	Iserbyt	0.11	Belgium
	Liu	0.10	China

familiarity with the work of researchers reported in the 85 studies, we envisage the trend of investigations on this topic to continue and to expand into other areas. For example, the study of CCK is currently limited to knowledge of movement, health-related fitness, and observed via individual performance. But there are current investigations occurring and being planned that will expand the scope of CCK into more cognitive content such as health education and social justice content (Ward & Kim, 2022). In such cases, new sub-domains of CCK to address this content will need to be developed. Similarly, studies into SCK are likely to focus more on task representation and error analysis where there is little investigation occurring compared to content development. These new investigations into CCK and SCK provide evidence that the research focus on content knowledge is still growing. Viewing the studies collectively approximately 50% of the designs were descriptive, were quasi (i.e., non-control group) or experimental (38%), and the remaining designs were instrument development studies typically using Rasch methodology and there have been a small number of qualitative studies. These approaches to studying content knowledge reflects both the multiple methods that have been brought to bear on the study of content knowledge and the search for ways to measure it.

Our second research question examined how distributed was the research in the network. Articles in our analysis originated from 13 different countries. A majority of the papers were published by lead authors located in the United States, however, many of these research articles were not conducted in the United States. Most studies were published in English. The World Bank (2022) assigns the world's economies to four income groups—low, lower-middle, upper-middle, and high-income countries. All of studies we reviewed occurred in high-income economies. We do not think this is a different finding for other topics in the field of physical education and physical education teacher education. However, it does raise questions about how to financially and collaboratively support research and researchers in other countries. Collaboration provides a mechanism for the engagement of scholars in other countries (Dunn et al., 2012). At present we find little indication of this. From a global perspective, there is a need to create links to low-income economies to strengthen their research capacity and networks can aid in this approach. Within many countries included in our analysis, there are multiple established networks (e.g., USA, Turkey, China). Despite some strong networks a lot of content knowledge research is not conducted within recurring networks suggesting a fragmented approach that simply indicates that we have a distributed network overall. There is a collaboration among researchers both within and across countries.

Our third research question examined what were the co-authorship relationships in the network. Network graphs allow us to visualize co-authorship connections and the SNA graphs in this paper show that there is extensive collaboration (Dunn et al., 2012; Fonseca et al., 2016). Our data show that most highly published scholars in the content knowledge network collaborate with other scholars. This is understandable because many authors distribute the load and make research productivity higher than if you were alone. This is supported by findings in other studies (e.g., Yang et al., 2010). These researchers shape scientific knowledge relative to content knowledge, and determine which problems will be addressed and how they will be addressed and potentially solved.

Limitations and future research

There are a number of limitations to this study that provide direction for future research. First, though we endeavored to capture non-English publications using Scopus it should be recognized that we may not have been as comprehensive as we were with research published in English. This study has Turkish and American authors perhaps future studies might draw authors from other countries that have access to country-specific search engines that might identify more non-English speaking papers. We do not know the feasibility of such efforts. Second, in this study, we report on collaborations among researchers we did however, not examine the reasons for collaboration or how such collaboration is sustained. This is clearly an area for future research. Finally, co-authorship analysis is not the only strategy to examine collaboration. Qualitative interviewing might provide some insight into a collaboration that is not available in an SNA (e.g., Ward et al., 2021).

Conclusions

Co-authorship network analysis is a powerful method for determining the scope, trend, and focus of research around a topic. It represents an important contribution in determining the collaboration among researchers that would otherwise remain hidden. Moreover, it provides a way to evaluate both the growth of a field and how to measure collaboration. We support calls for more research collaboration across countries and more investigation into ways to support and sustain such collaboration.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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