Published in final edited form as:

Adopt Foster. 2017 December ; 41(4): 369–390. doi:10.1177/0308575917714714.

The emergence of team science: Understanding the state of adoption research through social network analysis

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Abstract

The notion of team science has recently gained popularity in European and American health sciences considering increasing evidence that scientific collaboration produces higher-impact research and that complex scientific problems are better investigated by interdisciplinary teams. While publication metrics indicate adoption research is expanding, the comprehensive structure of adoption studies as a scientific field has not been formally evaluated for collaborative and cross-disciplinary activity. This article aims to elucidate the structure, composition, and dynamics of scientific relationships within adoption research that may inform research and practice strategies, competencies, and cohesion within the field. Using social network analysis, we extracted bibliographic data on 2767 peer-reviewed adoption-related articles from 1930s to 2014 and evaluated the resulting co-authorship and co-citation networks. We found that adoption research has grown substantially over the last 25 years, and is conducted in varied disciplines, with increasing collaboration across geography and disciplinary areas. The co-authorship and co-citation networks are approaching numeric thresholds and structural configurations distinctive of well-established and more institutionalized fields of study. These findings reveal the maturation of adoption studies as a team science and argue for the development of institutional mechanisms that support such evolution. Implications for professional and research planning are discussed.

Keywords

Adoption; adoption research; team science; co-authorship; co-citation; interdisciplinary teams; social network analysis; research planning; organization

Introduction

In its report *Child Adoption: Trends and Policies*, the United Nations (2009) estimates that 260,000 children under 18 years old are adopted annually in 195 countries worldwide. The

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US leads with 125,000, or half of all adoptions per year, and is estimated to have one hundred million individuals affected by adoption within their immediate families (Adoption Facts, 2013). Following the US, numbers of adoptions are higher in Europe, Russia, China, Mongolia, India, Canada, Korea, and Brazil (United Nations, 2009), demonstrating the global reach of the practice. Once thought to be benign, we now know that prenatal, early life, and adoptive experiences may leave the adopted child vulnerable to unique and complex psychological, developmental, cognitive, and biochemical pathologies that may persist throughout his or her lifetime and affect the adoptive and birth family systems (Brodzinsky et al., 1998; Rueter et al., 2009; Rutter et al., 2007; Wismer Fries et al., 2008). Ultimately, they exert pressure on society at large through greater demands on healthcare services, educational and child welfare systems, and justice services.

Proactive adoption services are shown to ameliorate these effects and promote the success of the adoption (Smith, 2010; van Ijzendoorn and Juffer, 2006; van Ijzendoorn et al., 2011), but despite provision of some services by government agencies, private adoption agencies, and individual professionals, many members of the adoption triad still are not connecting to the support they need. A consortium of US adoption organizations has identified major impediments to adoption services, three of which are directly related to the production and circulation of scientific knowledge: limited adoption-competence among mental health and other professionals, inadequate knowledge about problems and interventions addressing challenges of adoption, and the unpredictability of need of the adoptive triad over time (Smith, 2010). While the volume of adoption research that mediates these deficiencies may be increasing, countervailing forces hinder the translation of this research to practice for the benefit of the very educational institutions, caregivers, and adoptive and birth families who need it (Smith, 2010). Historically, the separate disciplines of psychology and social work have dominated modern adoption research and care (Palacios and Brodzinsky, 2010; Finley, 2001a; Finley, 2001b). Increasingly, however, studies are appearing out of medicine, neuroscience, nursing, and other domains. While this is good news for adoptive families, it can create an environment of increasing complexity, specialization, and scientific fragmentation. These disciplinary “silos” may impede access to comprehensive and holistic knowledge among researchers, caregivers, families and students, and discourage scientific collaboration, integration of knowledge, and timely translation of research to the care of the population in need.

The problem of scientific fragmentation is well-recognized within biomedical, clinical and translational sciences (Luke et al., 2015). In response, the notion of cross-disciplinary collaboration has gained proponents and expanded internationally throughout scientific and organizational research communities. Today, the US National Institutes of Health considers interdisciplinary collaboration a strategic goal aimed to “yield new conceptual frameworks, methods, measures, and technologies that will speed the improvement of population health”; and the European Commission’s “Horizon 2020” research and innovation initiative has earmarked a portion of its €80 billion budget specifically to fund interdisciplinary research. (National Institutes of Health, 2008; European Commission, 2009)

Evidence shows that cross-disciplinary teams are more adept at solving complex problems (Younglove-Webb et al., 1999), produce a greater number of publications (Lee and

Bozeman, 2005), and produce publications with higher scientific impact (Wuchty et al., 2007) than traditional teams from a single discipline. The recognition of the benefits of cross-disciplinary teams has led to an emphasis on team science and to the development of the Science of Team Science (ScTS), which studies the formation, makeup, assembly and operation of cross-disciplinary research teams (Vacca et al., 2015; National Institutes of Health, 2014; Bachrach et al., 2015). Within the adoption research community, there is an awareness that adoption research has increased in volume and enjoys broader geographic and disciplinary participation (Palacios and Brodzinsky, 2010), but its status as team science has not been rigorously described to the extent that ScTS methods can confidently be applied to establish professional infrastructure and strategies to support the production, accessibility, and application of research findings.

Scientific networks, co-authorship and co-citation

Social Network Analysis (SNA) is the study of patterns of interactions and relationships between individuals (Valente, 2010). A social network is a set of individuals and the relationships between them. In network visualizations, individuals (also called nodes) are represented by dots, and relationships (also called ties) are represented by lines that connect the dots (see Box 1 for easy reference to SNA terms). Applications of SNA have contributed to unique insights in areas as diverse as the social and political sciences, economics, human and animal behavior, business, epidemiology, and the health sciences (Scott and Carrington, 2011). Scientific and Scholarly Network Analysis (S&SNA) applies SNA theories and methods to the study of the structure and dynamics of relationships between scholars and their works within a defined body of literature (Groh and Fuchs, 2011; Luke et al., 2015; Manlove et al., 2016; Moody, 2004). Over the last decade, researchers have applied large-scale bibliometric analyses to characterize the attributes of these complex interacting scholarly systems. They have shown S&SNA to effectively identify networks within a body of literature (Liu et al., 2005; Moody, 2004; Yin et al., 2006), measure structural characteristics of known networks (Cronin et al., 2003; Hou et al., 2008; Moody, 2004), describe the dynamics and evolution of the networks (Abbasi et al., 2010; Barabasi et al., 2002; Wagner and Leydesdorff, 2005), and evaluate the collaborative activities of scholars within the network (Abbasi et al., 2011; Bales et al., 2011; Ding, 2011) and their performance in a given discipline (Abbasi et al., 2011; Chambers et al., 2012). This knowledge, in turn, is utilized to enhance and direct research, strategic planning, development, and collaboration (Silva et al., 2013; Vacca et al., 2015).

Co-citation and co-authorship are two common subjects of S&SNA, each lending its own perspective to the understanding of collaboration and knowledge flow within and between scientific disciplines (White, 2011). Co-authorship occurs when two researchers are listed as authors on one or more common scholarly publications, the strength of the relationship measured by the number of times the two researchers appear together as co-authors within a corpus of publications. Co-authorship is created by the authors themselves through their choice of collaborators, and, therefore, tells us something about personal and professional relationships and the emergence of “invisible colleges” (Crane, 1972) that may influence the collaborative process and direction of science (White, 2011).

Co-citation occurs when works from two unique authors are cited in a common publication, the strength of the relationship measured by the number of documents that cite both works or both authors within a corpus of publications. Co-citation may be measured between works or between authors, and is a relation created by a third party, namely, the *citing* publication. It reveals the views of *other* researchers regarding the cited authors' ideas, influence, and connection with each other, and can identify intellectual leaders and opportunities for collaboration (Scott, 2013; White, 2011).

The network measures and visualizations derived from these analyses reveal unique features of individuals, teams, and broader research communities within a scientific field. They uncover macro-relationships between researchers, including discipline affiliation, collaboration patterns, knowledge diffusion, authority transfer, and scientific cohesion and fragmentation; and micro-relationships, including activity between two individuals or small groups of researchers (Ding, 2011; Moody, 2004). The visualizations provide a bird's-eye view or map that, "at-a-glance", informs the viewer of what is being studied by whom, who is leading thought and innovation, who is collaborating with whom, and where additional research may be needed. Ultimately, this perspective of the research corpus may be leveraged to identify potential collaborators, set research agendas, inform development of the field, provide evidence of scientific activity for outside entities such as funding sources, and contribute to an informed approach to the field's development and organization.

The primary purpose of this study is to elucidate the network structure and characteristics of co-authorship and co-citation relationships within adoption research. Our findings describe the multi-dimensional status of this community that may inform strategic decisions and proactive forces to promote cohesion, professional skills development, and timely translation of research to practice. Specifically, this study aims to *identify the predominant disciplines* in which adoption research is conducted, *map relationships* of existing cross-disciplinary collaboration, *uncover current and merging intellectual leaders* and, and *detect structural network characteristics* that may be leveraged to improve the creation, flow, and application of knowledge throughout the adoption community.

Methods

The primary method of analysis for this study is social network analysis (SNA) used to conduct bibliometric analyses of co-authorship and co-citation networks in adoption research. All data considered in these analyses are gleaned from peer-reviewed academic articles published from the 1930's to 2014 (referred to herein as "the study period") and retrieved from Thomson Reuters Web of Science™ (WoS), PsychInfo, and Academic Search Premier databases (see detailed procedure below). Due to an accelerated rise in the volume of research between 1990 and 2014, network analyses focus on this 25-year period. To demonstrate the network evolution over time, these data are disaggregated into five-year time periods: 1990–1994, 1995–1999, 2000–2004, 2005–2009, and 2010–2014. The R programming language for statistical computing (R Core Team, 2015) was used to extract, analyze, and visualize co-authorship and co-citation networks. Characteristics of the dataset are summarily described.

Publication search in Web of Science, PsychInfo, and Academic Premier

Terms.—In the WoS database, relevant publication records were identified through a bibliographic search of adoption-specific terms appearing in the title, abstract, and/or keywords of articles within that database and refined to only English language articles for all years. To assure relevancy, terms specific to child adoption, such as “adopted children”, “adoptive parents”, and “adult adoptee” were identified through a review of abstracts and keywords and the investigators’ experience. Each term was first individually searched and the returned data reviewed, with 14 terms or phrases excluded due to no return or irrelevancy. Ultimately, 54 individual terms and 19 combined and refined phrases were included.

Procedure.—The WoS search was conducted in batches and individually. The 54 single-phrase terms were searched in three batches and results were combined. The 19 combined and refined terms were searched individually, and the returned data added to the results of the batched data.

During the process, it was noted that a critical source of published adoption–related articles, *Adoption Quarterly*, was not in the WoS database. Because of its singular contribution to adoption research, a search of the PsychInfo and Academic Premier databases was performed to extend the dataset to all articles published in this journal. The combined WoS, PsychInfo, and Academic Premier searches ultimately yielded 2,767 appropriate articles.

Network construction

Co-authorship and co-citation networks were constructed separately for each 5-year time period, as previously described, using only and all articles published during that period.

Co-authorship

For the co-authorship network construction, we identified all scholar names listed together as authors on a single article. We then produced a network from these data wherein a node represents an author and a tie represents the two authors co-appearing on the same article(s). This relationship is visualized in the network structure as two separate dots (two authors) connected by a line (both listed on the same article). When those scholars, in turn, coauthor with others, additional dots and lines are added until the connections between all scholars grow into a broader network. Two scholars may co-author more than one article in a single 5-year period, and, therefore, the tie between them is weighted indicating the number of articles they coauthored in that period. In our analyses, two scholars are considered connected if they have co-authored at least one article.

Co-citation.—For construction of the co-citation network, we extracted the list of references from each article in each 5-year period and identified all unique author names cited by each article. We then produced a network wherein a node (dot) represents a cited author and a tie (line) represents a connection between two authors whose names appear in the reference list of the same article(s) in the database. The tie weight between authors A and B indicates the number of publications in the corpus that cited both A and B. Because co-citations are much more numerous than co-authorships, particularly in a large database,

one or few co-citations between authors do not necessarily reflect a meaningful association between their works. *Recurrent* co-citations, however, indicate a stronger tendency of these authors to be read and studied together. To capture recurrent co-citation patterns of very frequently co-cited authors, in our visualizations, we retain a tie between two authors only if the tie weight is equal to or greater than the 75th percentile of tie weights in that time period.

Data Analysis

Summary frequencies are calculated for papers, authors, journals, and other relevant measures for total data; papers and co-authored papers for co-authorship data; and papers and cited references for co-citation data. Also described are top-cited authors and leading disciplines, described by WoS categories, in which adoption research was conducted. The co-author and co-citation metrics analyses are conducted for the entire study period, unless otherwise indicated. Network visualizations are created for time periods 1990–1994, 1995–1999, 2000–2004, 2005–2009, and 2010–2014.

Co-authorship networks are analyzed for number of nodes, density and attributes of their components to identify their size, activity, influence, and disciplinary and geographic affiliation of the collaborative communities in adoption research. Measures of degree and betweenness centrality of authors are analyzed to identify the degree of connectedness of the authors and the role they play in bridging research communities.

Co-citation networks are analyzed for component attributes, density, and measures of degree and betweenness centrality of authors to identify growth, cohesion of recognized theoretical foundations, and the position of ideas within the network (White, 2011; Scott, 2013).

Results

Table 1 presents the summary characteristics for the total analyzed database.

In this table, unique listed authors are the nodes in the co-authorship networks. Unique cited authors are the nodes in the co-citation networks. A reference is a cited document (e.g. article, book) in one citing article. The number of (non-unique) references is determined by summing the number of references in each citing article. A reference is counted every time it is cited.

Co-authorship

Metrics: During the study period, adoption research and collaboration between researchers grows. There is a remarkable rise in the number of coauthored papers per year (132 vs. 786, +496%) and listed co-authors (176 vs. 1941, +1003%) (Figure 1). This is reinforced by a greater rate of rise in the average number of coauthors per paper (1.64 vs. 3.77, +130%) vis-à-vis the average number of papers (1.23 vs. 1.53, +24%), indicating that greater numbers of authors collaborate on single papers.

Network: Over the study period, substantial change is observed in the measures of the co-authorship network (Figure 2).

The number and size of components increase. New ties (new collaborations) are added to the network, and new authors enter the field. This indicates not just more co-authorship, but more new co-authorship occurring over time through collaboration with each other and existing authors. This finding is reinforced by the number of authors in the largest component compared to the number authors working singly (isolates). Prior to the 1980s, there were 1.8 collaborating authors in the main component for every 10 single authors (13 authors in the main component over 73 isolates, Figure 2). There is a slow rise in this ratio until 2010–2014, when it dramatically increases to 37 collaborating authors in the main component for every 10 single authors (377 authors in the main component over 102 isolates, Figure 2), indicating a surge of collaboration among adoption researchers during this time period. It is worth noting that network density decreases over time. Density is an overall measure of connectedness in the network. If the number of *potential* ties grows faster than the number of *actual* ties in a network (due to an increase in the number of nodes), network density decreases. In this network, this phenomenon is an indicator of new authors joining the network and creating opportunities for collaboration.

The evolution of the growth in co-authorship is visualized in the sequential network maps of the time periods (Figures 3 and 4). The early network figures show an insular structure composed of many small and separate components, indicating fragmentation and authors working in smaller disciplinary “silos” (isolates are not shown). Over time, the smaller groups begin to connect, creating larger components.

In 2010–2014 (Figure 4), the co-authorship network coalesces to create a central “giant component”, which emerges as the international scientific “mainstream” of adoption studies. This component is multidisciplinary, has a very definable central core, and is surrounded by a constellation of peripheral clusters not yet connected to it. The larger components and their clusters are demarcated in Figure 4 and identified for their disciplinary and geographic affiliation in Table 2.

Many of the collaborative communities in the 2010–2014 network are found in regions of the U.S. and Europe, however, Russia and South America are also represented. Developmental and other specialty areas of psychology dominate the collaborating disciplines and make up the central core of the network. Since 2000, also connecting to this core are psychiatry, behavioral genetics, pediatrics, family studies, social and child welfare, law, policy, and education. Top disciplines in the 2010–1024 network (as determined by WoS) are described in Table 3.

Table 4 indicates the most central authors in the co-authorship network.

Measures of centrality reveal who is most connected in various ways and, therefore, has greater influence and power in the network (Borgatti and Everett, 2006). Degree centrality measures the number of direct connections a given node has with other nodes in the network. In the co-authorship network, it indicates how many co-authors a given individual author has in the given time period and, thus, reveals the extent of that author’s collaboration with other authors. Note that over time, the most degree central authors change, implying

active collaboration dynamics, and the measure of degree centrality rises, reflecting expansion in collaboration and growth in team size.

Betweenness centrality measures the degree to which a node is positioned between other nodes in the network. This is an important position, particularly when the network is being leveraged for interventions, as these individuals can act as bridges, gateways, and cut-points between otherwise unconnected areas of the network. Highly between-central individuals are considered influential, while also making the network vulnerable to their status. In this analysis, betweenness identifies authors who may be reaching across different disciplinary or geographic areas in the conduct of their research, but also ones that, if lost to the network, could create a significant gap in collaboration and knowledge diffusion. Again, the measure of the most between central authors herein markedly increases over time, reflecting the growing size of the network and the formation of larger and more distinct research communities.

Co-citation

Metrics.—Over the study period, the occurrence of co-citation rises, mirroring the rise of numbers of papers (Figure 5).

Unlike the co-authorship network, the top co-cited authors change little over time, with authors Rutter, Bowlby, Brodzinsky, Zeanah, Gunnar, Barth, and O'Connor repeatedly emerging as top-co-cited in the last 15 years (Table 5). Together, these findings imply that theoretical associations between researchers and their works (whether in agreement or opposition) are increasingly and consistently recognized by the adoption research community forming an acknowledged, cohesive theoretical foundation represented by these authors.

Networks.—Over the study period, the main component of the co-citation network grew in number of nodes, in parallel with a decrease in number of isolates (Figure 6).

Fueled by new researchers entering the field, more authors were cited together, indicating shared knowledge and increased cohesion in the way authors' works are read and connected. This is reflected in the network visualizations. In 1990–1994, the co-citation network exhibits a smaller, sparser and more factional main component (Figure 7) indicating more limited co-citation and gaps in shared knowledge.

The size and density of the co-citation main component consistently increases over the years, resulting in network that departs from the factional structure of 1990–1994 and approach a typical core-periphery structure (Borgatti and Everett, 1999). By 2010–2014, there exists a large and dense main component with a clear core-periphery configuration (Figure 8). This indicates that the field of adoption research has developed into a single, coherent theoretic community, with growing consensus in citation patterns as well as recognized and agreed-upon intellectual leaders who are sharing knowledge across participating disciplines.

Table 6 presents the measures of degree and betweenness centrality for co-cited authors. In a co-citation analysis, the power of these central nodes is determined by other citing researchers and implies an association with other researchers that simply “most cited” does not. As would be expected, both measures increase markedly as the size of the network increases. The consistency of the authors implies a stable theoretic base shared across the field of adoption studies.

Discussion

In this study, our purpose was to describe and understand the state of adoption research through the network structure and characteristics of scientific relationships as a first step in addressing knowledge-based impediments to care. To this end, we analyzed the co-authorship and co-citation relationships between adoption researchers over the last 25 years, and visualized the resulting networks. In doing so, we established a comprehensive understanding of the academic disciplines in which adoption researchers are working, their productivity, collaboration, and influence, and created a road map forward, with implications for the development of an adoption team science and timely translation of science to practice, including cross-disciplinary teams, professional organization, and research and practice planning.

Emergence of Team Science

Generally, the production of adoption research has grown substantially over the last 25 years. It is conducted in a growing number of disciplines and more authors are collaborating within and beyond their disciplinary comfort zone and increasingly share knowledge across disciplinary and geographic boundaries. Our strongest finding is a tenfold growth in the number of co-authors and the formation of the giant co-authorship network component typical of academic collaboration networks of well-established disciplines. This indicates the co-authorship network of adoption studies is approaching a numeric threshold and a structural configuration distinctive of mature and autonomous fields of study. The co-citation findings reinforce this. The rise in the average number of references per paper indicates that there is more research on adoption, and adoption authors are more aware of, and are citing, each other. Additionally, the development of a dense giant component and a core-periphery structure in the co-citation network indicates that adoption researchers are increasingly citing recurring groups of authors, suggesting they share an increasingly coherent body of knowledge across all disciplines with identified foundational theorists and intellectual leaders.

These findings reveal adoption research to be an emerging team science: a maturing, unique field of study that is unifying through collaboration and shared references, while at the same time diversifying across disciplines and expanding its base of research. This is evidenced at the micro-level, as the increase in degree centrality indicates researchers working with more collaborators, and at the macro-level, as the growing size of main components indicate a stronger, more robust shared body of knowledge. The systemic repercussion of these behaviors signal a readiness for the development of institutional mechanisms that enhance, exploit, and promote the continued evolution of adoption research as a legitimate team

science. For consideration are two potential opportunities to organize and optimize holistic, relevant and coherent adoption research and its translation to practice: intentional cross-discipline team-building and a unified professional organization.

Building cross-disciplinary teams

Collaborative cross-disciplinary teams are now recognized to have a superior creative and productive impact in our complex healthcare environment, and, for this reason, are favored and encouraged by governmental and academic research and funding entities (Disis and Slattery, 2010; National Institutes of Health, 2014; Bachrach et al., 2015). As our understanding of adoption increases, so does our appreciation of its psycho-social, bio-behavioral, and environmental complexities that transcend any single discipline and beg for the application of the cross-disciplinary theoretical and methodological approaches of team science. This study reveals ample evidence of increasing collaborative research among adoption researchers. The co-authorship network patterns, however, suggest that this collaboration is encouraged by natural forces, such as proximity, common specialty area, shared research interests, and personal relationships, including preferential attachment. This phenomenon, described as “success breeds success”, is based on the theory that an individual’s time and recognition within a network increase its number of ties, which attracts more ties, creating growing density around that individual (Price, 1976). In the co-authorship network, we described clusters of collaborators by geography and/or academic affiliations. The central core is dominated by the US and European authors and the disciplines of developmental and other specialty areas of psychology. Over time, however, there is evidence of researchers from Russia and South America and disciplines of psychiatry, behavioral genetics, pediatrics, family studies, social work and child welfare, law, policy, and education increasingly connecting to the core.

Despite the strengthening network core, there are still many single authors and disconnected groups of researchers working in the network periphery, separated from the academic and practical supports of the core component. These structural gaps represent opportunities for intentional collaborative team-building to strengthen the network, promote innovative thinking, and accelerate research to the clinical setting. For example, it is remarkable that researchers from some regions of the world in which greater numbers of adoptions occur, such as Asia, e.g., China, India, Korea, the Philippines (United Nations, 2009), do not reach the numeric threshold to appear in our networks. Methodological bias not with-standing, this finding may offer meaningful direction to promote inclusion and advance understanding of cultural differences in adoption. Additionally, considering the dominance of psychology in the adoption network core, adoption researchers in this discipline may consciously consider the benefit of connecting to new and/or presently more peripheral disciplines that include “bench” scientists and researchers representing end-users, e.g., social work, education, pediatrics.

Purposive, collaborative team-building as team science has been embraced and widely-encouraged in the larger healthcare research arena. *Collaboration & Team Building: A Field Guide* (Bennett et al., 2010) and *Enhancing the Effectiveness of Team Science* (Cooke and Hilton, 2015) provide soundly-supported guidance regarding the value, assembly, and

maintenance of successful collaborative teams working to solve complex scientific problems. More germane to this study, SNA has been applied to design effective interdisciplinary teams (Meltzer et al., 2010; Vacca et al., 2015). Indeed, a social network intervention that leverages the characteristics of a scientific collaboration network, as identified in this study, to create potential interdisciplinary teams is proposed by Vacca et al. (2015). Through a process of "network alteration", they deliberately connect individuals and communities of researchers in this university-based population across structural holes, or "missing links", in the network to purposefully promote cross-disciplinary synthesis.

Governing professional organization

The success of team science is greatly dependent on supportive infrastructure (Cooke and Hilton, 2015) in the form of academic, corporate or professional entities. Adoption research has a shared yet fragmented infrastructure of individual academic institutes and programs, government entities, and national and regional non-profit and private organizations. Despite past calls to unify the adoption research community (Finley, 2001a; Finley, 2001b), there is little recent discussion in the literature regarding this goal. This study reveals that the body of adoption research alone demonstrates a critical mass and structure that would justify such an effort.

The benefits of a unified multi-disciplinary professional organization to the field of adoption studies are myriad. In the research domain, wherein now there is scant evidence of conscious planning beyond traditional literature reviews (Palacios and Brodzinsky, 2010; Wiley and Baden, 2005; Wilson, 2004; Wood, 2009), it could provide a forum to identify and drive a coherent research agenda. Palacios and Brodzinsky (2010), for example, give us a sweeping, comprehensive state of the adoption literature, which, in concert with the network structure revealed here, provides a roadmap that could be operationalized through supportive infrastructure, identified leadership, open communication, and the previously discussed collaborative, multi-disciplinary teams (Disis, 2010). Such an organization would also act as a professional marketplace, where new and young researchers find support through mentorship, training, and camaraderie (Ameredes et al., 2015). Ultimately, it would provide a single, comprehensive, and authoritative information resource for mental health and other professionals and the public, and improve their access to current, evidence-based "adoption-competent" information regarding the support and care of the adoption triad. Together it would act to close the gap on knowledge-based impediments to care (Smith, 2010) by helping to bolster "adoption-competence" among professionals, identify and communicate the needs of the adoptive triad, and foster development of evidence-based interventions that provide for their support and care.

A unified professional organization would also act to define and defend the field, support its members, and safeguard the public through its actions to: 1) codify education and practice standards, 2) certify competency, 3) provide ongoing continued education, 4) define and enforce professional ethics, 5) steer strategic policy, political action, and advocacy, and 6) expand and support adoption research institutes and centers. Formal communication and cohesion would be enhanced through a professional publication and annual conference. The foundations of such an organization exist today in actions taken individually (Smith, 2010;

Atkinson et al., 2013). Such an organization would not supplant the many adoption organizations that presently exist, but instead serve to concentrate, coordinate and give direction to these efforts.

Conclusions

This study reveals adoption research to be a maturing, unique field of study that is unifying through collaboration, diversifying across disciplines, and sharing knowledge of recognized intellectual communities and leaders. The authors have provided a synopsis of the current state of the structure of the adoption research and propose that there are strong indicators that it is reasonable and justified to consider greater collaboration through intentional multi-disciplinary team building and unification of this community of practice through a unifying governing organization. The authors acknowledge the significant advancement through research made by the adoption research community over the past three decades to provide the best possible care to the adoption triad, and we offer these findings for its consideration for the future.

Future study

In light of the discussed findings, future research would be needed to investigate the feasibility, design and effects of cross-disciplinary teams and professional organizations in adoption research. Also of importance is understanding the mechanisms of the flow of knowledge from the researcher to the end-users, including professionals and the public. How do end-users learn of adoption research findings? How and in what form is this knowledge accessed? Who are the recognized intellectual leaders and authoritative sources? To what extent do they incorporate into practice and use this knowledge? What are the impediments to their awareness, access and use of research knowledge? Social network analysis, alone or in a mixed methods design, is one of the methods available to investigate these questions.

Limitations

Some inherent weaknesses in the method of this study deserve review. Firstly, the study data were entirely gleaned from peer-reviewed English-language journals. Non-English journals and books, conference papers or any other type of communications were not included. Additionally, we relied solely on the Web of Science, PsychInfo and Academic Search Premier databases for these journals, and, to accommodate for the absence of a leading adoption journal in our original WoS search, applied different search strategies across databases. Considering this, we think it is reasonable to consider that we did not capture the entire corpus of adoption research, including “hidden collaboration” and informal, foreign-language, and unpublished data. It is also apparent that additional research has been published since the original acquisition of the data. In both these cases, however, we feel that the original volume of data retrieved constitutes a large and representative sample of all co-authorship and co-citation data in adoption research.

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Box 1.

Social Network Analysis terms.

1. **Social network** – A set of nodes (individuals) and ties (relations) among them.
2. **Node** – An individual in the network, visually represented by a point or dot.
3. **Tie** – Interaction or relation between two nodes, visually represented by a connecting line.
4. **Path** – A sequence of links in the network.
5. **Degree centrality** – Number of ties an individual sends to or receives from other nodes in the network.
6. **Betweenness centrality** – The degree to which an individual lies on the shortest paths connecting other individuals in the network.
7. **Clustering –** The occurrence of dense pockets of interconnectivity (Valente, 2010).
8. **Component** – A set of individuals who are reachable for each other through paths of one or multiple links.
9. **Isolate** – A node that is not connected to any other node.
10. **Density** – Overall level of connectedness in the network, as measured by number of existing ties in the network as a proportion of all possible ties.

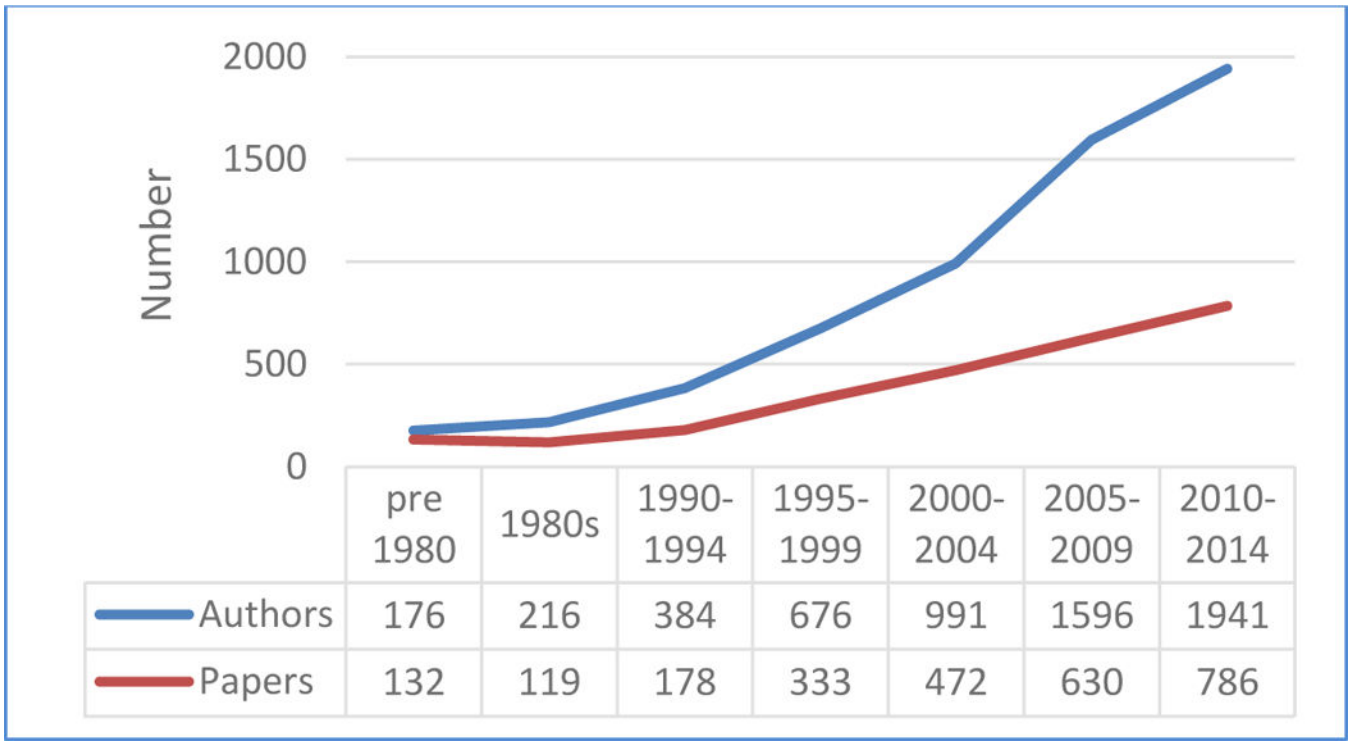
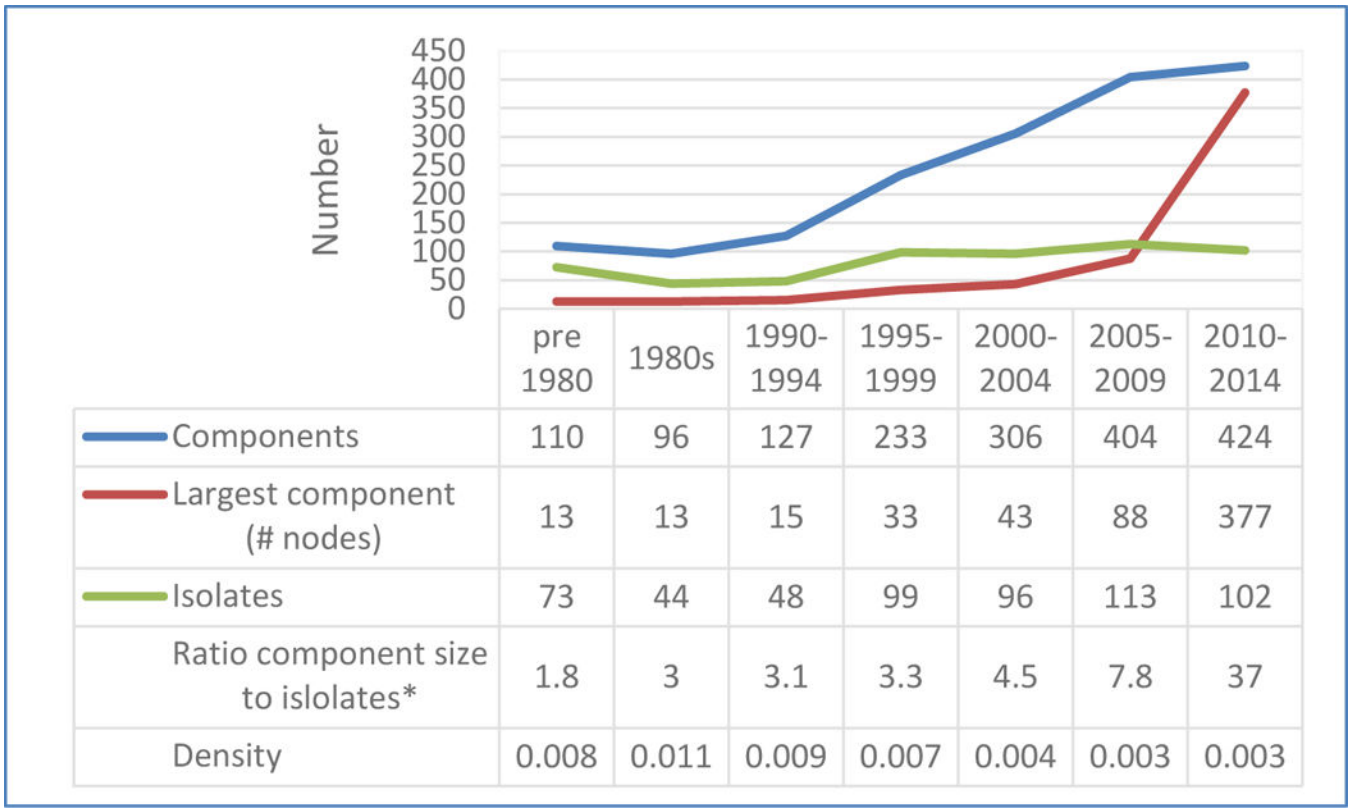


Figure 1.
Number of co-authors and co-authored papers rise over time.



	pre 1980	1980s	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014
Components	110	96	127	233	306	404	424
Largest component (# nodes)	13	13	15	33	43	88	377
Isolates	73	44	48	99	96	113	102
Ratio component size to islolates*	1.8	3	3.1	3.3	4.5	7.8	37
Density	0.008	0.011	0.009	0.007	0.004	0.003	0.003

Figure 2.

Co-authorship network by components characteristics and isolates. ** Number of nodes in largest component per every ten isolates*

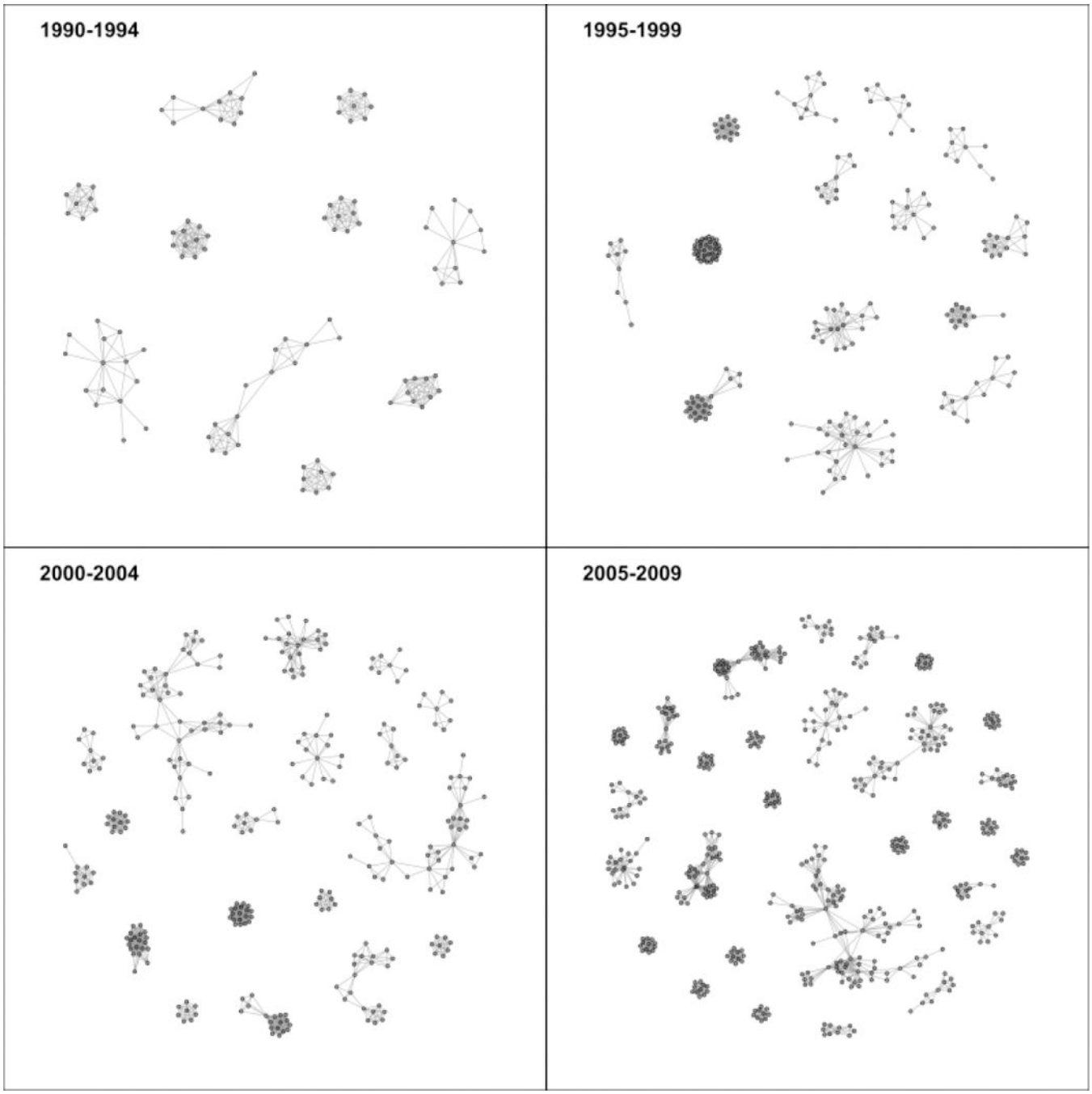


Figure 3.
Co-authorship networks over time. For each network, only the 5% largest connected components are shown.

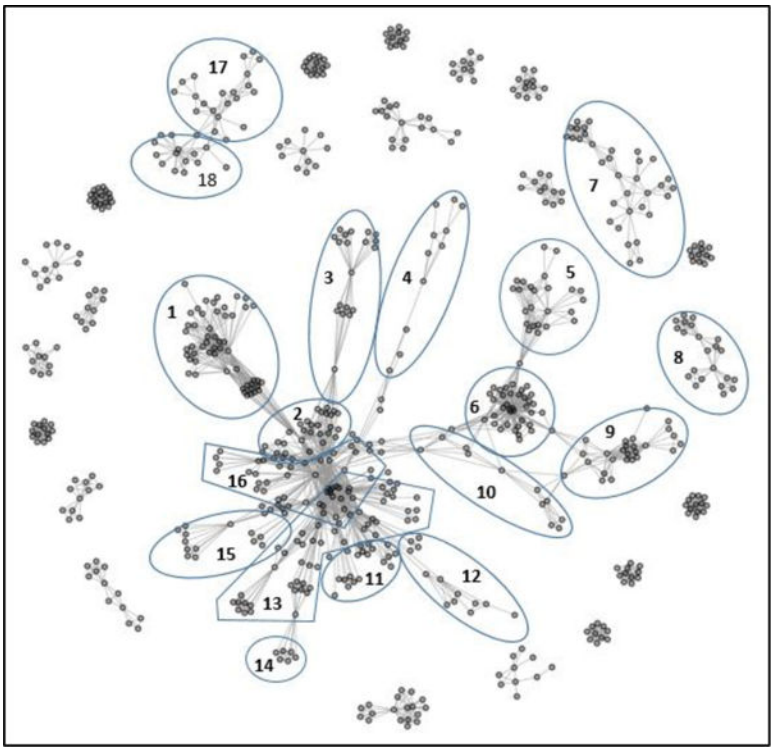


Figure 4.

Co-authorship network 2010–2014. Only the 5% largest connected components are shown. Demarcated areas indicate approximate geographic and disciplinary affiliation identified in Table 2.

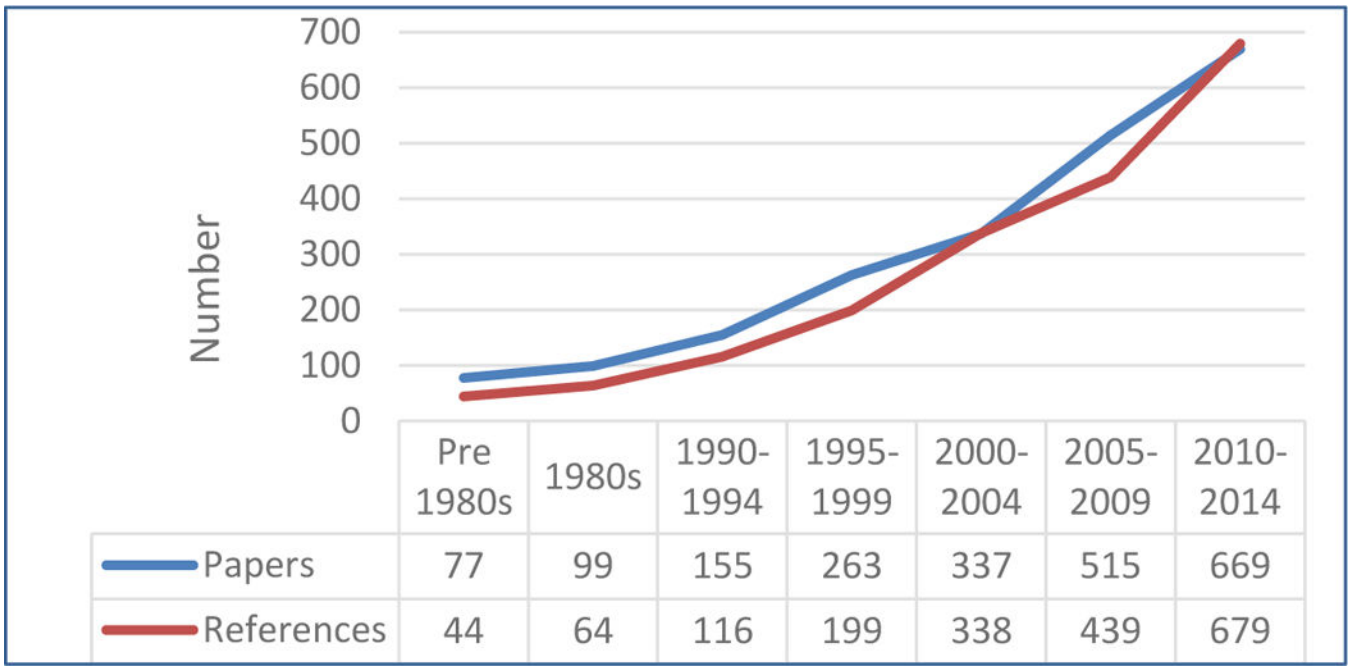
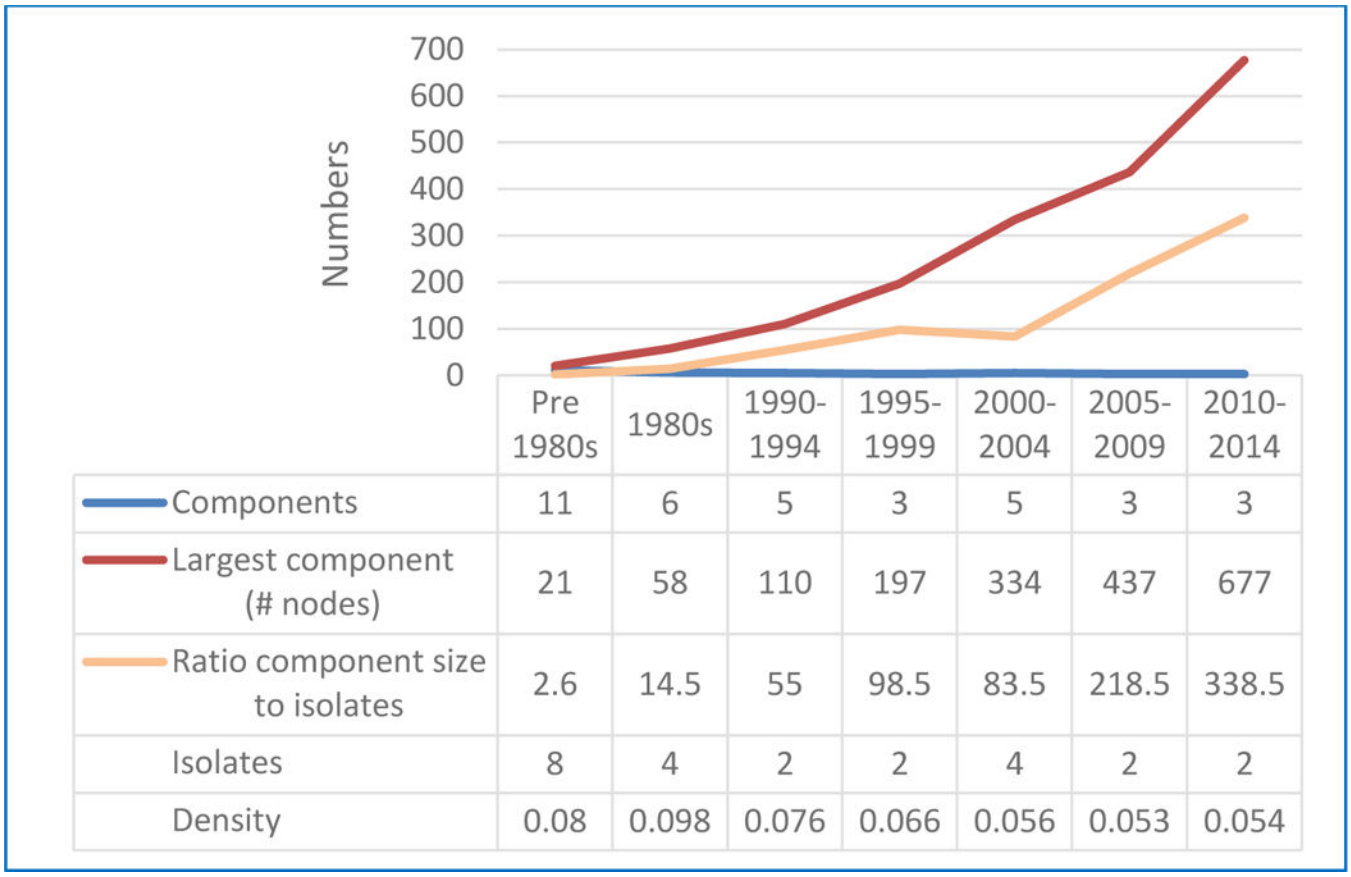


Figure 5.
Number of papers and recognized co-citations (references).



	Pre 1980s	1980s	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014
Components	11	6	5	3	5	3	3
Largest component (# nodes)	21	58	110	197	334	437	677
Ratio component size to isolates	2.6	14.5	55	98.5	83.5	218.5	338.5
Isolates	8	4	2	2	4	2	2
Density	0.08	0.098	0.076	0.066	0.056	0.053	0.054

Figure 6.
Co-citation networks by component characteristics and isolates.

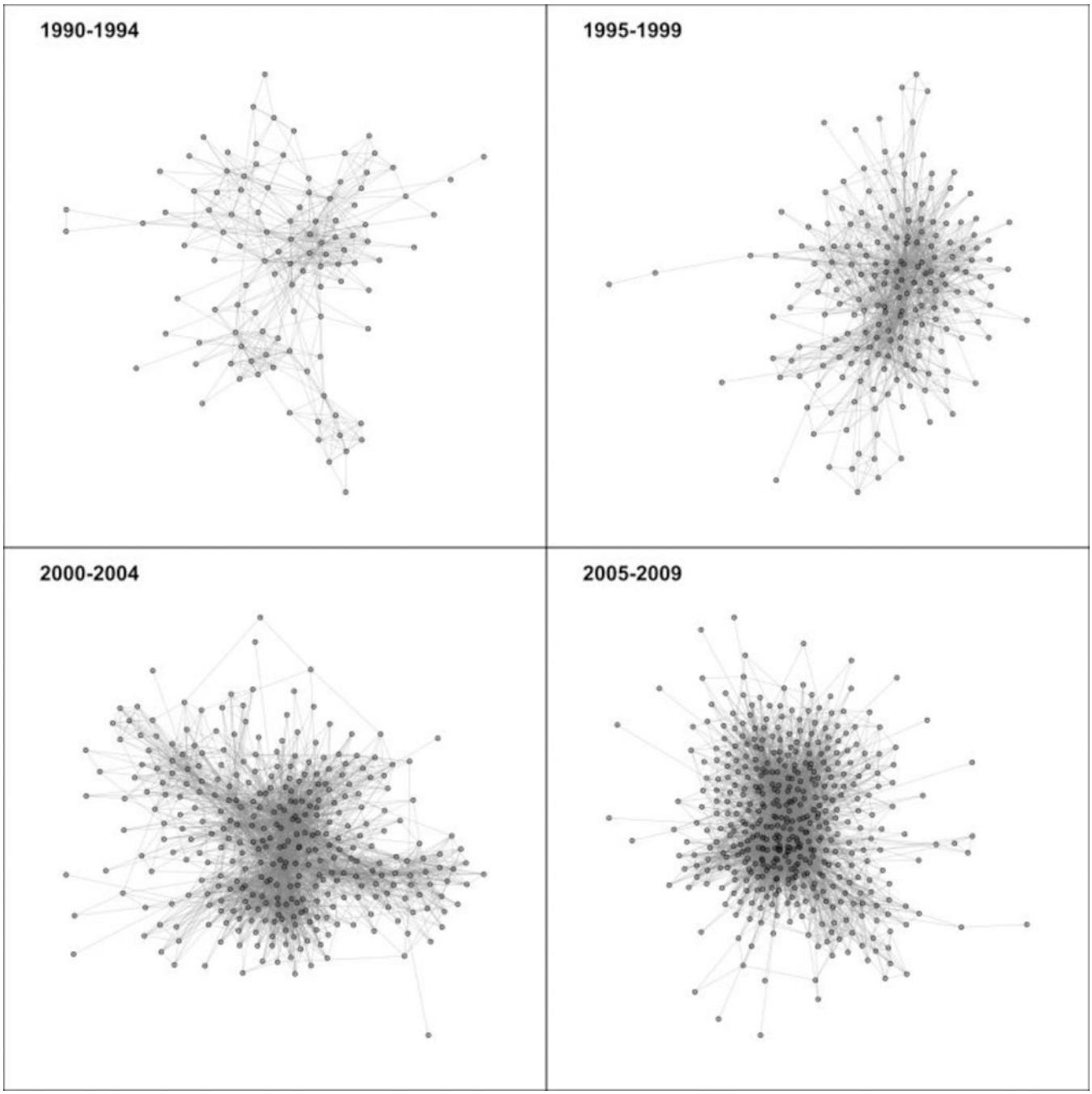


Figure 7.
Main component of adoption research co-citation networks over time.

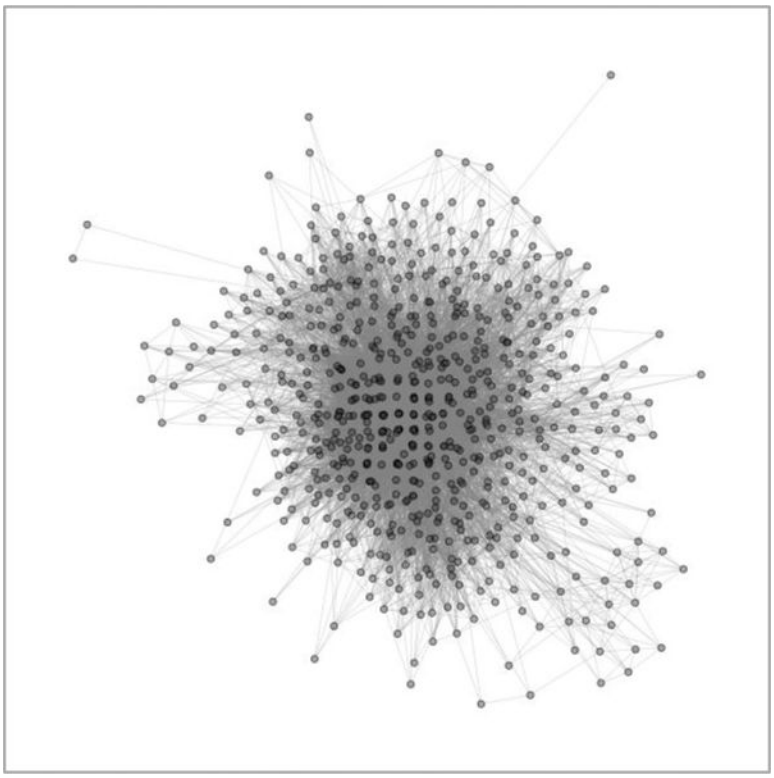


Figure 8.
The single complex giant component of co-citation network 2010–2014.

Table 1.

Summary characteristics:

Total database.	**(N)**
Articles	2767
Journals	735
Disciplines (WoS categories)	125
Listed authors (unique)	5306
Cited authors (unique)	1095
References (non-unique)	95782
Avg. number references/article	34.6

Table 2.

Co-authorship: Geographic and disciplinary affiliation of larger components in 2010–2014 network.

Area	Geographic region	Predominant discipline/s
1	Scotland/UK	Psychiatry, Psychology
2	US (New Orleans)	Psychiatry
3	US	Pediatrics, Law, Policy, Education
4	US (Wisconsin)	Psychology, Social work
5	US (Oregon)	Social and Child welfare
6	US, UK	Developmental psych, Psychology
7	Europe (Scandinavia)	Mixed
8	US	Behavioral pediatrics
9	US (Colorado)	Behavioral genetics, Psychology
10	US (Oregon)	Developmental Psych, Family
11	US (Pennsylvania)	Psychiatry, Clinical psychology
12	Russia	Mixed
13	Europe	Psychology, Psychiatry, Social work
14	Chile	Mixed
15	US (Minnesota)	Pediatrics
16	US	Developmental psychology/Psych
17	US (Minnesota)	Behavioral genetics
18	US (Massachusetts)	Psychology, Family

Note: Area numbers refer to demarcated areas in Figure 4.

Table 3.

Co-authorship: Top WoS disciplinary categories in 2009–2014 main component.

Category	# Nodes
Psychology, developmental	538
Psychiatry	175
Psychology	96
Pediatrics	88
Family Studies	81
Psychology, educational	66
Social work	62
Psychology, clinical	50
Multidisciplinary sciences	42
Public, environmental & occupational health	36

Table 4:

Co-authorship: Most central co-authors (measure value) over time.

	1990–1994	1995– 1999	2000–2004	2005–2009	2010–2014
Degree centrality	Fulker, D.W. (12)	Alimenti, A. (32)	Zeanah, C.H. (21)	Miettunen, J. (28)	Gunnar, M.R. (70)
	Verhulst, F.C. (10)	Asensibotet, F. (32)	Tienari, P. (19)	Johnson, D.E. (26)	Zeanah, C.H. (60)
	Kavela, M. (10)	Bates, I. (32)	Wahlberg, K.E. (19)	Grotevant, H.D. (26)	Nelson, C.S. (56)
	Lahti, I. (10)	Belfrage, E. (32	Koistinen, P. (18)	Tienari, P. (25)	Minnis, H. (52)
	Laksy, K. (10)	Bohlin, A.B. (32)	Tarvainen, T. (18)	Wahlberg, K.E. (25)	Fox, N. (44)
Betweenness centrality	Kinney, D.K. (48.17)	Plomin, R. (249.93	O'Connor, T.G. (460)	Johnson, D.E. (2249.26)	Gunnar, M.R. (32931.4)
	Kendler, K.S. (48)	Weitzman, M. (68)	Van Dulmen, M.H. (424.3)	Grotevant, H.D. (1614.37)	Fisher, P.A. (27399.7)
	Plomin, R. (42.75	Cadoret, R.J. (41.78)	Plomin, R. (412.13)	Gunnar, M. (1428)	Zeanah, C.H. (19556.5)
	Fulker. D.W. (34.13)	Carey, G (40)	Rutter, M. (314.37)	McRoy, R.G. (657.19)	Acock, A. (10711.3)
	Verhulst, F.C. (33)	Sorensen, T. (36.5)	Grotevant, H.D. (306.17)	Van Dulmen, M.H. (532.15)	Harold, G. (10655.7)

Table 5.

Co-citation: Top-cited adoption research authors (number citations) over time.

1990–1994	1995–1999	2000–2004	2005–2009	2010–2014
Brodzinsky, D. (70)	Plomin, R. (122)	Brodzinsky, D. (154)	Rutter, M. (247)	Rutter, M. (324)
Bohman, M. (52)	Brodzinsky, D.M. (103)	Rutter, M. (141)	O'Connor, T.G. (161)	Gunnar, M.R. (203)
Scarr, S. (48)	Verhulst, F. C. (84)	Barth, R.P. (101)	Brodzinsky, D. (142)	Zeanah, C.H. (202)
Achenbach, T.N. (48)	Simon, R. (82)	Bowlby, J. (96)	Miller, L.C. (139)	Brodzinsky, D. (189)
Plomin, R. (39)	McRoy, R.G. (74)	O'Connor, T.G. (84)	Barth, R.P. (135)	Van Ijzendoorn, M.H. (176)
Verhulst, F.C. (36)	Bohman, M. (64)	Groze, V. (79)	Zeanah, C.H. (107)	Juffer, F. (172)
Barth, R.P. (32)	Barth, R.P. (66)	Zeanah, C.H. (74)	Johnson, D.E. (103)	Bowlby, J. (153)
Kendler, S. (30)	Tizard, B. (59)	Grotevant, H.D. (67)	Verhulst, F.C. (96)	O'Connor, T.G. (140)
Rutter, M. (30)				

Note: The top eight to nine authors are included as there is a marked break in the number of citations at these levels.

Table 6.

Co-citation – Most central co-cited authors (measure) by time periods.

	1990–1994	1995–1999	2000–2004	2005–2009	2010–2014
Degree y	Brodzinsky, D. (46)	Brodzinsky, D. (87)	Brodzinsky, D. (159)	Rutter, M. (224)	Rutter, M. (386)
	Achenbach, T.M. (31)	Plomin, R. (68)	Rutter, M. (144)	Brodzinsky, D.M. (174)	Juffer, M. (321)
	Bohman, M. (30)	Verhulst, F.C. (59)	Bowlby, J. (139)	O'Connor, T.G. (164)	Brodzinsky, D.M. (316)
	Sorosky, A.D. (28)	McRoy, R.G. (52)	O'Connor, T.G. (110)	Verhulst, F.C. (162)	Van Ijzendoorn, M.H. (294)
	Bowlby, J. (25)	Achenbach, T.M. (52)	Barth, R.P. (101)	Achenbach, T.M. (151)	Gunnar, M.R. (288)
Betweenness centrality	Achenbach, T.M. (1125.8)	Barth, R.P. (1842)	Bowlby, J. (5365.1)	Brodzinsky, D.M. (8742.5)	Barth, R.P. (11356.14)
	Sorosky, A.D. (811.7)	Scarr, S. (1749.7)	Barth, R.P. (3848.6)	Achenbach, T.M. (6327.1)	Brodzinsky, D. (10317.6
	Cloninger, C.R. (755.4)	McRoy, R.G. (1344.3)	APA (3698.4) *	Rutter, M. (6152)	Juffer, F. (10138.83)
	Bowlby, J. (678.5)	Bowlby, J. (1269.93)	Brodzinsky, D. (3203.7)	Barth, R.P. (4394.3)	Achenbach, T.M. (9158.4)
	McRoy, R.G. (628.8)	Achenbach, T.M. (1236.8)	Groze, V. (3044.2)	HHS (4157.1) **	Rutter, M. (7547.58)

* American Psychiatric Association

** U.S. Health and Human Services