Social network analysis of publication collaboration of accelerating change in MedEd consortium

Sally A. Santen, Jeff Smith, Jeff Shockley, John W. Cyrus, Kimberly D. Lomis, Martin Pusic, George C. Mejicano, Luan Lawson, Bradley L. Allen & Susan Skochelak

MEDICAL TEACHER
2022, VOL. 44, NO. 3, 276–286
https://doi.org/10.1080/0142159X.2021.1985096

Social network analysis of publication collaboration of accelerating change in MedEd consortium

Sally A. Santen[a], Jeff Smith[b], Jeff Shockley[b], John W. Cyrus[c], Kimberly D. Lomis[d], Martin Pusic[e], George C. Mejicano[f], Luan Lawson[g], Bradley L. Allen[h] and Susan Skochelak[d]

[a]Senior Associate Dean, Virginia Commonwealth University School of Medicine, Richmond, VA, USA; [b]School of Business, Virginia Commonwealth University, Richmond, VA, USA; [c]Virginia Commonwealth University Medical Center Tomkins-McCaw Library, Richmond, VA, USA; [d]American Medical Association, Chicago, IL, USA; [e]Pediatrics and Emergency Medicine, Harvard Medical School, Boston, MA, USA; [f]Senior Associate Dean for Education, School of Medicine, Oregon Health & Science University, Portland, OR, USA; [g]Emergency Medicine, East Carolina University Brody School of Medicine, Greenville, NC, USA; [h]Clinical Medicine and Infectious Diseases, Indiana University School of Medicine, Indianapolis, IN, USA

ABSTRACT

Introduction: The American Medical Association formed the Accelerating Change in Medical Education Consortium through grants to effect change in medical education. The dissemination of educational innovations through scholarship was a priority. The objective of this study was to explore the patterns of collaboration of educational innovation through the consortium's publications.

Method: Publications were identified from grantee schools' semi-annual reports. Each publication was coded for the number of citations, Altmetric score, domain of scholarship, and collaboration with other institutions. Social network analysis explored relationships at the midpoint and end of the grant.

Results: Over five years, the 32 Consortium institutions produced 168 publications, ranging from 38 papers from one institution to no manuscripts from another. The two most common domains focused on health system science (92 papers) and competency-based medical education (30 papers). Articles were published in 54 different journals. Forty percent of publications involved more than one institution. Social network analysis demonstrated rich publishing relationships within the Consortium members as well as beyond the Consortium schools. In addition, there was growth of the network connections and density over time.

Conclusion: The Consortium fostered a scholarship network disseminating a broad range of educational innovations through publications of individual school projects and collaborations.

KEYWORDS
Social network; undergraduate medical education; consortium

Introduction

Transformation of medical education often occurs at the institutional level with a slow transfer of innovative ideas to the broader community (McGaghie 2010; Santen et al. 2012; Novak et al. 2019). Calls to revolutionize undergraduate medical education (UME) have accelerated since the centennial anniversary of Abraham Flexner's report (Cooke et al. 2010; Irby et al. 2010). In response, medical schools' efforts have focused on enhancing their own UME programs but typically with minimal connection to innovations happening at other schools or across the medical education continuum (Novak et al. 2019). UME innovation processes are frequently insular, not grounded in external knowledge and experiences, and unlinked to parallel changes occurring in other educational programs and across disciplines (Skochelak 2010a; 2010b; Skochelak and Stack 2017; Novak et al. 2019).

One barrier to UME change is that the diffusion of novel ideas is slow and difficult. There are a number of reasons, including the increasingly complicated nature of our missions, individual institutional siloes, resistance to change based on funds linked with the status quo, the constraints on any one school's resources, limitations in the ability to demonstrate outcomes, and the scope of ambitions to affect change. The traditional dissemination of the products of local program development typically report only mature, fully implemented innovations. This may limit peer-review and peer-learning of nascent programs at earlier stages of the innovation curve (Supovitz 2013). Parallel development of innovations in isolation generates redundant investment of precious

Practice points

- A consortium as a formal alliance of organizations and individuals can achieve significant collaboration through publications.
- Social network analysis demonstrated rich publishing relationships within the Consortium members as well as beyond the Consortium schools.
- Resources provided by a grant to create a consortium may provide the opportunity to increase collaboration and publication.

CONTACT Sally A. Santen sally.santen@vcuhealth.org Virginia Commonwealth University School of Medicine, P.O. Box 980565, Richmond, VA 232980-565, USA

Supplemental data for this article can be accessed here.

resources yet often results in competing frameworks aimed at similar goals.

National consortia are emerging in response to the call for innovation in medical education (Schwartz and Schon 1987; Cangiarella et al. 2017; Lomis et al. 2017; Andrews et al. 2018). We define consortium as a formal alliance of organizations and individuals coming together to achieve specific objectives, often with funding to support that work. These consortia typically have a 'hub' organization that serves to coordinate and connect the collaborating institutions in pursuit of one or more common innovative goals (Peurach 2016). The connections can form a catalyst for faculty in the hierarchical legacy administrative structures that characterize medical schools that can impede innovation locally (Peurach 2016). Consortia have advantages, including diverse learner populations, healthcare systems, and resources which allow a greater range of implementation and evaluation approaches and greater ecological validity of study outcomes.

In 2013 the American Medical Association (AMA) launched the Accelerating Change in Medical Education (ACE) consortium of 11 institutions (Cohort 1) and in 2015, an additional 21 schools (Cohort 2) investing over 14 million dollars. The UME innovation goals of the consortium were competency-based medical education (Frank et al. 2010), teaching and assessing health systems science (Gonzalo et al. 2018), and optimizing the learning environment. In addition to the schools' projects, there was an expectation that schools would engage in the consortium to share innovations, disseminate advances, and share challenges and lessons learned to the larger medical education community (Lomis et al. 2020). Collaboration within the consortium was facilitated through multiple methods, including face-to-face meetings, electronic communication, consortium meetings, visiting scholars, co-citation and coauthorship that created a social network.

One of the major goals for the AMA through ACE was to impact UME innovation across the United States with dissemination extending beyond the individual schools. It was expected that the ACE schools would disseminate their own innovations, and they would contribute to a collaborative network of scholarship in the form of publications and presentations. This included scholarship through coauthor collaboration engaging different institutions. For the purpose of this project, we wanted to explore the dissemination of innovation through co-author collaboration of the ACE consortium.

Consortia create a social network of individuals (Wasserman and Faust 1994), groups, and organizations with shared goals and interests. The ACE network included the medical schools as well as the students, faculty, administrators members, as well as other organizations with which they interact. To better understand the consortium, we sought to utilize social network theory to understand how the collaboration through coauthorship and cohesiveness of the network might indicate the dissemination of innovation. Social network theory is characterized by the study of how people, groups, and organizations interact within a network by social network analysis (SNA) analyzing the interactions, relationships or ties between each of the members (Wasserman and Faust 1994). Networks are interconnected associations of persons or groups and can have positive effects on career development, organizations, and teamwork. These self-organizing networks are found to have a preferential attachment of members and growth (Barabási and Bonabeau 2003) where the networks add more nodes and links over time.

When studying social networks through social network analysis (SNA), the focus is on the interactions and connections between each of the members of the network. These create a graphic representation (sociogram) and can be analyzed through a set of mathematical algorithms (Wasserman and Faust 1994). The analysis explores how do members: 1) interact and influence one another, 2) what is the level of closeness or connectedness, and 3) how do these relationships change over time? In a social network, not every node, and individual network member, is tied to every other node. There may be clusters of densely knit connections, while other members may only be connected from the periphery through a central member. The relationships are interdependent and reflect a flow of resources and opportunities (Wasserman and Faust 1994). While all members are connected by the overall network, not all the nodes are connected with the same degree of interaction. It is these varying degrees of connectedness, that determine the value of that node to the network and the influence that node may have on others. Social network analysis seeks to discover who interacts with whom, the degree of connectedness of interactions between members, and how the relationships between nodes arise.

While there are numerous medical research networks and consortia (Sorantin 2014), little is known about the development, successes, and failures of consortia networks in medical education. Through bibliometric analysis, we measured the impact of an educational consortium, the ACE consortium, on dissemination of innovation through scholarly publications. Specifically did the collaboration between different institutions in the consortium increase over time, as measured by an increase in multi-institutional publications? As innovations and ideas disseminate amongst the consortium as well as outside the consortium, we hypothesized that there would be an increase in multi-institutional publications and connections amongst the consortium members. In addition, through SNA, we examined the patterns of consortium network publications generated by faculty at the member schools, the degree to which they demonstrated connections between schools and how those connections changed over the grant period.

Methods

Concepts of social network analysis

Inherently, individuals are embedded in thick webs of social relationships and interactions (Borgatti and Li 2009). In order to effectively understand the manner in which these relationships are constructed and evolve, a social network analysis (SNA) methodology is utilized to help ascertain the structure of the web as a whole, as well as the locations of individual members (i.e., nodes/institutions). SNA is a structured process for investigating social structures using concepts established from both network analysis and graph theory (Otte and Rousseau 2016). Accordingly, SNA is a tool that is capable of visualizing and analyzing these complex social webs by measuring the manner and strength of relationships between pairs of members of the network and the density of the network as a whole.

Network data

Every six months over the five years of the ACE grants ending in the fall of 2018, the 32 consortium schools submitted progress reports to the AMA. The report included scholarship defined as publications that were indexed in Pub Med and related to the site's grant project participation in consortium interest groups or otherwise associated with the ACE consortium. Thus, the SNA publication dataset was created from these written reports and the articles' information including authors' institutions confirmed from PubMed™ (Supplementary Appendix 1). The network was described using the level of the institution, not the author. This was to represent the medical school level innovation and to not load the SNA with multiple authors from the same institution. Some authors were associated with organizations outside the consortium such as the Accreditation Council for Graduate Medical Education and medical schools beyond consortium institutions. A team verified the SNA publication dataset and noted the following: that publications were appropriately related to the ACE grant, numbers of publications by institution, number of citations from google scholar™, and Altmetric Attention Score (Altmetrics™) measuring social media dissemination as of October 2018. There are three primary sources for traditional citation metrics: Web of Science; Scopus (Elsevier); and Google Scholar. Although each uses somewhat different databases, Google Scholar includes nontraditional sources such as conference proceedings, international non-English journals, course syllabi, blogs, and magazine articles and is freely accessible (Meho and Yang 2007; Vaughan and Shaw 2008; Harzing and Alakangas 2016). Articles were coded as to whether the content included health systems science and competency-based assessment since these were two prominent objectives upon forming the consortium. Other ACE consortium primary objectives and themes did not have sufficient publications to analyze separately. The evaluation of the ACE consortium was determined exempt by the University of Illinois IRB and this study utilized publicly available data.

Analysis

First, we reported descriptive statistics of the numbers of publications and collaborations from the ACE consortium. Second, the institutional affiliation of coauthors on ACE consortium publications was compiled into a relational matrix representing the network. These are presented as a figure, sociogram, for time periods with the members of each network and whether they were a part of the ACE Cohort 1, Cohort 2, or outside of the ACE consortium and the links between the members of the network. We used the social network analysis software UCINET (Analytic Technologies; analytictech.com) to generate sociograms and network-wide and node (member-level) statistics/metrics and to depict the structure of the network visually. To demonstrate how the collaborations have evolved over time, we explored the connections of all organizations (nodes) at two stages of the project, developing a visual representation for the middle of the grant cycle representing the first three years (Figure 1), the last two years, (Figure 2) the conclusion of the grant cycle (Figure 3). From the numerical perspective, a set of metrics was calculated that describes the status of the entire network including metrics calculated at the node level to describe the characteristics of each organization represented in the network.

Specific metrics of interest at the network level:

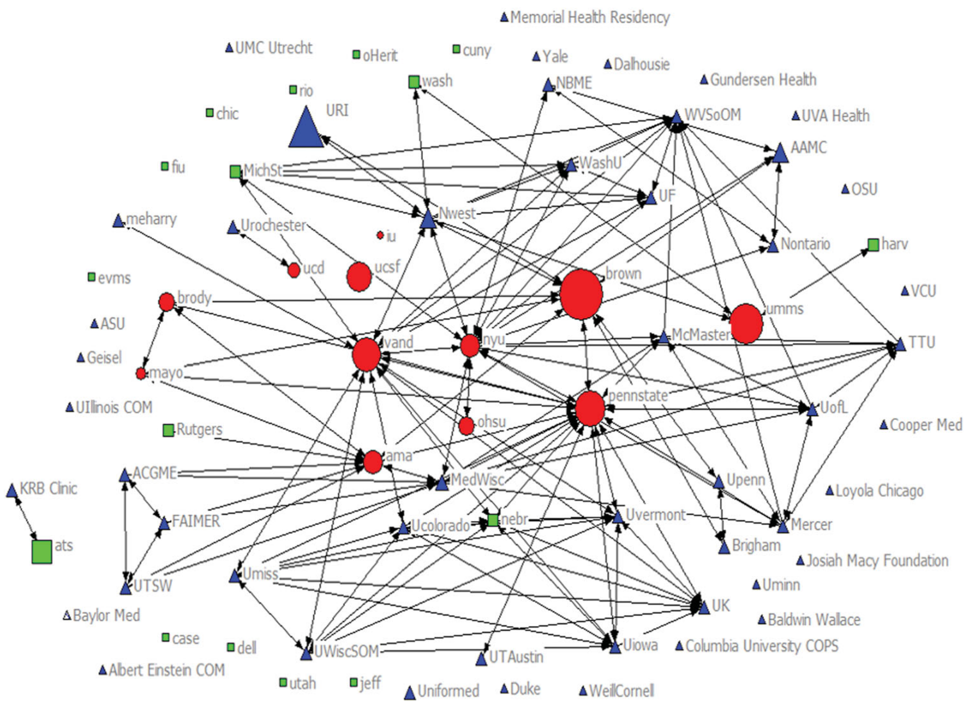

Figure 1. Social network for years 2014–2016 (3 years). Key: Circle = ACE Cohort 1; Diamond = ACE Cohort 2; Square = non-ACE member (Sized by total publications).

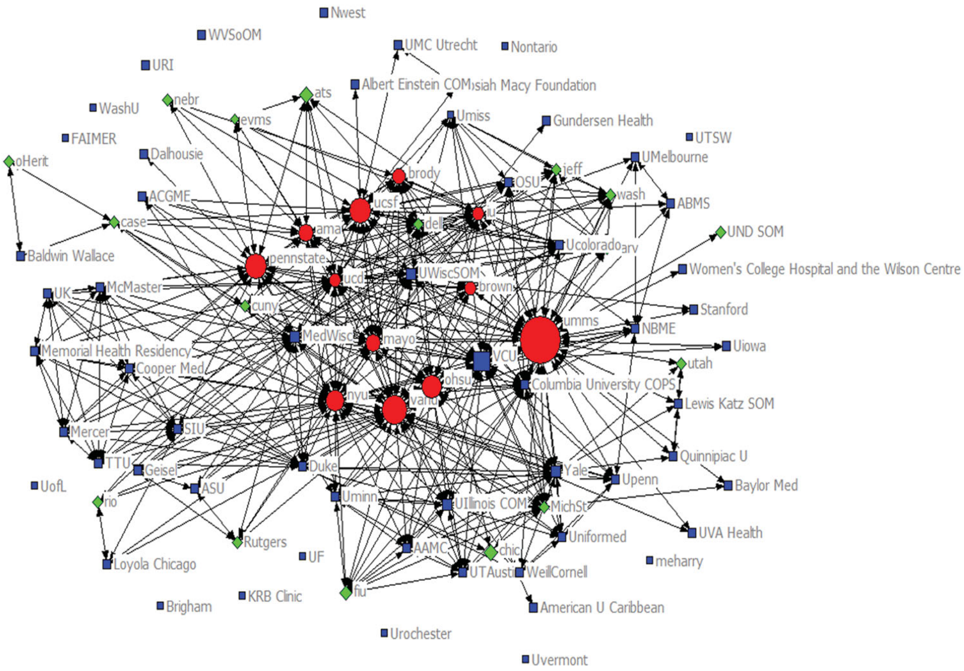

Figure 2. Social network for years 2017–2018 (2 years). The network consists of institutions and organization with authors publishing together. It includes all of the 11 Cohort 1 institutions, the majority 17 of the 21 of the Cohort 2 members, and the AMA engaged in the network, as well as 50 non- members. Key: Circle = ACE Cohort 1; Diamond = ACE Cohort 2; Square = non-ACE member (Sized by total publications).

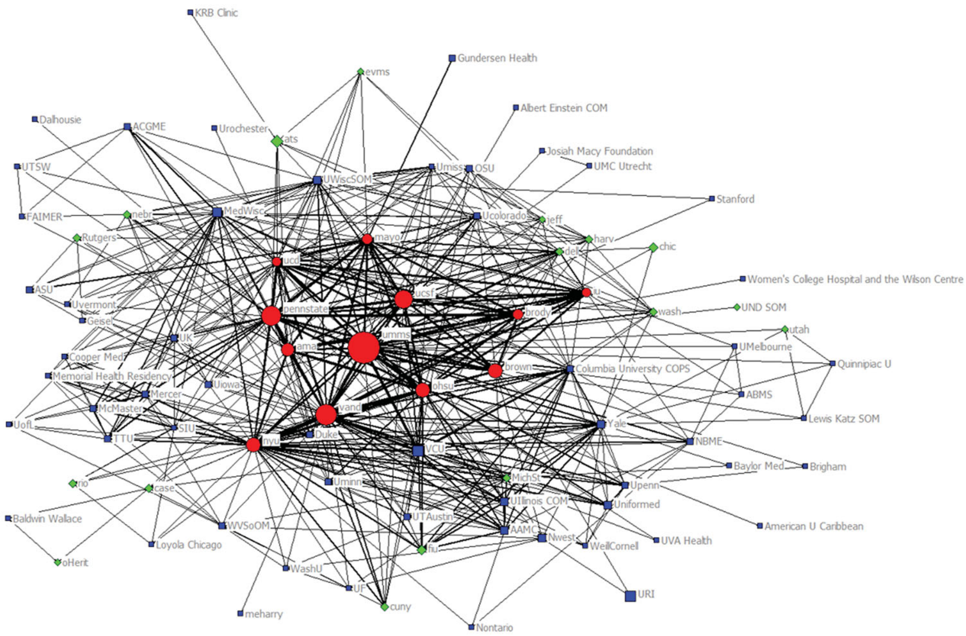

Figure 3. Social network for years 2014–2018 Cumulative (Sized by total publications). The network consists of institutions and organization with authors publishing together. It includes all of the 11 Cohort 1 institutions, the majority 17 of the 21 of the Cohort 2 members, and the AMA engaged in the network, as well as 50 non- members. Weight of line is based on number of connections with thicker lines demonstrating more connection between those members Key: Circle = ACE Cohort 1; Diamond = ACE Cohort 2; Square = non-ACE member (Sized by total publications).

- Average degree describes how connected a typical organizational member is within the network. It is calculated by taking the average number of connections for each organization.
- Network density describes the number of connections between members. In the context of this study, a denser network would mean organizations are more directly connected to each other while a less dense network would mean fewer connections. Network density is calculated as the proportion of actual connections to all possible connections (range: 0-1).
- Degree centralization indicates measures of concentration of popularity, efficiency, and power in a network; namely it assesses the ability of specific organizations to serve as central hubs of information extensively involved in relationships among network members. Here, a high degree indicates that few organizations dominate the network.

The specific metrics of interest at the node (member) level:

- Degree centrality is the total number of connections directly between a node (institution) and any other node. This measure indicates how connected an institution is via a 'one hop' move.
- Betweenness centrality is the number of times a node lies on the shortest path between other nodes. This

measure indicates that a certain member is the *key connecter or bridge* between other members.

Results

Nature of connections

Over the five years of the ACE consortium, scholarly dissemination included 168 publications related to consortium projects, an average of 5 papers per institution, ranging from 38 publications for faculty authors from one institution to no publications for faculty from one institution. These publications demonstrated the dissemination of consortium-related educational innovation. Of the publications, 97 were single institution, and 69 (40%) were multi-institutional. When examining the domains of scholarship, 92 papers were about elements of health systems science, with 15 focused on population health, 16 on informatics or analytics, 12 on interprofessional education and several papers on the Master Adaptive Learner (Cutrer et al. 2017; 2018; Pusic et al. 2018). Thirty papers were about competency-based medical education. Articles were published in 54 journals including: *Academic Medicine* (53 manuscripts), *Medical Education* (11), *Medical Science Educator (*8), *Medical Teacher* (7). The average number of citations was 8 (range 0-96) and the average Altmetric Attention Score was 11 (range 0-86).

Change over time

When examining the consortium's social network sociogram, Figure 1 demonstrates collaborative coauthorship relationships after the first three years of the consortium, which represents primarily Cohort 1 networks. Figure 2 represents the last two years. Figure 3 reflects the end of the five-year grant period including Cohort 1 and 2 schools. As expected, there is growth in the number of publications over time and a marked increase in the interconnectedness of the consortium. In addition to the 28 consortium member institutions and the AMA, 59 other schools and organizations (such as the Accreditation Council for Graduate Medical Education, the Association of American Medical Colleges, and the National Board of Medical Examiners) are represented in the network. Four Cohort 2 schools did not publish and are not represented. A small portion of connections beyond consortium member schools represents the impact of individual consortium participants who moved to positions at institutions not previously engaged (for example, individual authors assumed new positions with the American Board of Medical Specialties and Virginia Commonwealth University.

Reflecting on the first years of the ACE consortium, in 2016, Cohort 1 schools demonstrate varying levels of publication activity. Their connections are approximately equally distributed among non-consortium members and members (Figure 1). Figure 3 represents all interactions from 2014-2018. There is increased centralization of Cohort 1 schools, with greater connections among them. Some Cohort 2 schools also shift to a more central position, while others remain less connected.). Figure 4 represents the changes in network density over time and Figure 5 is a summary of the number of publications by year.

Table 1 reports the social network metrics over the years. The average degree (numbers of connections), degree centralization (authority concentration), and density all increased with time. While network density does increase, the network density is still considered low density. However, the average degree increased by over three times, demonstrating more institutions publishing with others. Several institutions were more connected and changed over time (Table 2). Figure 6 represents the only health system science publications for the entire grant period. Some core institutions were connected and driving the publications in this arena. The network has little centralized power so to speak, but individual nodes have a greater number of connections when viewed across all four years of the grant period.

Discussion

Scholarly productivity of the ACE consortium

Using social network analysis of a large consortium, we analyzed the dissemination of consortium innovations through publications. Through school-level projects and the consortium at large, the ACE group was effective in publishing numerous articles in high-impact journals. Further, 40% of the publications were multi-institutional, demonstrating collaborating coauthorship. The network demonstrated increased connections and centralization over time. In addition, there were key influencing members who were connected to a greater degree and connected more broadly across members. Thus, the consortium supported publication collaboration across schools working on similar educational innovations. Cohort 2 schools had less exposure time and less funding and were understandably less connected at both time points compared to Cohort 1 schools. This was a natural experiment without a clear control group; therefore we cannot determine causation.

While SNA has been applied across other fields and within areas of medicine such as primary care practices and accomplishments of internal medicine residents (Scott et al. 2005; Keating et al. 2007; Shapiro et al. 2015), few studies have explored social networks and consortia. Warm and colleagues explored the association of program directors in internal medicine and found that higher connectedness was associated with increased academic rank and university-based residency programs (Warm et al. 2018; Dow et al. 2020). This study highlighted that it could not be taken for granted that connections will be formed even within an outwardly homogenous group such as internal medicine program directors or medical educators. Dow et al. used SNA to explore an interprofessional education center (Dow et al. 2020). Even as the number of programs and faculty involved in the center grew, the faculty maintained a similar number of connections within the network. At the same time, certain key faculty were important connectors between clusters of faculty performing similar inter-professional educational activities. For each of these networks, SNA helped to describe the relationships of the members.

Schwartz and the Association of Pediatric Program Directors Longitudinal Educational Assessment Research Network described 15 medical education research networks that formalize and institutionalize multi-site collaborations

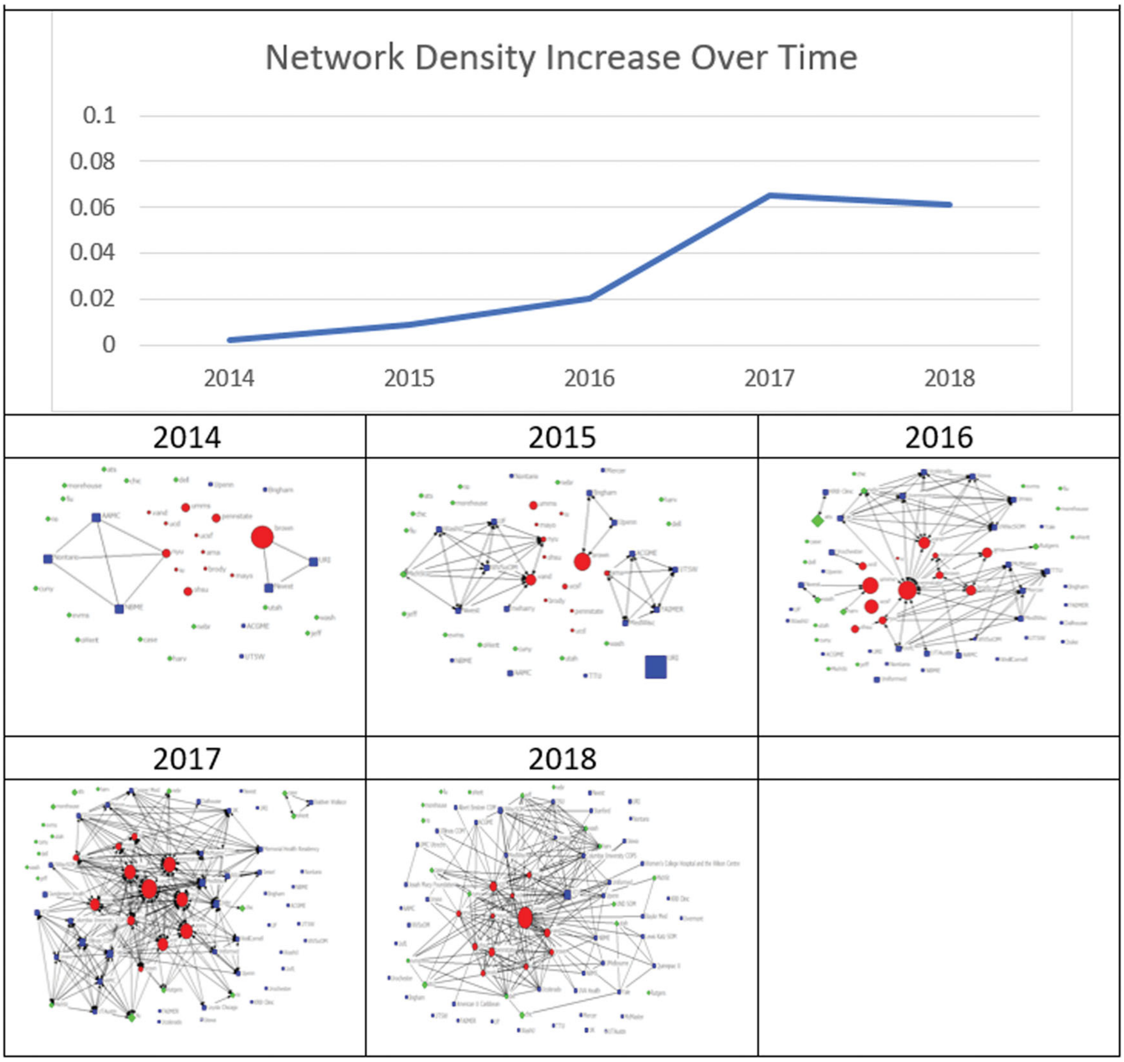

Figure 4. Network density changes by year. Upper panel demonstrates the network density metric. Lower panel demonstrates the sociograms by year.

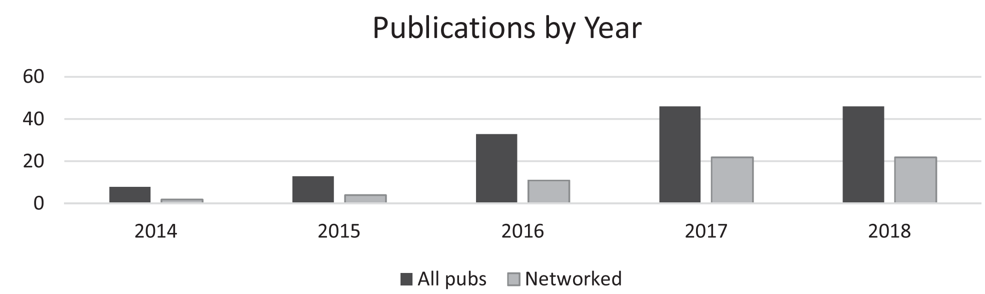

Figure 5. Publications by year.

Table 1. Network measures from early phase to cumulative span of ACE.

Network Cohesion Metrics	2014	2015	2016	2017	2018	2014–2016	2017–2018	2014–2018
Density	.002	.009	.020	.065	.061	.031	.111	.127
Avg. degree	.202	.787	1.730	5.685	5.395	2.719	9.326	11.135
Degree centralization	.033	.072	.201	.329	.391	.189	.374	.429
# of nodes	89	89	89	89	89	89	89	89
# of ties	14	70	154	506	480	242	830	991

Density: The proportion of actual connections to all possible connections across the entire network (range: 0–1). In the context of this study, a denser network (higher value, closer to 1) would mean the authors' institutions are more directly connected to each other, while a less dense network (closer to 0) would mean fewer direct connections between author institutions making up the MedEd consortium network of publication.

Average degrees: The average number of connections for a member of the network. This helps describe how connected an average (typical) institution is across the MedEd consortium network of publications.

Degree centralization: Measures the concentration of power or influence within a network or the variance in the distribution of centrality in a network. This is a normalized value of the importance of single players within the given network. In our case, high degree centralization would suggest that the network is characterized by few centralized institutions whereas a low centralization score would suggest that institutions are more evenly distributed across the MedEd consortium network of publications.

Table 2. Node Member Measures from Early Phase to Cumulative Span of ACE Institutions included and orderd as the top 10 for degree for entire grant period.

Node Members with ordered by highest degree by end of grant	Degree (rank) 2014–2016	Degree (rank) 2017–2018	Degree (rank) 2014–2018	Between (rank) 2014–2016[a]	Between (rank) 2016–2018[a]	Between (rank) 2014–2018[a]
Vanderbilt	15 (3)	102 (1)	117 (1)	0.037 (4)	0.083 (2)	0.160 (2)
U Michigan	3 (tie 29)	95 (2)	98 (tie 2)	0.034 (5)	0.165 (1)	0.178 (1)
New York U	16 (2)	80 (3)	98 (tie 2)	0.04 (3)	0.165 (4)	0.123 (3)
Penn State	19 (1)	67 (7)	86 (4)	0.002 (10)	0.083 (5)	0.063 (5)
Oregon HSU	1 (*)	78 (4)	79 (5)	0 (*)	0.033 (11)	0.035(11)
UC Davis	1 (*)	70 (tie 5)	71 (6)	0 (*)	0.038 (6)	0.061 (6)
UCSF	0 (8)	70 (tie 5)	70 (7)	0 (*)	0.038 (3)	0.086 (4)
AMA	9 (6)	54 (10)	63 (tie 8)	0.066 (1)	0.019 (13)	0.042 (9)
Mayo	4 (23)	59 (8)	63 (tie 8)	0.023 (6)	0.036 (8)	0.040 (10)
Indiana U	0 (*)	55 (9)	55 (10)	0.018 (7)	0.015 (14)	0.020 (17)

In early phase, some of the schools were networking more than the others, yet not many degrees or connections. Throughout the life of the consortium, the numbers of degrees (connections). Those members who had high degree (connections) also had more betweenness- meaning they were connecting to other through the connections.

Betweenness centrality: a node-level measure of how often a member lies on a shortest path connecting two other members; it captures the difference in centralization between the most centralized node and all other nodes and implies that a certain member is the key connecter between other members.

[a]Normalized Between values *Multiple institutions tied at that low degree.

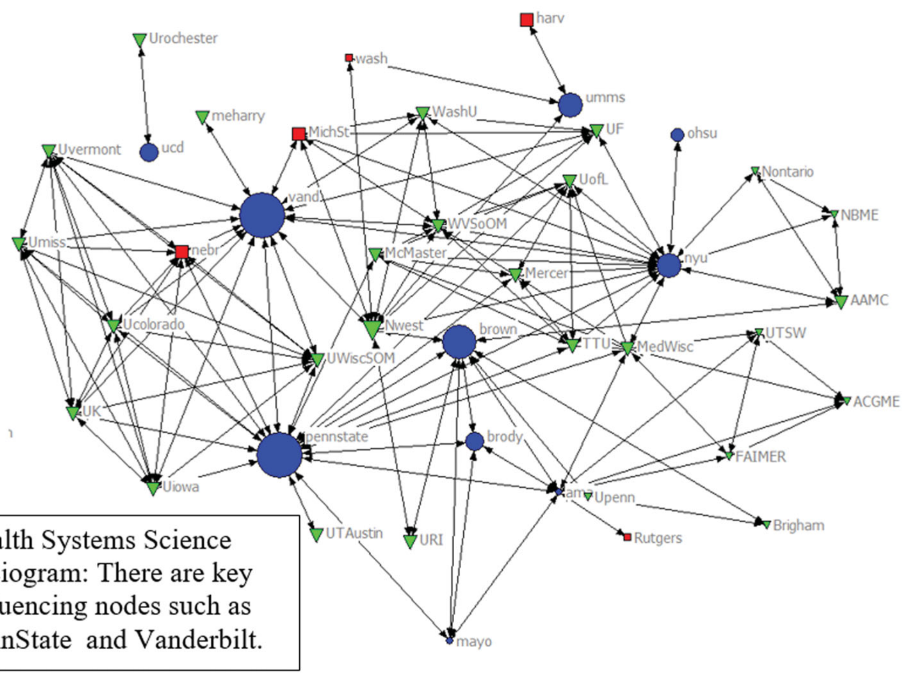

Figure 6. Health systems science network (Years 2014–2018 Cumulative sized by total publications). The network demonstrates strong nodes in the network of HSS dissemination including Penn State and Vanderbilt. Key: Circle = ACE Cohort 1; triangle = ACE Cohort 2; Square = non-ACE member

Table 3. Practices encouraging scholarship for the ACE consortium.

Resources provided (AMA inputs and activities)
Grant support of AMA (Cohort 1- $1,000,000, Cohort 2 $75,000)
Administrative support of AMA through calls, interest groups, meetings
Meetings (bi-annual and 2-3 theme or interest group meetings each year)
AMA organizational structure with 9-15 FTE
Mini-grants ($10–30,000)
Additional funding for special projects
Innovation webinars (@ 6 a year)
Support for interest groups through monthly phone calls, face-to face meetings twice a year (e.g., health systems science, competency assessment, evaluation, master adaptive learner)
Support for primary investigator phone calls monthly and in-person meetings twice a year
Shared interest in educational innovation themes emerged or grew
Encouraging authorship participation from multiple institutions
Accountability to AMA and group
Fostering of junior faculty
The celebration of dissemination through press releases, weekly updates,
Community – shared experiences, shared failures

by establishing infrastructure to enable network members to participate in multiple studies, propose new studies, and exploit study data to maximize scholarly output (Schwartz et al. 2016). These networks existed for the purpose of research as compared to the innovation focus of the ACE consortium. Yet the ACE consortium has some similarities to research networks in that it facilitated multi-institutional studies through connections, administrative support and funding. Like the research networks, ACE connections brought together faculty with similar interests and expertise, such as health systems science and competency assessment. This study demonstrates the scholarly productivity of the network.

We believe there are several major influences on publication productivity of the consortium (Table 3). The first is the resources provided by the AMA in the form of grants as well as centralized administrative support. AMA hosted thematic or consortium-wide meetings, in-person and via teleconference, as well as project management support facilitated group interactions and decreased administrative burdens placed on member institutions. Second, faculty were brought together around shared interests through overarching goals established at the formation of the ACE consortium. This generated multi-institutional publications, especially in the area of HSS. Third, some site-based projects intentionally invited other cohort members to participate. For example, all Cohort 1 schools were invited to partake in participant recruitment and authorship on a Mayo Clinic headed the survey of cost-consciousness attitudes among medical students (Leep Hunderfund et al. 2018). Some collective research projects were centrally coordinated. Fourth, scholarly dissemination of innovations was actively encouraged through tracking publications in the semi-annual progress reports and highlighting member publications in consortium communications. Finally, the consortium facilitated a community of practice around the frequent sharing of ideas and practices. The resulting relationships made it easy to reach out to colleagues to collaborate on publications.

Returning to challenges of diffusion of innovation, the ACE consortium helped to remove individual institutions siloes by providing support, interested parties, and opportunities for the sharing of innovations. HSS is one example of an innovation that was disseminated through sessions at national meetings, support of an interest group, and the formation of a collaborative research group studying one aspect of HSS, cost-conscious care. Along the same lines, the ACE consortium helped in part to address constraints on the school's resources through the larger ACE grant as well as human resources in the form of scheduling, organization, and a research associate.

Dissemination of innovation

This study provides a template for applying social network analysis to the activities of a consortium. Innovation is diffused and adopted following paths that can be difficult to identify and comprehend. Rogers noted that diffusion is the process by which an innovation is communicated over time among the participants in a social system. He proposed that four main elements influence the spread of a new idea: 1) the innovation itself, 2) communication channels, 3) time, and 4) a social system as the innovation is widely adopted and becomes self-sustaining (Rogers 1983). The ACE consortium facilitates both the innovation as well as the diffusion channels.

Understanding the dynamics of diffusion of innovation from the business realm offers insight into educational consortia. Network dynamics lead to the generation and diffusion of innovation resulting in firms that belong to networks being more innovative than isolated firms (Ceci and Iubatti 2012). In fields of rapid innovation, the traditional concept of intellectual property is challenged. Any specific piece of information now experiences a rapid depreciation in value, so serving as a hub through which information flows has become more meaningful than hoarding information (Friedman 2016). In medical education innovation, there is an impetus to share information. Multidimensional links, those that include both personal and professional connections, contribute in different ways to the development of networks such as were found in the ACE consortium relationships. Relationships build trust between players and foster transparency around challenges, which in turn enables progress through shared strategies. We can see these dynamics at play in the ACE consortium (Jippes et al. 2013).

In some businesses, Ceci found that the locus of strategy may not be the locus of innovation (Ceci and Iubatti 2012). The locus of strategy in the ACE consortium was the medical education staff at the AMA led by Dr. Skochelak and advised by an executive committee comprised of principal investigators of the consortium. The AMA education group directly contributed to some of the publications but does not appear as a major node in the network. Successful maturation of the consortium to the role of locus of innovation is indicated in the sociograms by the emergence of multiple hubs overshadowing the AMA. The majority of the innovation was initiated by the members of the consortium. Diffused leadership of publication within the network, drawing upon a variety of relationships fostered through the consortium, indicates collective ownership of the work. Further, the significant involvement of non-member institutions in the publication network speaks to an open-source, share-alike orientation that significantly extended the influence of the locus of strategy. This is valuable to consider in constructing future consortia: rather than top-down controlled dissemination of protocols or approaches, a grassroots ownership for transformation may be more productive.

Examining the nodes of the network reveals varying patterns that drove connectivity. Some institutions emerged as leaders in a specific conceptual area that was relevant to many others in the network. Pennsylvania State College of Medicine is an example of this pattern. The institution quickly took the lead in defining the construct of health system science (Gonzalo et al. 2014), which related directly to two of the central ACE consortium goals. The Brody School of Medicine developed a strong faculty development program related to HSS (Baxley et al. 2016; Walsh et al. 2019). Consortium members and non-member institutions may have had existing efforts underway in innovation areas independently or through forged relationships prior to the start of the consortium (Gonzalo et al. 2017; Leep Hunderfund et al. 2018; Dekhtyar et al. 2020). Some nodes, such as Vanderbilt, were undertaking expansive site-based projects that lead to early engagement in multiple thematic areas and drove a high degree of connection. Other nodes had a longstanding emphasis on publication but had tended toward single-institution efforts. The University of Michigan Medical School and the University of California, San Francisco School of Medicine are examples of schools that leveraged strong existing support structures for scholarship to bolster collaborative activities. Early in the consortium, these institutions published independently, but they were more networked by the end of the grant.

Several of the nodes were also engaged in other consortia, which amplified their connections. The New York University School of Medicine is one example, simultaneously engaged in the ACE consortium, the pilot group for the AAMC's Core Entrustable Professional Activities for Entering Residency, and the Macy Foundation Consortium of Accelerated Medical Pathway Programs. Nodes that showed the greatest growth over the grant period, such as Oregon Health & Science University School of Medicine and the University of California, Davis School of Medicine, seized the opportunity to build their network through consistent engagement in consortium activities.

It may also be important to examine member institutions that did not significantly grow in connectivity in the network over time. Such schools may have had narrowly focused projects that did not lend themselves to generalization. Alternatively, perhaps the local institutional infrastructure may not have emphasized or supported faculty engagement in scholarship. There may have been other barriers to engagement including limited bandwidth of individuals, lack of openness of early members to engage new members, and lack of prior connection. In addition, structural issues of the consortium must also be considered; the consortium locus of strategy may need to conduct continuous monitoring of the distribution of attention, relationship-building and resource allocation to ensure an inclusive environment. Many medical schools were involved in the network, but very few were involved in any one paper. So, although innovation did diffuse, it is not clear how widely.

There are limitations to this study. First, this study does not have a clear control group for comparison. While there are changes over time, it is unclear what changes might have occurred without the ACE Consortium. Second, the network reflects publications listed on the grant reports. We did not conduct an independent search since it would not have been clear which publications were related to the ACE work. This analysis was focused solely on ACE-related activities. The social network shows the connections at discrete points in time. The analysis does not indicate whether prexisting relationships existed, the strength of those relationships, or whether the relationship resulted in multiple papers. Additionally, any preexisting strength in publication/innovation, funding of medical education, numbers of faculty engaged at each institution, was not noted. Directionality (who sparked each publication) was also not captured in our primary data set. The network demonstrates the relationships but does not explain why or how the publication relationships occurred. This analysis focuses on publication, which is only one form of networking that occurred and may not fully reflect the richness of connections that were forged. Thus this article underrepresents other forms of dissemination such as meeting presentations, informal conversations, and visiting lectures. Further work might explore 'cliques' as part of asocial network analysis to describe the connections between groups of members.

The study suggests directions for future exploration and refinement of this approach for innovation consortia. Successful consortia must bring value to all participants and involve collaboration, as opposed to solely focusing on the exchange of information. While the structure and formal processes are necessary, a dense web of interpersonal connections enhances learning and diffusion of innovation. Frequent discussion platforms and interest group meetings created through this consortium supported the communication, integration, interdependence of complementary skills, and investment in common goals. Consortia leadership can encourage innovation, provide resources, and use shared goals to leverage innovation themes and their dissemination. Dynamic tracking of social networks in real-time over the course of a consortium's life span could offer opportunities to amplify relationships and ensure that outputs of those relationships are aligned with the primary goals of the consortium.

In conclusion, the ACE consortium fostered a network of scholarship disseminating a broad range of educational innovations through publications of individual school projects and collaborations across the consortium. The publications and network connections increased over the grant.

Acknowledgment

The authors acknowledge Courtney Blondino and Michael Dekhtyar for assistance with data management.

Prior presentation

AAMC November 2019.

IRB

This was non- human subjects research using publicly available data at the level of institutions.

Disclosure statement

The authors have no declarations of interest to report.

Glossary

Social network analysis: Is the analysis of the interactions and connections between each of the members of the network.

Consortium: Is a formal alliance of organizations and individuals coming together to achieve specific objectives, often with funding to support that work.

Data availability statement

Data is not available.

Funding

This work was supported by the American Medical Association's Accelerating Change in Medical Education through grants to the 32 consortium schools as part of the consortium. Dr. Santen received funding through VCU from CTSA award No. UL1TR002649 from the National Center for Advancing Translational Sciences.

Notes on contributors

Sally A. Santen, MD, PhD, is senior associate dean, assessment, evaluation and scholarship, and professor of emergency medicine, Virginia Commonwealth School of Medicine, professor of emergency medicine, University of Cincinnati, and consultant, American Medical Association.

Jeffery S. Smith, MBA, PhD, is professor and chair, supply chain management, Virginia Commonwealth School of Business.

Jeff Shockley, MBA, PhD, is associate professor, supply chain management, Virginia Commonwealth School of Business.

John W. Cyrus, MA, MLIS, is assistant professor and research and education librarian, Virginia Commonwealth University Tompkins-McCaw Library for the Health Sciences.

Kimberly D. Lomis, MD, is vice president, undergraduate medical education innovations, American Medical Association American Medical Association.

Martin Pusic, MD, PhD, was associate professor of emergency medicine & pediatrics, NYU Grossman School of Medicine and is associate professor of pediatrics and emergency medicine, Harvard Medical School.

George C. Mejicano, MD, MS, is professor of medicine and senior associate dean for education, Oregon Health & Science University School of Medicine.

Luan Lawson, MD, MAEd, is associate dean, curricular innovation in medical education, and associate professor of emergency medicine, Brody School of Medicine at East Carolina University.

Bradley L. Allen, MD, PhD, is senior associate dean for medical student education and associate professor of clinical medicine and infectious diseases, Indiana University School of Medicine.

Susan E. Skochelak, MD, is Senior Associate Dean for Medical Student Education, Indiana University School of Medicine, Indianapolis, IN, USA.

ORCID

Sally A. Santen http://orcid.org/0000-0002-8327-8002
Jeff Smith http://orcid.org/0000-0002-2760-1012
Jeff Shockley http://orcid.org/0000-0002-5638-5806
Kimberly D. Lomis http://orcid.org/0000-0002-3504-6776
Luan Lawson http://orcid.org/0000-0001-8408-2581
Bradley L. Allen http://orcid.org/0000-0002-8846-9342

References

Andrews JS, Bale JF, Soep JB, Long M, Carraccio C, Englander R, Powell D, EPAC Study Group 2018. Education in Pediatrics Across the Continuum (EPAC): first steps toward realizing the dream of competency-based education. Acad Med. 93(3):414–420.

Barabási A, Bonabeau E. 2003. Scale-free networks. Sci Am. 288(5): 60–69.

Baxley EG, Lawson L, Garrison HG, Walsh D, Lazorick S, Lake D, Higginson J. 2016. The teachers of quality academy: a learning community approach to preparing faculty to teach health systems science. Acad Med. 91(12):1655–1660.

Borgatti SP, Li X. 2009. On social network analysis in a supply chain context. J Supply Chain Manag. 45(2):5–22.

Cangiarella J, Fancher T, Jones B, Dodson L, Leong SL, Hunsaker M, Pallay R, Whyte R, Holthouser A, Abramson SB. 2017. Three-year MD programs: perspectives from the Consortium of Accelerated Medical Pathway Programs (CAMPP). Acad Med. 92(4):483–490.

Ceci F, Iubatti D. 2012. Personal relationships and innovation diffusion in SME networks: a content analysis approach. Res Policy. 41(3): 565–579.

Cooke M, Irby DM, O'Brien BC. 2010. Educating physicians: a call for reform of medical school and residency. Stanford (CA): Jossey-Bass.

Cutrer WB, Atkinson HG, Friedman E, Deiorio N, Gruppen LD, Dekhtyar M, Pusic M. 2018. Exploring the characteristics and context that allow Master Adaptive Learners to thrive. Med Teach. 40(8): 791–796.

Cutrer WB, Miller B, Pusic MV, Mejicano G, Mangrulkar RS, Gruppen LD, Hawkins RE, Skochelak SE, Moore DEJ. 2017. Fostering the development of master adaptive learners: a conceptual model to guide skill acquisition in medical education. Acad Med. 92(1):70–75.

Dekhtyar M, Ross LP, D'Angelo J, Guernsey J, Hauer KE, Lawson L, Pusic MV, Hawkins RE. 2020. Validity of the health systems science examination: relationship between examinee performance and time of training. Am J Med Qual. 35(1):63–69.

Dow AW, Sewell DK, Lockeman KS, Micalizzi EA. 2020. Evaluating a center for interprofessional education via social network analysis. Acad Med. 95(2):207–212.

Frank JR, Snell LS, Cate OT, Holmboe ES, Carraccio C, Swing SR, Harris P, Glasgow NJ, Campbell C, Dath D, et al. 2010. Competency-based medical education: theory to practice. Med Teach. 32(8):638–645.

Friedman TL. 2016. Thank you for being late: an optimist's guide to thriving in the age of accelerations. 1st edn. New York: Farrar, Straus and Giroux.

Gonzalo JD, Baxley E, Borkan J, Dekhtyar M, Hawkins R, Lawson L, Starr SR, Skochelak S. 2017. Priority areas and potential solutions for successful integration and sustainment of health systems science in undergraduate medical education. Acad Med. 92(1):63–69.

Gonzalo JD, Caverzagie KJ, Hawkins RE, Lawson L, Wolpaw DR, Chang A. 2018. Concerns and responses for integrating health systems science into medical education. Acad Med. 93(6):843–849.

Gonzalo JD, Haidet P, Wolpaw DR. 2014. Authentic clinical experiences and depth in systems: toward a 21st century curriculum. Med Educ. 48(2):104–105.

Harzing A-W, Alakangas S. 2016. Google scholar, scopus and the web of science: a longitudinal and cross-disciplinary comparison. Scientometrics. 106(2):787–804.

Irby DM, Cooke M, O'Brien BC. 2010. Calls for reform of medical education by the carnegie foundation for the advancement of teaching: 1910 and 2010. Acad Med. 85(2):220–227.

Jippes E, Steinert Y, Pols J, Achterkamp MC, van Engelen JML, Brand PLP. 2013. How do social networks and faculty development courses affect clinical supervisors' adoption of a medical education innovation? an exploratory study. Acad Med. 88(3):398–404.

Keating NL, Ayanian JZ, Cleary PD, Marsden PV. 2007. Factors affecting influential discussions among physicians: a social network analysis of a primary care practice. J Gen Intern Med. 22(6):794–798.

Leep Hunderfund AN, Starr SR, Dyrbye LN, Gonzalo JD, George P, Miller BM, Morgan HK, Hoffman A, Baxley EG, Allen BL, et al. 2018. Value-added activities in medical education: a multisite survey of first- and second-year medical students' perceptions and factors influencing their potential engagement. Acad Med. 93(10): 1560–1568.

Lomis K, Amiel JM, Ryan MS, Esposito K, Green M, Stagnaro-Green A, Bull J, Mejicano GC, AAMC Core EPAs for Entering Residency Pilot Team 2017. Implementing an entrustable professional activities framework in undergraduate medical education: early lessons from the AAMC core entrustable professional activities for entering residency pilot. Acad Med. 92(6):765–770.

Lomis KD, Santen SA, Dekhtyar M, Elliott VS, Richardson J, Hammoud MM, Hawkins R, Skochelak SE. 2020. The accelerating change in medical education consortium: key drivers of transformative change. Acad Med. 96(7):979–988.

McGaghie WC. 2010. Medical education research as translational science. Sci Transl Med. 2(19):19cm8.

Meho LI, Yang K. 2007. Impact of data sources on citation counts and rankings of LIS faculty: web of science versus scopus and google scholar. J Am Soc Inf Sci. 58(13):2105–2125.

Novak DA, Hallowell R, Ben-Ari R, Elliott D. 2019. A continuum of innovation: curricular renewal strategies in undergraduate medical education, 2010-2018. Acad Med. 94(11S Association of American Medical Colleges Learn Serve Lead: Proceedings of the 58th Annual Research in Medical Education Sessions):S79–S85.

Otte E, Rousseau R. 2016. Social network analysis: a powerful strategy, also for the information sciences: J Inf Sci [Internet]. [accessed 2020 Apr 16]. https://journals.sagepub.com/doi/10.1177/016555150202800601.

Peurach DJ. 2016. Innovating at the Nexus of Impact and Improvement: Leading Educational Improvement Networks. Educ Res [Internet]. [accessed 2020 Apr 16]. https://journals.sagepub.com/doi/10.3102/0013189X16670898.

Pusic MV, Santen SA, Dekhtyar M, Poncelet AN, Roberts NK, Wilson-Delfosse AL, Cutrer WB. 2018. Learning to balance efficiency and innovation for optimal adaptive expertise. Med Teach. 40(8): 820–827.

Rogers EM. 1983. Diffusion of innovations. 3rd ed. New York, : Free Press, Collier Macmillan.

Santen SA, Deiorio NM, Gruppen LD. 2012. Medical education research in the context of translational science. Acad Emerg Med. 19(12): 1323–1327.

Schwartz A, Young R, Hicks PJ, APPD LEARN F. 2016. Medical education practice-based research networks: Facilitating collaborative research. Med Teach. 38(1):64–74.

Schwartz HS, Schon DA. 1987. The reflective practitioner: how professionals think in action. Adm Sci Q. 32(4):614–617.

Scott J, Tallia A, Crosson JC, Orzano AJ, Stroebel C, DiCicco-Bloom B, O'Malley D, Shaw E, Crabtree B. 2005. Social network analysis as an analytic tool for interaction patterns in primary care practices. Ann Fam Med. 3(5):443–448.

Shapiro J, Zhang B, Warm EJ. 2015. Residency as a social network: burnout, loneliness, and social network centrality. J Grad Med Educ. 7(4):617–623.

Skochelak SE, Stack SJ. 2017. Creating the medical schools of the future. Acad Med. 92(1):16–19.

Skochelak SE. 2010a. A decade of reports calling for change in medical education: what do they say? Acad Med. 85(9 Suppl):S26–S33.

Skochelak SE. 2010b. Commentary: a century of progress in medical education: what about the next 10 Years. ?Acad Med. 85(2): 197–200.

Sorantin E. 2014. Pathways and barriers to developing pediatric research consortia. Pediatr Radiol. 44(10):1213–1217.

Supovitz J. 2013. Situated research design and methodological choices in formative program evaluation. Yearb Natl Soc Study Educ. 112(2): 372–399.

Vaughan L, Shaw D. 2008. A new look at evidence of scholarly citation in citation indexes and from web sources. Scientometrics. 74(2): 317–330.

Walsh DS, Lazorick S, Lawson L, Lake D, Garrison HG, Higginson J, Vos P, Baxley E. 2019. The teachers of quality academy: evaluation of the effectiveness and impact of a health systems science training program. Am J Med Qual. 34(1):36–44.

Warm E, Arora VM, Chaudhry S, Halvorsen A, Schauer D, Thomas K, McDonald FS. 2018. Networking matters: a social network analysis of the association of program directors of internal medicine. Teach Learn Med. 30(4):415–422.

Wasserman S, Faust K. 1994. Social network analysis: methods and applications. Cambridge (England): Cambridge University Press.