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And then the internet happened: Thoughts on the future of concept mapping

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ABSTRACT

Over 25 years ago, in the late twentieth century, concept mapping emerged as a mixed method approach to inquiry that enables a group of people to conceptualize their thinking about a specific topic. Since then, the application of concept mapping has spread widely and an easy prediction for the future is that this trend is likely to continue; a more important and greater challenge is to think about the ways in which concept mapping may and should evolve. Discussed here are thoughts about the future of concept mapping including some predictions of likely directions and suggestions for new possibilities. Thoughts on the future are grounded in concept mapping applications that have emerged and gained ground in recent years; these include exploring wicked problems in communities and integrating concept mapping with other methods of inquiry. Thoughts on the future are also grounded in the social and cultural milieu in which we find ourselves at this time. The influence of social media and internet technologies has led to the emergence peer production and crowdsourcing as approaches to co-create information, knowledge, products and services. These tactics may create fertile ground for the further spread of concept mapping. This same collaborative milieu has produced the open software movement which in turn, offers opportunities to enhancing the methodology of concept mapping.

In the latter part of the 20th century concept mapping was introduced (Trochim & Linton, 1986; Trochim, 1989c) and what started as a few projects and several articles has since expanded to a body of work cited in numerous publications (Trochim, 2017) and implemented in multiple dissertations (Donnelly, 2017). Not accounted for are all of the applied planning and evaluation projects that have relied on concept mapping methodology and are not shared in the literature. I know, from my own work and that of colleagues, that concept mapping has been a key aspect of many projects in corporate, not for profit and government settings but the details were confined to the project and never shared with the evaluation community. I suspect this occurs more often than not and if these projects could be counted the number of planning and evaluation projects that implemented concept mapping is likely to be substantially increase beyond what is currently known. Clearly, implementation of the concept mapping methodology has increased and this trend will likely continue, which is, of course, an easy prediction about the future. More challenging would be to predict how concept mapping might evolve in the future. But rather than try to predict the future, a task fraught with risk and certain error, a more useful and safer approach is to start in the recent past and explore the maturation of concept mapping as a means of pointing toward future possibilities. I decided to look at trends that I noticed as I looked back on the start of the new millennium and used these observations as guideposts for some thoughts about the future of concept mapping methodology beginning with the growth of the internet, social media, and related technologies as a framework.

1. Here comes the crowd

> Once you open the possibility that people are not only using the web as a platform to produce their own individual content, but also to pool their efforts, knowledge, and resources . . . the possibilities for what they can create are astounding (Benkler, 2002, p. 145).

At the time of the special issue of Evaluation & Program Planning in 1989, concept mapping was a nascent application. At the same time, the Internet was also in its early stage, "Tim Berners-Lee, the inventor of the Web, first started working on its development at CERN, the high-energy physics laboratory in

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Switzerland, in 1989 (Hall, De Roure, & Shadbolt, 2009, p. 993) and since then the web has grown to over four billion pages (de Kunder, 2016). That growth is interesting but more pertinent is that connecting people through the web has, as the quote by Benkler suggests, enabled new behaviors to emerge. A culture of cooperation and collaboration has emerged that has been enabled by internet technologies. Collaborative behavior of this sort has been most noticeable in technology development; examples include the development of the Linux operating system and the Firefox browser (Benkler, 2007; Brabham, 2008). Development of the Linux operating system relied on the internet to connect individuals who volunteered the contribution of their expertise; the result was many people with diverse expertise contributing to a complex whole (Moody, 2002). This culture of collaborative problem solving is not limited to software and is emerging in "... every domain of information and cultural production (Benkler, 2007, p. 5)." For example, the creation of content for Wikipedia, an information resource, is largely based on unpaid volunteers whose work to create content is comparable in terms of quality though more prolific than approaches that rely on corporate control and paid experts (Giles, 2005). Terminology has emerged to describe this behavior and Benkler (2007) describes "... the rise of effective, large-scale cooperative efforts ... (p. 5)" as peer-production. Rheingold (2002) used the term "smart mobs" to describe individuals using Internet and mobile technologies to form virtual communities. Not mobs in the usual sense but people with a common interest who use technology to find and connect with each other, form the smart mob, share information, collaborate, and take action. Surowiecki (2004) described the intelligence of groups and cites multiple instances in which the wisdom of crowds, that is, many individuals contributing their unique and individual perspective, can produce a better solution than experts. Recognizing the potential benefit of this phenomenon, organizations have implemented processes to take advantage of the wisdom of crowds through "crowdsourcing" – a term coined by Howe (2006, 2008) which describes a "... web-based business model that harnesses the creative solutions of a distributed network of individuals ..." (Brabham, 2008, p. 76). And in other instances, the crowd is a network of experts, what Page (2008) calls a "wise crowd," collaborating on a complex challenge. Increasingly this is an approach that is finding its way into scientific research (See, for example, Franzoni & Sauermann, 2014; Nielsen, 2012; Wuchty, Jones, & Uzzi, 2007) and is appropriate for addressing challenges in public health (Brabham, Ribisl, Kirchner, & Bernhardt, 2014).

2. Concept mapping and the wisdom of crowds

> One thing a person cannot do, no matter how rigorous his analysis or heroic his imagination, is to draw up a list of things that would never occur to him. Attributed to Thomas Schelling, Economist and Nobel Laureate

The wisdom of the crowd phenomenon pre-dates the Internet and does not require technology but has emerged in the public consciousness because Internet and social media eases access to people who can form a crowd. However, it is not just a crowd that is necessary, Surowiecki (2004) named three elements that must be present to take advantage of the wisdom of a crowd: (1) diverse points of view, (2) independence of each point of view from the influence of others, and (3) a mechanism for aggregating the many individual points of view into a collective. These three elements ensure that diverse viewpoints emerge; these diverse views coexist and are integrated. These three elements also seemed to me to be an apt description of concept mapping and I considered concept mapping within this framework. Concerning (1) diverse points of view, Trochim (1989c) noted that, "... conceptualization is best when it includes a wide variety of relevant people (p. 2)." The concept of (2) independence is evident in two data collections tasks: (a) in ideation generation, typically done through brainstorming, a task in which participants respond to the focus prompt; and (b) in card sorting, a task in which individuals complete an unstructured (card) sort of the ideas generated in the prior task. Trochim (1989c) wrote about the importance of independent thinking in the method; in idea generation, "... there should be no criticism or discussion regarding the legitimacy of statements which are generated ... also allow each participant to submit several statements anonymously on paper so that confidentiality will be preserved" (pp. 4–5) and in card sorting individuals should sort the cards "in a way that makes sense to you" (p. 5). Regarding the need for (3) a mechanism for aggregating individual input, Trochim (1989c) wrote, "... conduct a two-dimensional nonmetric multidimensional scaling" (p. 7)" and "... hierarchical cluster analysis ... to group individual statements on the map into clusters of statements which presumably reflect similar concepts" (p. 8). Concept mapping was at its inception illustrating properties that have emerged in this millennium. Trochim and the other authors in 1989 may have been ahead of their time in implementing a method to capitalize on the wisdom-of-crowds phenomenon. As collaborative approaches to problem solving, product development and a host of other challenges become more accepted and seem more the norm, the value of concept mapping will become more apparent and stakeholders will be more likely to recognize and understand that value. That understanding between individuals who implement concept mapping and stakeholders facing complex challenges will continue to increase the number of and diversity of projects for which concept mapping is an appropriate intervention. And, in fact, this millennium has seen the emergence of concept mapping as a method for understanding serious challenges in communities, designing solutions and engaging members of those communities in the discovery of the elements of the challenges and the design of interventions; the wisdom of "wise" crowds in collaboration has relevance to the emergence of concept mapping as a method for community engagement and participatory research.

3. Concept mapping in communities: wise crowds and wicked problems

> ... it becomes morally objectionable for the planner to treat a wicked problem as though it were a tame one, or to tame a wicked problem prematurely, or to refuse to recognize the inherent wickedness of social problems (Rittel & Webber, 1973, pp. 160-161).

Rittel and Webber (1973) coined the term "wicked problem" to distinguish between tame or benign problems where it is clear "... whether or not the problems have been solved ... and wicked problems which are, in contrast, vicious ... or tricky ... (p. 160)" and for which there is a moral obligation on the part of those charged with intervening to recognize and work with the wicked nature of the problem. In commenting on the nature of evaluation in the face of a wicked problem, Mertens (2015) urged adoption of mixed methods as an appropriate methodological framework to address wicked problems. A particular strength of mixed methods is the opportunity for methods of inquiry to include the voice and experience of community members. Concept mapping is, by definition, a mixed method approach consisting of both qualitative and quantitative components and seems well-suited to wicked problems for that methodological reason. But more importantly, concept mapping is a participatory method that is well-suited to tapping into the experience and expertise of the

community members for whom the wicked problem is part of the lived experience solving (Burke et al., 2005; Rosas, 2012; Vaughn, Jones, & Burke, 2017; Windsor, 2013).

There is no hard definition of a wicked problem and that judgment may be in the eye of the beholder but it seems that concept mapping has addressed a number of wicked problems. I gathered the focus prompts from several published studies to illustrate that point (Table 1). The focus prompt for a project offers a unique opportunity to gain insight quickly into the emphasis of the project. Creating the focus prompt is the point at which the key stakeholders grapple with the language to clearly express the problem that needs to be defined or the intervention that needs to be designed. I would argue that focus prompts for these studies are evidence of inquiry to address a wicked problem: violence in schools, intimate partner violence, drugs in the community, and HIV/AIDS. This is not an exhaustive list by any means but does illustrate that concept mapping has emerged as a method to engage stakeholders in the understanding the nature of wicked problems.

While the focus prompt offers a window into the nature of the challenge, a well-designed concept mapping project needs diverse viewpoints. In the case of participatory approaches to inquiry, responding to the prompt requires participation by community members. The examples in Table 1 included substance abusers, service providers, neighborhood residents, religious leaders, researchers, HIV positive individuals, parents, teachers, administrators as well as children. The inclusion of youth in concept mapping studies has also emerged and Table 2 illustrates a number of studies in which the community included or was solely comprised of youth. Additionally, because the methodology is flexible, the language of the community is not a barrier to participation. In a study to explore the reasons immigrant women were not seeking a screening mammogram, the sample included "SA [South Asian] immigrant women . . . could speak and read Urdu, Hindi, Punjabi or the English language . . . (Ahmad, Mahmood, Pietkiewicz, McDonald, & Ginsburg, 2012, p. 243)." Also in an immigrant community, a methodological enhancement by Haque and Rosas (2010) integrated photovoice, with concept mapping – rather than text on cards, photos were used in the sorting task.

Concept mapping has emerged as a participatory method of inquiry that includes the community in inquiry and problem solving; relying on concept mapping to engage community members in understanding and addressing wicked problems will likely increase in the future. The term "participatory" and its synonyms have been used loosely to describe different levels of community involvement. In in this issue Vaughn et al. (2017) provide a more nuanced view of community involvement in concept mapping and a further prediction is that the implementation of concept mapping with communities will increase as evaluators and planners better understand variation in community participation.

4. What goes around comes around, visualizing program theory in this millennium

> Group concept mapping is consistent with the growing interest in the role of theory in planning and evaluation (Trochim, 1989c).

Logic modelling, like concept mapping emerged in the late twentieth century as a means to illustrate program theory. McLaughlin and Jordan (1999) noted that "Evaluators have found the Logic Model process useful for at least twenty years (p. 66)." Cooksy, Gill, and Kelly (2001) describe the value of this approach for expressing program theory as " . . . communicating the relationship of program resources and operations to outcomes in a simple picture (p. 127)." Both logic models and concept maps share an approach to making the complex accessible through pictures but differ in how these visual images are generated and what is portrayed. For example, a logic model illustrates directionality and can indicate how elements of the program are linked. Concept maps do not illustrate linkages but may be more efficient at including more people and generating more detail to describe a program. Rather than commend one method over another, concept maps and logic models can be integrated in a way that takes advantage of the strengths of both methods. Concept mapping has been used as a precursor to the development of a logic model in order to efficiently include a large number of people in the modeling process and efficiently generate the elements of a logic model (e.g., resources, activities, outputs). Anderson et al. (2006) implemented concept mapping to gather input from a large number of stakeholders regarding future directions for prevention research. The resulting map along with other data sources were

Table 1
Concept mapping as a participatory method addressing wicked problems.

Author, Date	Prompt	Crowd
O'Campo et al. (2005)	"Characteristics of neighborhoods that could relate in any way, good or bad, to women's experience of intimate partner violence" (p. 604).	"Most participants from the concept mapping activities were African American, had completed high school or the equivalent, and were over the age of 30 years. All participants (n = 37) were residents of Baltimore City" (p. 304).
Windsor (2013)	"What is the role of drugs and alcohol in Newark's low-income and predominantly African American neighborhoods" (p. 279)?	"The project engaged substance users, community residents, substance abuse service providers, and Researchers in order to identify key personal and community-level dimensions describing the dynamics and consequences of drugs and alcohol in Newark's distressed neighborhoods" (p. 277).
Abdul-Quader and Collins (2011)	"Structural factors associated with HIV transmission may include physical, social, cultural, organizational, community, economic, legal, or policy aspects of the environment. To address these structural factors, a specific action (e.g., project, intervention, or social change) that has been or could be taken to reduce HIV transmission is. . ." (p. 779).	" . . . stakeholders and subject-matter experts from a broad range of disciplines and regions of the U.S. The stakeholders and subject-matter experts were identified and selected based on their knowledge, expertise, and involvement in HIV prevention research and program activities and structural interventions" (p. 779).
Szaflarski, Vaughn, McLinden, Wess, and Ruffner (2014)	"To address HIV/AIDS in the Black faith community, I believe we need to . . . " (p. 98).	" . . . faith and community leaders, health professionals, and HIV-infected or at-risk individuals" (p. 97).
Vaughn et al. (2013)	"Thinking of your school, list the ways to deal with the problem of bullying in children . . . " (p. 677).	" . . . college students and school stakeholders (students, parents, teachers, administrators)" (p. 677).

Table 2
Concept mapping involving youth.

Author, date	Prompt	Ages
Johnson et al. (2011)Johnson, Burke, and Gielen (2011)	"generate a list of items that describe characteristics of your school environment that could relate in any way, good or bad, to a student's experience of violence" (p. 333).	"Primarily African-American students (n = 27) from Baltimore City high schools participated in concept mapping sessions . . . " (p. 331).
Borden et al. (2006)	"(a) One of the reasons young people take part in youth programs is ___" and (b) "One of the reasons other young people are NOT involved in youth programs is ___" (p. 191).	" . . . young people between the ages of 9 and 19 who participated in some type of organized youth program and identified their ethnicity as Latino" (p. 191).
Chun and Springer (2005)	" . . . Things that stress me out are ___ . . . " and "· · ·The way I deal with stress is to ____ "(p. 60).	" . . . runaway youths . . . ages of 13 and 18 years, had left their homes without permission for more than 24 h, and currently lived in a runaway shelter" (p. 61).
Davis, Saltzburg, and Locke (2010)	"Something GLBT youths need from their communities to feel supported is . . . " (p. 231).	" . . . included youths ages 14–23 . . . identified their sexual orientation as 55% lesbian, 35% gay, and 10% bisexual" (p. 230).
Johnson et al. (2011)	" . . . generate a list of items that describe characteristics of your school environment that could relate in any way, good or bad, to a student's experience of violence" (p. 333).	" . . . 10th and 11th grade . . . " and " . . . 9th and 10th grade . . . " (p. 332).
Ridings et al. (2008)	"Please tell us about a problem or issue facing young African American males between the ages of 10 to 16 in the Greater Roseland Community . . . " (p. 47).	"The youth were recruited from both high school and elementary levels . . . " (p. 44).
Ries et al. (2008)	"What things in the environment, both good and bad, might influence physical activity among adolescents" (p. 27)?	" . . . 9th through 12th graders from 2 magnet high schools located in Baltimore . . . " (p. 26).
Vaughn and McLinden (2016)	"In order to stop teen suicide, we need to . . . ."	" . . . adolescents were asked to identify and describe their perspectives about stopping teen suicide . . . "
Minh, Patel, Bruce-Barrett, and O'Campo (2015)	"In the [neighborhood name] and surrounding areas, a problem facing youth that can be addressed with local services and programs, is . . . " (p. 35).	" . . . residents within and around the neighborhood . . . who were either . . . (1) youth between the ages of 12 and 25, (2) adult family members of youth, or (3) providers of health and social services for youth who worked in the area" (p. 35).

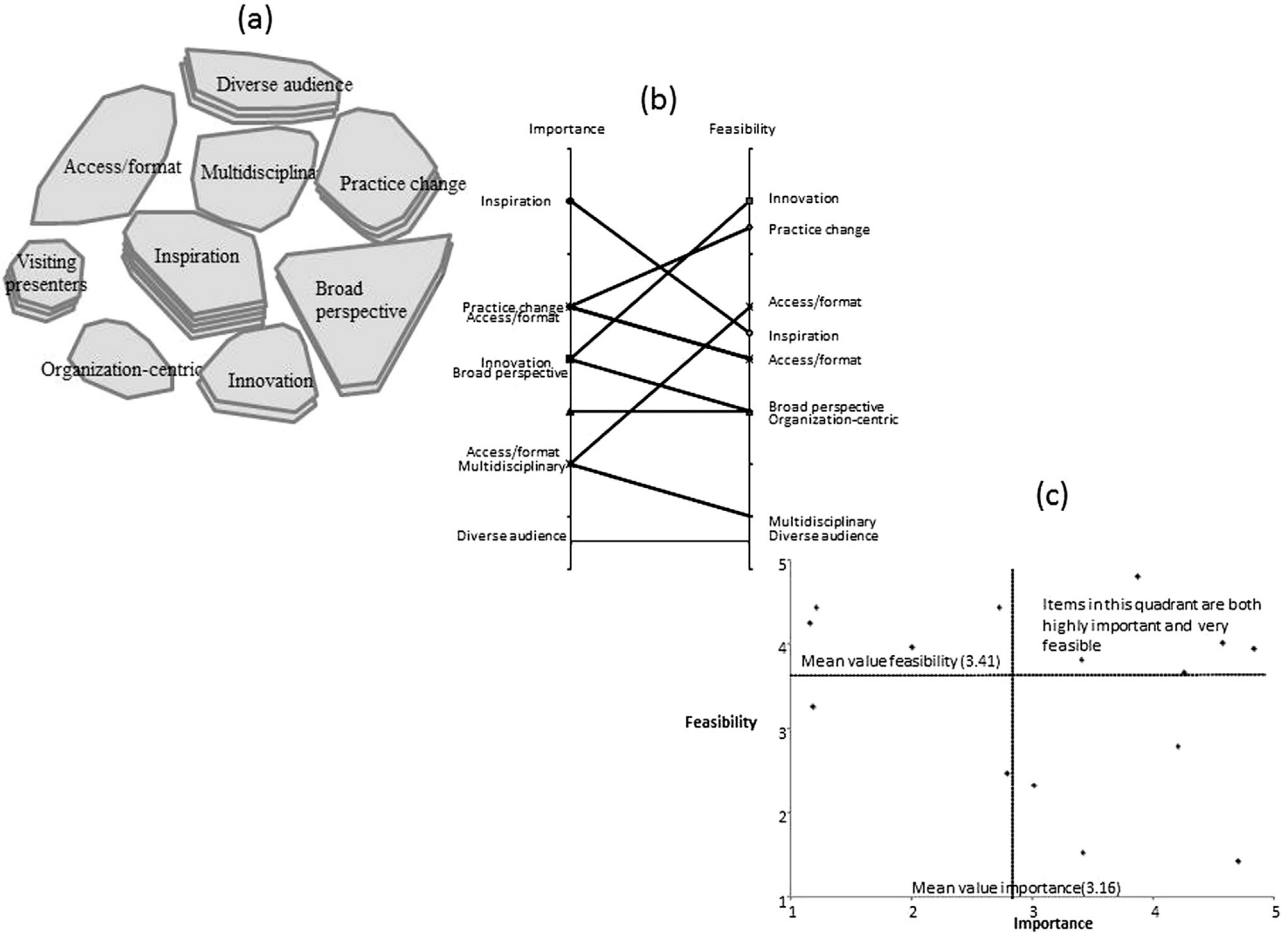

Fig. 1. Illustrating values with a concept map: (a) Illustrates a value such as importance as height on a map, (b) compares two values, importance and feasibility in this case, and (c) is a plot of importance and feasibility for the items within one cluster.

integrated into a logic model that was " . . . comprehensive and representative of the processes and outcomes involved in prevention research (p. 6)." Yampolskaya, Nesman, Hernandez, and Koch (2004) employed concept mapping to elicit stakeholder beliefs about program services and outcomes in a mental health setting; results from the map were used as input to a logic model to " . . . establish the linkages between the core elements of the program (i.e., target population, services, strategies, and expected outcomes) and to specify the theory of change (p. 194)." In other instances concept mapping has been used as an input for the creation of a logic model in order to establish causal linkages between program elements and form the basis for an evaluation plan for large initiatives in HIV/AIDS (Kagan, Kane, Quinlan, Rosas, & Trochim, 2009) and for evaluating transdisciplinary science (Stokols et al., 2003; Trochim, Marcus, Masse, Moser, & Weld, 2008). While not strictly a logic model, O'Campo, Burke, Peak, McDonnell, and Gielen (2005) used concept mapping results as input to subsequent work by community members to visualize their beliefs about the causal relationships between elements in the concept map and the issue of intimate partner violence in their community by creating path diagrams. In this issue, Hassmiller Lich, Urban, Frerichs, Dave (2017) illustrate the integration of system dynamics with concept mapping to create a program theory that incorporates nonlinearity, feedback loops and other dynamics of programs.

If a logic model needs to be inclusive of many and diverse viewpoints, then concept mapping may be a way to engage a large and wise crowd in creating the elements of the model (e.g., resources, activities, outcomes) so that the model represents the perspectives of many and diverse stakeholders. Likewise, extending a concept map through logic models offers the opportunity to enrich program theory by organizing the content of a map to illustrate the relationship between program resources, operations and outcomes. I hope that efforts to integrate concept mapping with logic models will increase as evaluators develop program theory that is reflective of many and diverse perspectives.

5. Speculating about future possibilities for soft science and hard art

> . . . the scientific side of concept mapping is viewed as "soft science" and the artistic one as "hard art" to imply that the process has some qualities of both, but probably does not fall exclusively within either's domain (Trochim, 1989a, p. 87).

5.1. The current state

The analysis and visualization of the data from concept maps has, for the most part, not changed much since 1989; multidimensional scaling in two dimensions and cluster analysis to partition the map with many items into a smaller number of concepts. When incorporating measures of value (e.g., importance, feasibility) into the map these data are averaged and can be displayed in several ways but typically in a way that shows the overall pattern of values or as Trochim (1989m) stated that the " . . . "pattern matching approach implies a different view of data . . . it treats relevant data about programs, measures, participants, or outcomes as patterns or as a whole rather than just as a collection of individual measures or observations (p. 358)." When there is a single stakeholder group and a single measure these data can be portrayed as height on a map, a z axis in which clusters that are higher are, for example, more important (Fig. 1a). Often there are multiple stakeholders groups and/or multiple measures and other ways to display the data are needed. When there are two groups or two measures, comparisons can be made among the clusters/concepts using what is sometimes referred to as a ladder graph, essentially two vertical number lines on which the cluster label is placed at the location of the average value for that cluster. Connecting the cluster locations on each number line then illustrates the pattern of values among concepts for two measures or two demographic groups (Fig. 1b). We've recently discovered that this type of graph has a long history that dates back to the late 1800s where it was originally termed a "parallel coordinates" graph, and that it is now at the leading edge of the field of data visualization (Inselberg, 2009) and bears a striking resemblance to ladder graphs. More recently Kane and Trochim (2007c) suggest the use of a bivariate plot of item level data which they termed a "go-zone plot" to examine the patter of item values within a cluster and highlight the items which are above average on both measures (Fig. 1c). When the measures are importance and feasibility, items that are above average on both of these measures are the likely first candidates on which actions should be taken. The increasing availability of software tools and especially the emergence of the open source software movement has the potential to explore opportunities to extend the analysis and visual display of concept maps.

5.2. Enhancing the analysis and display of a concept map

5.2.1. The open source revolution comes to concept mapping

R software is open source software which can be described as " . . . an integrated suite of software facilities for data manipulation, calculation and graphical display (https://www.r-project.org/about.html)." R is freely available and has quickly become a widely used tool for the analysis and display of data (Vance, 2009). R consists of multiple packages which " . . . come ready made with commands for statistical analysis and data visualization (Tippmann, 2015)." While there are commercially available statistical and graphical programs there is evidence that open source tools may be overtaking commercial products (Metz, 2015). At the time of this writing, 8039 packages were available in R (https://cran.r-project.org/web/packages/), each package can contain one or more statistical and/or graphing tools, so with over 8000 packages, there is an expansive number of options for the analysis and display of data; pertaining to concept mapping there are a number of options in R to explore with regard to the analysis of data and the display of data. R offers multiple algorithms for multidimensional scaling for analyzing sorting data such, the SMACOF package in R is an example (de Leeuw & Mair, 2009) and has been applied in several concept mapping projects (See, for example, Ewan, McLinden, Biro, DeJonckheere, & Vaughn, 2016; Vaughn & McLinden, 2016). Hierarchical analysis using Wards methods has been the mainstay approach for clustering items into concepts; R provides a variety of clustering algorithms and Orsi (2017) explores cluster analysis for concept mapping by assessing the impact of multiple different approaches to cluster analysis. Relative to the earlier point about parallel coordinate graphs, adding to that discovery, there are multiple programs in R that will produce these graphs including the parcoord in the MASS package (https://cran.r-project.org/web/packages/MASS) as well as variations in other packages based on data type. I predict that the use of R for the exploration of analytical and graphic enhancements will increase. I will also observe that R presents a barrier, using R requires an affinity for coding, something that is not required with large commercial statistical packages and special purpose programs that provide menu driven interfaces. However, it is possible to create packages that provide users with an interface such as Bar and Mentch (2017) illustrate.

5.2.2. A concept map is a network of ideas

Social network analysis (SNA) emerged in the latter part of the twentieth century as a method in sociology to analyze networks of people (See, for example, Wasserman & Faust, 1994). Essentially

the matrix that results from sorting could represent the proximity of people as in SNA or the proximity of ideas as in concept mapping. In both cases, the data represents a network and the quantitative methods and graphical methods in social network analysis are applicable. These approaches have been explored by Goldman and Kane (2014); McLinden (2013). These analyses can clarify features of a map that would otherwise not be known if relying solely on the standard approach to concept mapping, and like concept mapping, the quantitative aspects of network analysis can be visualized in a way that is intuitive and understandable by stakeholders. Fig. 2 illustrates several possibilities for additional analyses. This concept map was part of a project to develop a strategy for a continuing medical education program that was directed toward physicians in training and experienced physicians. Twenty two individuals sorted 90 ideas and multidimensional scaling and cluster analysis were applied to the data consistent with the common process for concept mapping; a nine cluster solution was chosen as the best representation. In addition to visualizing the points and clusters, network analysis allowed other features of the map to be quantified and visualized and Fig. 2 illustrates the results of two analyses. Lines connecting points (i.e., ideas) indicate which items were sorted with other items. In this case a cutoff of eleven was set meaning at least 50% of the sorters (n = 11) sorted the connected items together. With this cutoff one can see clusters which are isolated; these clusters contained ideas which participants sorted only or mostly with other ideas in the same cluster. Some items connect within and across multiple concepts indicating that these ideas were sorted in many ways such as with items in multiple different clusters and suggests that sorters had different perspectives on the meaning of these ideas. Calculating a measure known as centrality indicates the extent to which an item lies between other items, in this case "betweeness" centrality. The text for select items on the right side of Fig. 2 are items that had relatively high centrality values and these items can also be seen as connecting across multiple clusters. One interpretation is these items had a common theme of expressing a feature of program content but are in different clusters because there are nuances to the idea of program content. For example, item 73 was pertinent to multiple clusters. This idea was sorted with ideas in the cluster named "diverse audience" at the top of the map and this seems appropriate given the phrase in this idea, "cover a wide range of topics . . . " And this idea was also sorted with clusters below such as the cluster named "broad perspective" and on its face this seems appropriate. Adding visual elements from network analysis has the potential to increase understanding of the data and to enhance interpretation by stakeholders. Whether or not this potential will be realized is a matter of speculation, more projects will need to test and study these methods and overcome the barriers associated with understanding another methodology, the integration of one method (network analysis) with another method (concept mapping) and the software to support each. In spite of barriers the tools exist and the possibility exists to gain additional insights from the data collected for a concept map.

5.3. Visualizing the results

Multidimensional scaling is typically forced to two dimensions in creating a concept map, though MDS analysis can be accomplished with more than two dimensions. The advantage of more than two dimensions is that the loss of information is

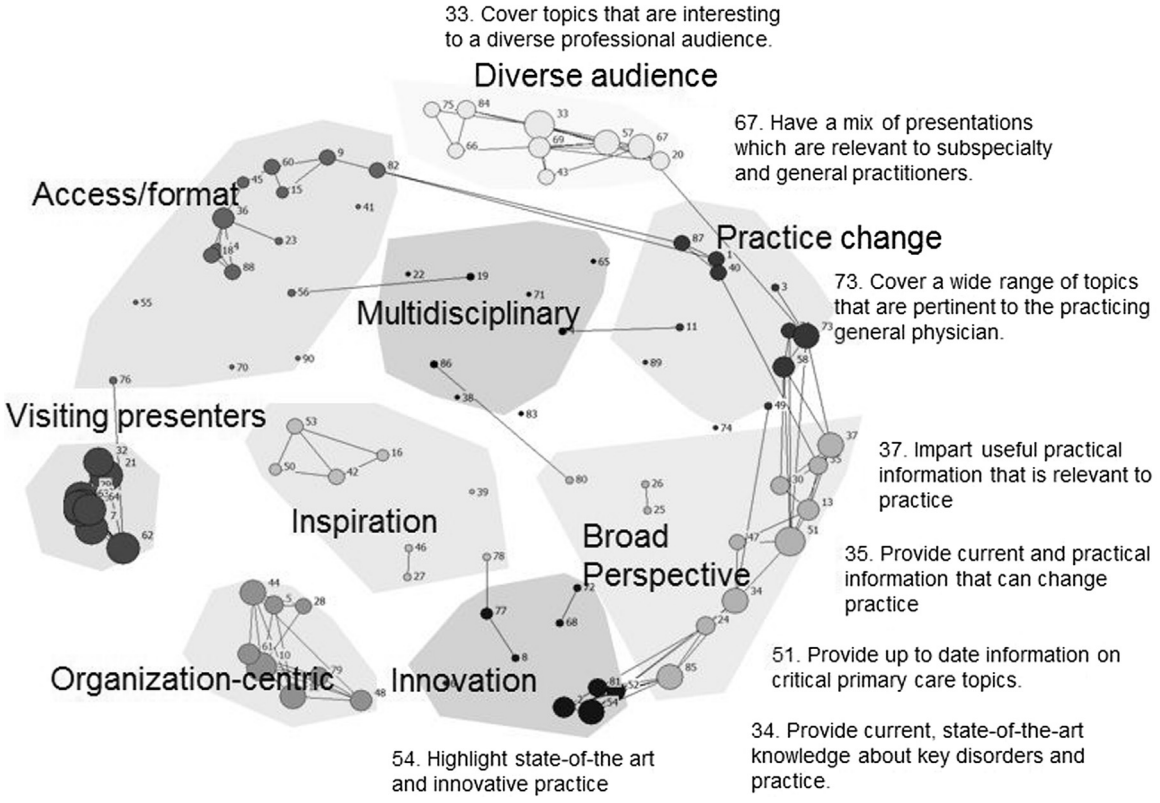

Fig. 2. This concept map shows two elements of network analysis. The lines connecting points illustrate the number of times the ideas represented by two connected points were sorted into the same group by a participant. In this map the criterion for showing a connection was set so that at least 50% of the respondents placed the respective ideas in the same group. Size of the points indicates "betweeness centrality" and corresponds to the extent to which a point is on a path between other points. When multiple connections or paths between points connect through a given point, the betweeness centrality for that point will be relatively large and is indicated by the size of the point. On the right side of the map is text from items with high betweeness centrality and which connect to items in other clusters.

reduced. The transformation of the NxN matrix of sorting data to 2×N matrix of coordinates results in the loss of information and this loss is indicated by the stress value from MDS. Adding dimensions can improve stress but adding dimensions makes visualization more difficult, more than three dimensions cannot be visualized in a single picture. Portraying a concept map in three dimensions is possible but, to my knowledge, has not been used much. In this issue Orsi (2017) suggests several avenues for additional research to illustrate a concept map in three dimensions and Soellner, Rudinger, and Lenartz (2017) present the results as a three dimensional concept map. Additionally, a version of multidimensional scaling known as SMACOF (de Leeuw & Mair, 2009) is available in R (R Core Team, 2015) and includes a variety of approaches for MDS including a version that creates a three dimensional sphere. To illustrate possibilities with three dimensions I created the concept map in Fig. 2 using smacofSym in R and the resulting stress value was 0.26 which is lower but not substantively different than the mean value of 0.28 reported in a summary of concept mapping studies (Rosas & Kane, 2012). Adding a third dimension and computing the map with smacofSphere lowered the stress value to 0.21 which is closer to the lower end of the range of stress values of 0.17 in concept mapping studies (Rosas & Kane, 2012). Unfortunately a 3D illustration is difficult to appreciate on a two-dimensional page and I invite readers to review this map http://dmclinden.github.io/to explore this map, access the code and form their own opinion (McLinden, 2016).

5.4. What's in the white space?

In many concept mapping studies the number of ideas generated in response to the focus prompt can exceed 100 and it is not unusual for studies to generate several hundred responses. One could imagine that if all of those statements were included in the sorting task then the map of the ideas would be quite dense and with less white space than is the case when the number of ideas to be sorted is kept to a more manageable number. Necessarily there is a tradeoff between inclusion of all the ideas and the inclusion of just enough ideas to represent all of the ideas and allow participants to complete the sorting without an excessive response burden. Necessarily some ideas are discarded and methods exist to accomplish this task (Kane & Trochim, 2007a). However, in many cases the process of statement reduction is not thoroughly described and it is not possible to judge the representativeness of the final statement set to the original statement set. Several studies more thoroughly report on the process of statement reduction, for example, Windsor (2013) describes a process using multiple coders and the process of coding and consensus to reduce 209 statements to 100 and in this issue (Hassmiller Lich et al., 2017) report on a method to assess the representativeness of the final statement set to the original, more numerous set of statements. I don't predict but advocate for more rigor in the selection of items when reducing many statements to a more manageable number for the sorting task.

6. Conclusions

Concept mapping methodology may have been ahead of its time as a method that resonates with trends in collaboration and peer production that have become prominent in the 21st century. This methodology has increasingly emerged as method engage a wise crowd to create idea networks to explore meaning and design solutions for complex issues and wicked problems. Throughout this paper I have suggested future directions that were based on recent work with concept mapping but a complete examination of where concept mapping is going is not possible. A literature search at the time of this writing shows that interesting and unique applications of concept mapping continue to emerge. The best I could hope to accomplish was to assert what I have noticed since I first became involved with concept mapping over 20 years ago. Another writer looking from a different perspective would, no doubt, see different trends emerging and see a different future. In spite of the variation that must exist, given the articles in the current issue and the gallery of projects published elsewhere in the literature, a safe summary prediction is that the methodology will continue to spread as users continue to apply it in familiar contexts, adapt the method to new situations, innovate to integrate concept mapping with other methods of inquiry and discover ways to improve the concept mapping method.

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