Taking Stock and Looking Ahead

Evolution of Accreditation Feedback for Simulation Centers Over 8 Years Using Epistemic Network Analysis

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Introduction: Since 2005, the American College of Surgeons Accredited Educational Institutes has provided accreditation of surgically focused simulation centers with the added benefit of identifying best practices defined as areas far exceeding the accreditation standards or novel methods of advancing high-quality, impactful education. This study aimed to examine the evolution of the best practices observed by accreditors during site visits over the 8-year period.
Methods: Accreditation included the completion of an application form followed by a site visit by a simulation expert and review of all materials by an accreditation committee to identify areas out of compliance along with areas far exceeding accreditation standards. These are termed "best practices." To evaluate the evolution of accreditation feedback and embedded associations, the compiled list of 337 best practices identified from all 247 site visits over an 8-year period was analyzed and visualized using epistemic network analysis, a quantitative ethnographic technique for modeling the structure of connections in qualitative data.
Results: The overall association network of the data indicates that the strongest associations were between assessment, curriculum development, faculty development, research, and teaching methods, demonstrating a highly interconnected model of accreditation feedback. Best practices evolved from an early focus on teaching methods, faculty, and curriculum development to more advanced educational topics including assessment, research, resources, and overall center governance. Distribution of associations also increased over the 8-year period with more nuanced and interconnected statements demonstrating higher-level feedback including explanations, contributing factors, impact on other areas, and, in some cases, recommendations to share best practices outside the organization.
Conclusions: The epistemic network analysis of this 8-year database of simulation center feedback provides a novel perspective on an organization and the evolving field of simulation from an optional to essential modality in healthcare professions education.
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Key Words: Accredited education institutes, ACS-AEIs, best practice, health professions education, surgical education, simulation.

Accreditation of simulation centers, modeled after traditional institution accreditation processes, involves the review of an application and supporting materials and a site visit by an experienced reviewer to assure the accuracy of reporting and compliance with accreditation standards. Since 2005, the American College of Surgeons[1] has established standards for how simulation-based surgical training should be offered at accredited education institutes to improve patient safety and promote the development of new techniques, technologies, research, and collaboration. The American College of Surgeons Accredited Education Institutes (ACS-AEI) provide simulation-based education to train practicing surgeons, surgical residents, medical students, and other members of the surgical team. As an added benefit of the accreditation process, the ACS-AEI Consortium added the identification of best practices defined as areas far exceeding the accreditation standards or novel methods of advancing high-quality, impactful education, both to recognize centers for their innovations and to share these practices and advance the field.[2] The organization began to compile all best practices from accreditation reviews in 2011 for dissemination to members of the ACS-AEI Consortium through journal articles, online videos, newsletters, and workshops at the Annual ACS Surgical Simulation Summit.[3] Essentially, the ACS-AEI provides a forum for its members to share and learn from innovative approaches to common problems in simulation-based surgical training, ranging from curriculum development and evaluation to management and governance models and scholarly activities that can advance the field of simulation-based education.

In addition to sharing innovative approaches to common problems in simulation, the compiled list of 337 best practices from 247 site visits over 8 years provides a rich source of data to understand not only the evolution of the field over a decade but also the evolution of the accreditation process and organizational perspectives over that same period.

By constructing a repertoire of best practices and the connections among them, this article aims to provide evidence about the evolution of best practices that guide how simulation-based surgical training can be most effectively offered. Best practices included observations on a wide variety of subjects from

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curriculum design processes and instructor development to more organizational topics, including the quality of equipment and facilities and overall center governance. We argue that it is important not only to understand how the implementation of individual best practices has changed over time but to explore the associations among those practices—that is, to explore how various sites implemented multiple best practices at different points in time to achieve larger goals. Understanding the evolution of individual best practices in isolation is thus less useful than understanding how sites integrated them to improve simulation center services.

To explore associations among best practices, the authors used epistemic network analysis (ENA), which models and visualizes structures of associations among key themes in data. Despite being a relatively new methodology, ENA is increasingly used in the fields of medicine and health sciences education. For example, ENA has been used to analyze (a) surgery trainees' operative performance during a simulated procedure[4,5]; (b) care transitions of adult and pediatric trauma patients from the operating room to the intensive care unit[6]; and (c) communication among healthcare teams[7,8]; and (d) how surgeons learn operative procedures using simulation. Epistemic network analysis is most commonly used to investigate thematic associations in verbal and nonverbal datasets of individual care providers or teams[4,5,7,9] or task allocation among care teams,[6] but in this case, we use the technique to better understand how an organization communicates with its members through the analysis of compiled accreditation data.

Critically, ENA enables comparison of association structures both visually and via summary statistics that reflect the structure of connections among themes. This makes it possible to identify significant differences among groups of units and explain those differences in terms of the associations between themes. While there are many multivariate techniques that model interactions among variables, the number of interactions rises exponentially in relation to the number of elements, such that even models with a moderate number of interacting elements require very large amounts of data, and most do not produce visualizations that facilitate interpretation of the underlying model. Epistemic network analysis is thus well suited for exploratory analysis of associations among best practices observed by accreditors during site visits over the 8-year period. By modeling the relationships between best practices across 247 site visits as they occur within the accreditation reviews, we can better understand how the ACS-AEI organization is communicating with its members and how implementation of best practices is changing over time. Although an 8-year database of simulation center feedback is a rich source of data for sharing individual innovations, the authors wanted to explore the content and associations of best practices to understand the evolution of the field, of the accreditation process, and of organizational perspectives over the last decade.

In line with the aims of this study, the following 2 research questions were posed:

1) What is the scope of the best practice feedback provided to surgically focused simulation centers by the accreditation organization over the 8-year period?
2) How do associations among best practices observed by accreditors during site visits change over the 8-year period?

METHODS

Data Coding

Each of the 337 best practices identified during 247 accreditation reviews between December 2011 and June 2019 were coded by simulation content experts (A.R.R., J.M.C.) under 1 or more of the 9 themes, including (a) approaches to the development of curricula, (b) evaluation of curricula, (c) educational methodology, (d) faculty development, (e) scholarly activity, (f) use of resources, (g) assessment of learners, (h) collaboration between centers, and (i) governance processes. Identification and classification of these themes are based on prior qualitative analyses described in detail elsewhere.[2,3] The authors then confirmed all coded themes, and coding or thematic discrepancies were discussed, reaching agreement through consensus between 2 of the authors. Raw text for each best practice along with the center name, date of accreditation review, and coded themes were then uploaded to the ENA program. Analysis of data based on research questions was conducted, and overall networks were compared to generate additional hypotheses and analyses.

For example, a best practice that stated, "Best practice for very standardized method for development of simulation-based curricula" (McGill Medical Simulation Centre, December 2012) would only be coded under curriculum development. A more nuanced best practice, such as, "Best practice for the robust curriculum development model, which includes an outstanding template and faculty support from curriculum design and simulation experts" (STRATUS Center, December 2015), includes detailed information about why this process should be considered a curriculum development best practice and includes links to other thematic areas including the use of a standardized process and expert consultation, linking it also to faculty or instructor development. The study was approved by the university's institutional review board as exempt (HUM00202526) as this fell under policies for research using publicly available data sets and research on organizations.

Analysis

In this study, we applied ENA[10–12] to our data using the ENA web tool version 1.7.0.[13] Epistemic network analysis is a quantitative ethnographic technique for modeling the structure of connections in qualitative data. Epistemic network analysis assumes: (1) that it is possible to systematically identify a set of meaningful features in the data (codes) and (2) that an important feature of the data is the way that codes are connected to one another within conversations.[10–12] Epistemic network analysis models the connections between codes by quantifying the co-occurrence of codes within conversations (or any other relational context), producing a weighted network of co-occurrences, along with associated visualizations for each unit of analysis in the data. Critically, ENA analyzes all of the networks simultaneously, resulting in a set of networks that can be compared both visually and statistically.

We defined the units of analysis as all lines of data associated with best practices subsetted by period of site accreditation and simulation center. We used a "whole conversation" model as conversations are single lines of data consisting of best practice observations for each period and center. The ENA algorithm constructs a network model for each unit of

analysis, showing how the codes in all lines associated with that unit in each conversation are connected to one another. The resulting networks are aggregated for all conversations for each unit of analysis. In this model, we aggregated networks using a binary summation in which the networks for a given conversation reflect the presence or absence of the co-occurrence of each pair of codes.

Our ENA model included the following nine codes: CurriculumDev, CurriculumEval, TeachMethod, FacultyDev, Research, Resources, Assessment, Collaboration, and Governance (see Table 1 for codes, definitions, and examples of best practices). These codes were selected because they were the most common themes defined through prior qualitative analysis of this data set.[3]

The ENA model normalized the networks for all units of analysis before they were subjected to a dimensional reduction, which accounts for the fact that different units of analysis may have different amounts of coded lines in the data. Because we were interested in all 3 pairwise comparisons between the three 2.5- to 3-year periods, for the dimensional reduction, we used a means rotation based on each cycle in our data 2011–2013 (reviews starting July 2011 through December 2013), 2014–2016 (3 years inclusive), and 2017–2019 (reviews from January 2017 through June 2019). These projections highlight the differences between these periods by constructing a dimensional reduction that places the means of the cycle as close as possible to the x-axis of the projected space. Subsequent dimensions were projected using singular value decomposition, which produces orthogonal dimensions that maximize the variance explained by each dimension (see the study by Shaffer et al[11] for a more detailed explanation of the mathematics; see the studies by Arastoopour Irgens et al[14] and Sullivan et al[7] for examples of this kind of analysis).

Networks were visualized using network graphs where nodes correspond to the codes, and lines connecting the nodes reflect the relative frequency of co-occurrence, or connection, between 2 codes. Node size indicates frequency of occurrence of the code and thickness of edges shows the strength of the relationship. The result is 2 coordinated representations for each unit of analysis: (1) a plotted point, which represents the location of that unit's network in the low-dimensional projected space, and (2) a weighted network graph. The positions of the network graph nodes are fixed, and those positions are determined by an optimization routine that minimizes the difference between the plotted points and their corresponding network centroids. Because of this coregistration of network graphs and projected space, the positions of the network graph nodes—and the connections they define—can be used to interpret the dimensions of the projected space and explain the positions of plotted points in the space.

Epistemic network analysis can be used to compare units of analysis in terms of their plotted point positions, individual networks, mean plotted point positions, and mean networks, which average the connection weights across individual networks. Networks may also be compared using network difference graphs. These graphs are calculated by subtracting the weight of each connection in one network from the corresponding connections in another.

RESULTS

Data from all 337 best practices over the 8-year period was compiled into a single network analysis for an overall comparison of associations (Fig. 1), which demonstrated the strongest associations between assessment, curriculum development, faculty development, research, and teaching methods. There were also detectable associations between all content areas, demonstrating the very interrelated nature of simulation-based education. Modest associations were most commonly seen involving curriculum evaluation, which persisted throughout the 8-year period.

Figure 2 shows the mean plotted point position for the ENA networks for the best practices of all centers in 2011–2013 (A), 2014–2016 (B), and 2017–2019 (C). Associations between these 3 periods showed statistically significant changes in mean overall associations with both a change in mean content and diversity of connections in best practices in the 2011–13 period from the 2014–2016 and 2017–2019 periods.

A nonparametric Mann-Whitney U test showed that 2011–2013 (Mdn = 0.17, n = 45) was statistically significantly different at the $\alpha = 0.05$ level from 2014 to 2016 (Mdn = 0.17, n = 63, $U = 1706.00$, $P = 0.07$, $r = -0.20$). Specific associations in each of the periods demonstrate this evolution with the strongest associations between faculty development and curriculum development as well as faculty development and collaboration and faculty development and teaching methods in the 2011–13 period. During the 2011–2013 period, there were also very few associations involving research, curriculum evaluation, governance, and resources (Fig. 2A). In 2014–2016, the top 3 associations seen in the previous period persisted, respectively, but increased associations between curriculum development and teaching methods as well as teaching methods and resources (Fig. 2B). All associations including assessment, resources, and governance also increased.

The significant difference remained for the next period, 2017–2019. Namely, a Mann-Whitney U test showed that 2011–2013 (Mdn = −0.18, n = 45) was statistically significantly different at the $\alpha = 0.05$ level from 2017 to 2019 (Mdn = 0.02, n = 52, $U = 779.00$, $P = 0.00$, $r = 0.33$). In the 2017–19 period, strongest associations were seen between faculty development and teaching methods and teaching methods and assessment with all associations surrounding teaching methods and assessment and continued increases surrounding research and governance (Fig. 2C).

DISCUSSION

This study analyzed the best practice feedback provided to surgically focused simulation centers by the accreditation organization, taking into consideration changes to these practices and associations among them over this period. Our analysis uncovered the dynamic complexity, nuance, and richness of the best practice feedback that guide how simulation-based surgical training can be most effectively offered and promote the establishment of processes likely to be associated with improved quality in simulation-based education.

To date, literature reviews and qualitative or comparative analysis of accreditation data or applications have been used to compare postgraduate program accreditation processes of different countries,[15] but this article examines the direct communications from an accrediting body to its individual members

TABLE 1. Codes, Definitions, and Examples of Best Practices

Code Name	Code Definition	Examples of Best Practices
Governance	Governance, leadership, and transparent, inclusive, and standardized operational and financial decision-making processes	–Best practice for creating a local network under the leadership of one individual with a common goal of providing simulation-based training in all its forms. –The breadth and sophistication of the research activities at the institute is the result of effective leadership. Research priorities are well aligned with the needs of the military. –The manner in which industry support has been developed and integrated into the CFS deserves special mention. There are no exclusive agreements with respect to equipment grants and all direct monetary funding is via unrestricted educational grants.
CurriculumEval	Ongoing process of collecting, analyzing, and interpreting qualitative and quantitate data to assess trainee learning and program effectiveness in each domain.	–Best practice for utilizing institutional developed standardized scenario template to evaluate curricula. Also uses a comprehensive evaluation summary report form with in-depth evaluation summary. –The robust process for the ongoing 360-degree evaluation of the educational offerings is a best practice. Learner feedback has frequently resulted in changes in curriculum or faculty. –The assessment of the effectiveness of education is based not only on the types of assessment used but also on the yearly collective assessment evaluation done by staff.
TeachMethod	Educational modalities and approaches used in medical and surgical training programs.	–Best practice for developing cutting-edge technology, eg, the liver app and surgical app for iPads as educational support. –Best practice for debriefing the debriefers. There is a program by which the debriefings are videotaped, and the education specialist then reviews the debriefing to see where it might be enhanced. –Extensive development (and/or) adoption of numerous curricula, especially for trauma care in preparation for deployment.
FacultyDev	Programs of faculty and/or instructors for curriculum development and simulation-based education echniques	–Best practice for the individualized simulation faculty education program, which identifies interested novice faculty and pares them with appropriate mentors. –Faculty is expected to follow a prescribed regimen to obtain certification as a simulation instructor. –The AEI has designed specific classes to introduce faculty to the essential components of simulation education.
Research	Research productivity, including regular dissemination of scholarly work, in-house development of simulator or training devices, and securing grant funding	–Best practice for a well-developed research and development program with several research grants and development contracts, and multiple publications and presentations. –The AEI is very active in educational research and has $15 million in grant funding. Multiple research projects have resulted in publications and many more are in process. –Best practice for innovation in developing inexpensive training models and simulators for a variety of curricula.
Resources	Access to resources necessary to deliver high-quality, simulation-based educational events, including space, staffing, equipment, and leadership support	–A substantial investment has been made to staff the AEI with trained educators. –Best practice for ingenious use of space, particularly in terms of manikin storage. Rooms are well laid out and engineered to maximize efficient delivery of curriculum in a seamless fashion. –Faculty compensation includes a variable nonclinical educational component and an incentive that serves as an effective means of getting faculty to participate.
Assessment	The use of simulation for standardized, objective, and repeated assessment of the learner with video review, debriefing, and the use of validated tools for both technical and nontechnical skills	–The institute has also begun targeted use of an electronic version of the OSAD tool to assist with faculty development and assessment of after-action debriefing. –Best practice for use of their smart phone app for the training and evaluation of psychomotor skills through self-created videos. –The institute is a world leader in the use of simulation to teach and assess nontechnical and teamwork skills.
Collaboration	Collaboration with national organizations, peer institutions, malpractice carriers, and industry	–Best practice for monthly interactive teleconferences with a large university that consults the institute on content delivery, faculty training, etc. –The AEI has been involved in multiple collaborative projects with other members of the consortium and has been equally involved with other simulation accrediting bodies. –As part of a multicenter study, the institute implemented a pediatric traumatic brain injury scenario that was both interdisciplinary and interprofessional.
CurriculumDev	A standardized process of curriculum development and review including the use of curricular templates and committee review and/or consultation with an educational or simulation expert	–Best practice for exemplary use of the institute to train surgical residents and incorporation of team training principles using the SCORE curriculum. –Best practices for involving an educational specialist in the curriculum development process; for their 2-d simulation instructor program; for their longitudinal faculty development program and train the trainer courses. –The institute has a very strong training program with multiple master TeamSTEPPS trainers and also is 1 of 5 areas in the United States that train master trainers on an AHRQ grant.

AHRQ, The Agency for Healthcare Research and Quality; OSAD, Objective Structured Assessment of Debriefing; SCORE, Surgical Council on Resident Education.

over almost a decade, providing deeper insights into the perspectives of the organization and its observations of its member centers. The ENA analysis provided key insight into the focus areas of the ACS-AEI accreditation process and the evolution of best practices feedback from relatively simple feedback relating to a single criterion to more complex and nuanced feedback often correlating governance processes, policies, procedures, and the involvement of educational experts with better curriculum,

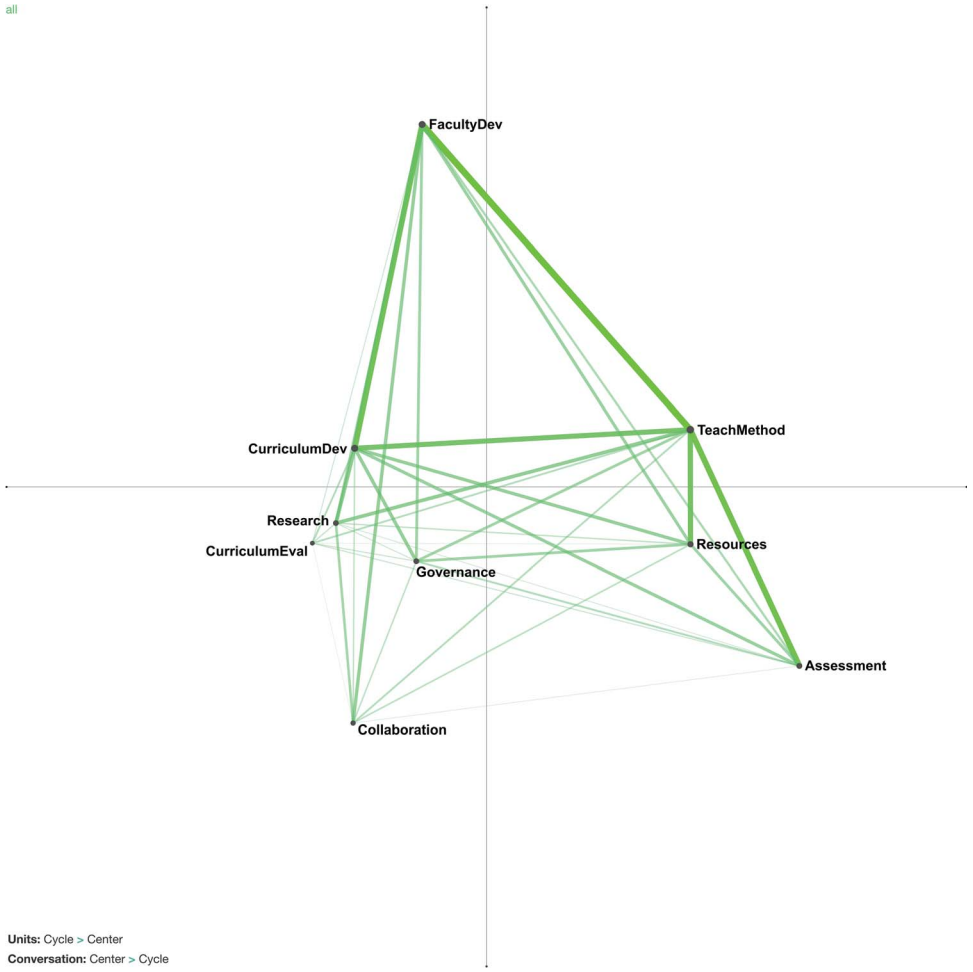

FIGURE 1. Epistemic network analysis for an overall comparison of associations between CurriculumDev, CurriculumEval, TeachMethod, FacultyDev, Research, Resources, Assessment, Collaboration, and Governance throughout the 8-year period.

assessment, and continuous educational improvement. These observations not only demonstrated higher-level feedback but also demonstrated a maturation of simulation centers over this period and how thinking about simulation-based education is evolving within an organization.

Changes in best practice associations demonstrate significant evolution both in terms of the content of associations and the variety and complexity of associations during this 8-year period. The increase in breadth, complexity, and variety of best practice feedback shows a consistent shift in the focus areas of best practices from an early focus on faculty and curriculum development to higher level or more advanced educational topics including assessment, teaching methods, research, and overall center governance. The focus shifted from more tactical issues or behaviors observed to more strategic observations connecting multiple inputs to improved educational outcomes. The increase and variety of associations also clearly demonstrate an increase in the complexity of the feedback, with more nuanced and interconnected statements demonstrating higher-level feedback, including explanations, contributing factors, impact on other areas, and, in some cases, recommendations to share best practices outside the organization. For instance, a site reviewer noted that a curriculum development process needed improvement, making positive changes to the instructor development process, governance, utilization of expert consultants, and providing additional resources may be required to impact long-term success. These changes could be attributed to the evolution of more simplistic affirmation of performance in a single area (ie, excellent curriculum development process) to a more nuanced explanation of the contributors or impacts of a specific area of excellence (ie, standardized, well-documented processes, and routine use of expert consultations in the development of robust curricula).

The study findings offer a systems perspective that helps visualize the system and track the progress of improvements over time. Simulation centers can be more effective in their mission by considering the focus areas systematically rather than in isolation. Conversely, if a reviewer observes a potential deficiency or area at risk, this type of analysis may inform other focus areas for the review. For instance, if an aging facility infrastructure is observed, providing interconnected feedback on resources, organizational structure, and governance may provide centers with the critical information needed to impact sustainable change. A systematic and interconnected approach may provide a deeper level of feedback to help impact change. As this database of best practices grows, the associations and

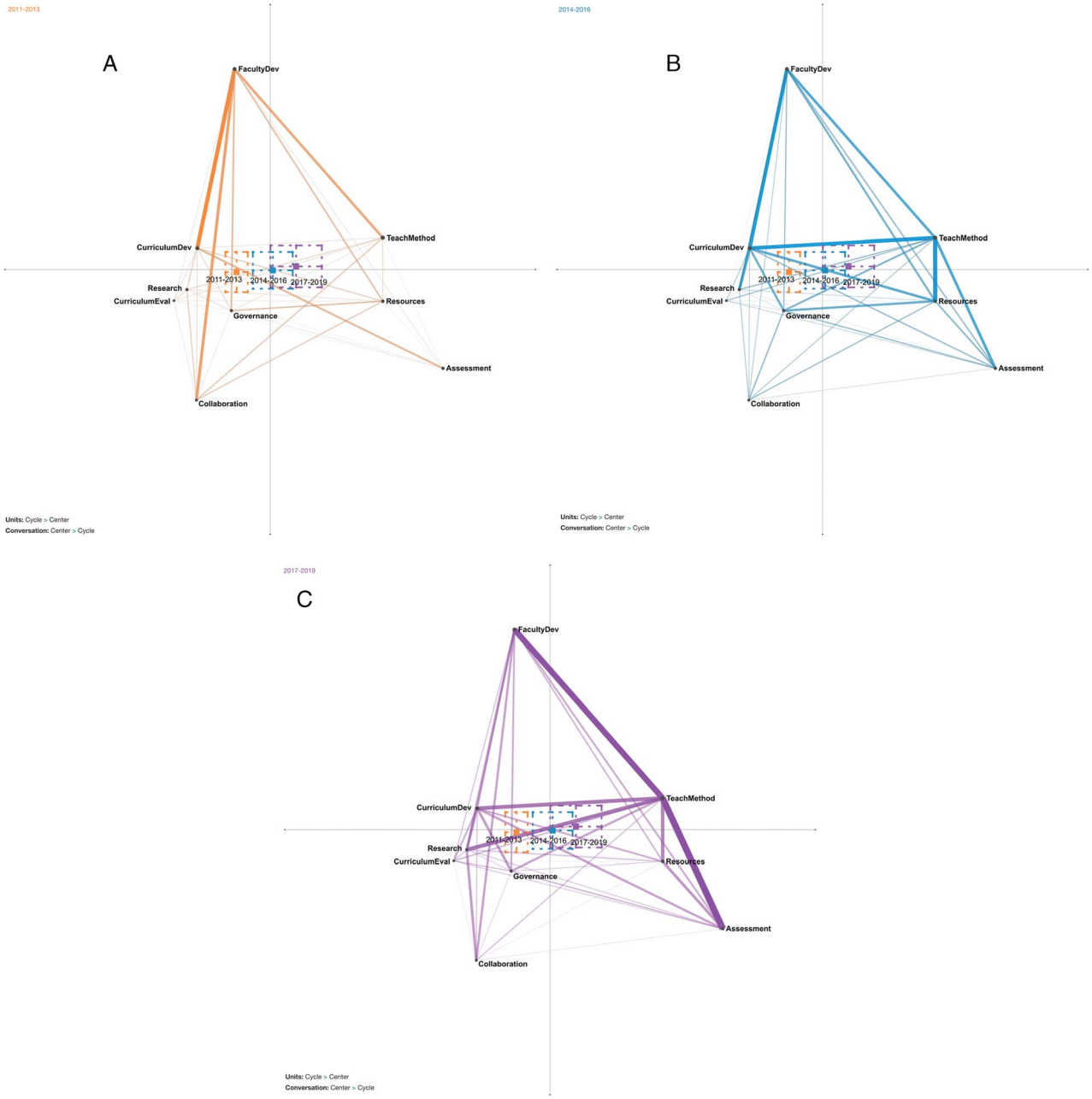

FIGURE 2. Epistemic network analysis models showing the mean network locations (colored squares) and 95% confidence intervals (dashed boxes) for three time periods: (A) 2011–2013, (B) 2014–2016, and (C) 2017–2019 along with their respective mean network graphs.

factors influencing success may become clearer and may provide center leadership a more comprehensive pathway for improving the system to support change.

Beyond how information is communicated, the content or priorities, perspective, and strategic goals of the organization may also influence the content and style of communications. For instance, a national focus among educational organizations on open governance practices may influence site reviewers and/or accreditation committee members to include this perspective in the development and communication of accreditation best practices. This perspective may influence or lead to bias in reporting or communications with an increase in related associations (ie, excellent curriculum development process with consultation from a committee including representatives from each stakeholder group). Despite this potential risk, there was no single content area or association that predominated. The content and number of associations increased over the study period.

It could also be hypothesized that some of the evolution in best practices could be attributed to the fact that many of the centers completed up to 3 accreditation visits during this period, which might encourage more complex or nuanced feedback; however, a comparison of compiled first compared with second and third accreditation best practices did not show a significant difference in mean association content; however, standard deviation did increase in these comparisons, which might reflect a wider variety of associations, but there were also fewer second and third accreditation reviews as new centers joined the consortium throughout the 8-year period.

It is also important to acknowledge that as with any organization-based review relying on reported data, confirmation

by site surveyors and evaluation by a committee, that there is potential for bias, subjectivity, or other limitations. The best practices data used for this analysis are based on a haphazard sample that is not equivalent to rigorous methods of sampling. However, this analysis provides insights into the process of simulation center accreditation as it is currently conducted and will likely continue to be conducted in the future. In addition to providing insights about the field of simulation in healthcare professions training, this analysis also provides an "evaluation of the evaluators" as well as observations about the process and observed priorities over this period, which can also inform the subjectivity of the accreditation process going forward.

CONCLUSIONS

Much like individual learner assessment, compiled longitudinal assessments can sometimes say as much about the assessors as it does the learners in terms of both written and unwritten goals, competing perspectives, and organizational priorities. This 8-year database of simulation center feedback provides a novel perspective on an organization and the nascent field of simulation that evolved from an optional to essential modality as well as relatively new centers evolved from small, cutting-edge programs to more established and integrated operations.

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