Original Research

Determining the University's Position in a Multi-stakeholder Collaborative Network

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Abstract

Complex problems are being approached through collaborations that cross sectors including businesses, nonprofits, public institutions, and academia. Social Network Analysis (SNA) methods have been adopted to help manage these large collaborations, and it is useful not only for exploring the network dynamics of the collaboration as a whole, but also for exploring where an individual organization lies within the network. Universities can benefit from understanding their position and ties within a network and utilize that information to strengthen their position within these collaborations while fostering collaborations within the network. This study applied SNA to determine the influential position of an urban university within a multi-stakeholder collaborative network (MSCN). The university in this study holds more formal intra-sector relationships and more informal inter-sector relationships with the organization types in the MSCN. The findings also show that the university does hold a prominent position within the informal network of the MSCN; however, it does not hold a position of prominence within the formal network of the MSCN. Fostering these formal and informal relationships would allow the university to strategically promote beneficial collaborations for the university and the network as a whole.

Keywords: collaboration management, cross-sector collaborations, social network analysis, social capital

Introduction

Collaborations among stakeholders from private, nonprofit, and public sectors that focus on addressing complex problems through the innovative combination of their knowledge and resources have become increasingly popular (Becker & Smith, 2018). These collaborations have been referred to as multi-stakeholder collaborative networks (MSCNs), and within MSCNs, universities are a key element because they produce human capital and contribute to innovation production through the development of new knowledge (Etzkowitz et al., 2000). Universities have also been shown to develop innovation networks within their communities (Benneworth & Hospers, 2007). One increasingly complex issue that requires the development of innovation networks to target is the Science, Technology, Engineering, and Mathematics (STEM) workforce shortage. Developing local and regional STEM Learning Ecosystems has been identified as one of the solutions. STEM Learning Ecosystems are localized MSCNs that are "dynamic collaborations among school, out-of-school time programs, STEM expert institutions (such as museums, science centers, institutions of higher education, and STEM professional associations), the private sector, community-based organizations, youth and families" (STEM Ecosystems, 2018). STEM Learning Ecosystems aim to provide the structure through which high-quality and cross-sector learning is available to all learners, resulting in the development of important skills and engagement within STEM disciplines necessary to develop and nourish the STEM workforce (STEM Ecosystems, 2018).

There are currently 84 STEM Learning Ecosystems that comprise the global STEM Ecosystems Community of Practice, including the Omaha STEM Ecosystem (OSE), which serves the Omaha, NE metropolitan area. The member organizations of the OSE comprise a variety of stakeholder groups including multinational companies, educational institutions, non-profit organizations, and science centers and museums. Within the OSE, the University of Nebraska at Omaha (UNO) has taken a large leadership role as one of the two founding institutions, as well as maintaining a strong presence on the OSE Founders board and the OSE Steering Committee. One of the guiding principles of the OSE is to:

> Sustain an overarching structure to bring community partners together to advance STEM learning as a priority in Omaha. We welcome diverse partners and experiment with innovative ways for engagement. By creating a network of community organizations, we provide a venue for collaboration around solutions to STEM issues and leveraging of resources (OSE Steering Committee, 2017).

This guiding principle clearly outlines the intention of the OSE to develop and foster an innovative and capacity building network to address the STEM workforce shortage in the Omaha metropolitan area. UNO's intense involvement in the OSE provides ample opportunity for it to help manage this collaborative network and its own network position. In order to do this, UNO

must evaluate the overall network structure in order to understand the existing ties of the overall network, as well as UNO-specific ties, in order to improve network innovation. With this knowledge, UNO can help the OSE focus efforts in order to maintain current ties while also facilitating the development of new ones.

In order to focus the efforts of a MSCN, such as the OSE, the network itself must be evaluated, which may be done through Social Network Analysis (SNA) in order to improve collaboration management. SNA is the methodology utilized to examine formal and informal relationships by investigating relational concepts, processes, and patterns within a social network. A social network is multi-faceted and may be described as a business, university, school, neighborhood, organization, or even a family. The participants in these networks are known as actors, and it is their interactions and relationships, known as ties, that are examined within SNA studies (Borgatti & Ofem, 2010; Kenis & Oerlemans, 2007; Wasserman & Faust, 1994).

The purpose of this article is to present a method employed by UNO and the OSE, which evaluates the development of its network by examining the presence and absence of ties, individual actor positions, and whole network metrics. SNA has been used by the OSE to evaluate its network and make strategic plans based on the data.

Social Network Analysis, Social Capital, and Innovation

As previously mentioned, MSCNs, such as the OSE, depend on the relationships present amongst the members, and many collaborations are recognizing the importance to analyze these relationships using SNA for management purposes. Social Capital (SC) has been identified as a popular theory used within SNA studies to help when managing innovation in collaborations. SC is often referred to as the actual and potential resources within a network because of the relationships present (Nahapiet & Ghoshal, 1998). Various dimensions of SC can be targeted; however, this study focuses on relational SC and structural SC. Relational SC refers to the underlying nature of the ties that are present amongst the actors within a network and is measured through network density, which represents the number of ties present as compared to the number of ties possible. Relational SC results from a history of interactions and has been shown to result in trust and the development of norms in cross-sector alliances, which aids in the flow of knowledge and willingness to collaborate on innovations (Vlaisavljevic, Cabello-Medina, & Pérez-Luño, 2016; Zach & Hill, 2017). The majority of research dedicated to the role of relational SC with regards to innovation has focused on analysis and development efforts within the pharmaceutical and technology sectors; researchers have found no existing scholarship that focuses on the relational SC of MSCNs, such as STEM learning ecosystems.

Due to the diverse nature of stakeholders within a MSCN, it is expected that certain organization types will bring varying degrees of relational SC with one another due to previous

collaborations, and typically, organizations within the same sectors seem to have existing ties (Reding, Sigmon, Jafri, Smith-Walker, Meyer, 2017). This clustering of relationships within sectors may also be due to a network phenomenon known as homophily, where actors tend to have ties with others that share certain commonalities such as attitudes, experiences, and education (McPherson, Smith-Lovin, Cook, 2001). Homophily has been shown to facilitate relationships through ease of communication because of these commonalities (McPherson, et al., 2001). Networks that are examined through a relational SC lens will result in varying degrees of ties because of the intent of the surveys. This study investigated formal and informal networks, since survey questions aimed to determine the nature of the existing relationships present in the OSE. The informal network represents the ties that were present in the network based on non-prescriptive and non-professional ties. Informal networks highlight the presence of loose ties. Further, informal ties can be used as the basis of developing and promoting new collaborations (The Connected Company, n.d.).

The formal network in this study represents the ties that were present in the network based on a history of collaboration. The identification and examination of these formal networks is important because they have been shown to increase the probability of future collaborations and innovation (Zach & Hill, 2017). Based on the information thus far, we present our first hypotheses:

H1. Within the informal network, the relational SC of 4+ year organizations (UNO) will be lower for intra-sector ties rather than inter-sector ties through the demonstration of network density.

H2. Within the formal network, the relational SC of 4+ year organizations (UNO) will be greater for inter-sector ties rather than intra-sector ties through the demonstration of network density.

While relational SC has been shown to increase the probability of future collaborations and innovation, one study has shown that the structural SC of an actor is a better measure of whether they will be involved in future collaborations (Zach & Hill, 2017). The importance of the structural SC in predicting and managing collaboration necessitates its inclusion in this study. Structural SC refers to how the patterns of ties determine the amount of SC present, not only to individual actors within the network, but to the network as a whole. Metrics within structural SC studies involve examining the positional centrality of the actors within the network. While there are numerous types of centrality metrics, two of the most common are degree and betweenness. Degree centrality is a measure of the number of ties an actor possesses as compared to the number of ties possible within the boundaries of the network. A high degree centrality indicates actors that have an increased awareness of others' knowledge, which allows for easier knowledge transfer (Brandon & Hollingshead, 2004; Nahapiet & Ghoshal, 1998). These

members are often called hubs and increase the scale of adoption of new innovations by passing on new knowledge to many actors (Goldenberg, et al., 2009; Rogers, 2010).

The other centrality metric, betweenness, looks at how often an actor acts as a link between two otherwise unconnected actors within the boundaries of the network. High betweenness indicates an actor that is able to moderate the flow of knowledge, has access to relatively new knowledge, is positively correlated with innovation, and increases the rate of innovations (Liu, Sidhu, Beacom, & Valente, 2017; Rogers, 2010; Shaw-Ching, Madhavan & Sudharshan, 2005). These actors are known as bridges or gatekeepers. It has been suggested that there are actors within networks that can hold positions of both hubs (high degree centrality) and gatekeepers (high betweenness centrality) (Guimarães et al., 2013). A previous study used a new methodology involving the determination of actors who act as both hubs and gatekeepers to determine emergent teacher leaders within a computer science education cohort (Reding, Dorn, Grandgenett, Siy, Youn, Zhu, & Engelmann, 2016). This current study adapted that methodology to determine which organization types within the OSE act as both gatekeepers and hubs by calculating a combined centrality score.

Historical network data used by the OSE shows that, on average, the organization types in the Academic stakeholder category tend to have lower numbers of loose ties than the organization types in the other categories. The same data show that, on average, the organization types in the Academic stakeholder category tend to have higher numbers of formal ties than the organization types in the other categories (Reding, et al., 2017). Through the possession of these different types of ties, the centrality scores of each organization type, including the 4+ year organization type (UNO), will be different in the different networks (i.e., formal and informal).
This brings us to our final hypotheses:

H3. Within the informal network, the 4+ year organization type (UNO) will possess a relatively low structural SC through the demonstration of one of the lowest combined centrality scores.

H4. Within the formal network, the 4+ year organization type (UNO) will possess a relatively high structural SC through the demonstration of one of the highest combined centrality scores.

Methodology

The purpose of this study was to develop a methodology to determine the position of an urban university within a MSCN. A document analysis of a digital survey administered via emailing an OSE listserv was utilized. SNA methods were used in this study. Eighty-six individuals who elected to complete the online survey comprise the population of this study. The respondents were asked to report the level of interaction they had experienced with members of various organization types within the OSE.

Data Collection

The first step in the data collection process was to assign an identification number to each respondent. The next step was to codify the various categorical factors of organization type, stakeholder category, asset type, and interaction level. Each organization received a nominal value and the possible organization types the respondents could select included 2 Year College, 4+ Year College, Business with less than 50 employees, Business with 51-200 employees, Business with more than 200 employees, Career or Technical Training, Charitable Foundation, Civic Organization, Faith Based Organization, Parent/Neighborhood Organization, Private P-12 Education, Public P-12 Education, Science Centers and/or Museums and Libraries, Youth Serving Organizations, Military, Government, and Other. Next, a nominal identifier based on the three stakeholder categories of Academic, Business, or Nonprofit was assigned. The nominal values and identifiers (ID) for the organization type can be found in Table 1.

TABLE 1. Nominal ID and abbreviation by organization type

Organization Type	Abbreviation	Nominal ID
Academic Sector		
2 Year College	2yr	1
4+ Year College	4yr	2
Career and/or Technical Training	CTT	3
Private P-12 Education	PrvP12	4
Public P-12 Education	PubP12	5
Business Sector		
Business with less than 50 Employees	<50	6
Business with 51-200 Employees	51-200	7
Business with more than 200 Employees	>200	8
Nonprofit Sector		
Charitable Foundation	CF	9
Civic Organization	CO	10
Faith-based Organization	FBO	11
Parent/Neighborhood Organization	PNO	12
Science Centers/Museums/Libraries	SCML	13
Youth Serving Organization	YSO	14
Military	MIL	15
Government	GOV	16
Other		17

Next, the interaction levels were assigned ordinal values of "0," "1," or "2." The ordinal values of the interaction levels can be found in Table 2.

TABLE 2. Ordinal ID by interaction level

Relationship	Interaction Level	Ordinal ID
I am not familiar with anyone in this category	No Interaction	0
I am familiar with someone in this category but we did not work together in a professional manner	Informal Interaction	1
We shared professional advice and/or materials when opportunity arose	Informal Interaction	1
We worked side-by-side as separate organizations but did not have a formal agreement	Formal Interaction	2
We worked together as a formal team with an established formal agreement (such as a memorandum of agreement)	Formal Interaction	2

Determining Relational Social Capital

Once interaction level frequencies were determined, an adjacency matrix for both the informal and formal relationship levels were generated. These matrices were then used to determine density, which represented the relational SC of each organization type based on the interaction levels that were previously determined. Density is a measure of the number of ties that are reported as compared to the number of possible ties that could exist. The intra-sector density and inter-sector density for the informal and formal networks were calculated for each organization type (refer to Table 1 for organization types and their sectors). The intra-sector density for the informal network for the Academic organizations was calculated based on the number of possible ties present within the Academic sector which included the organization types of 2-year College, 4+ year College, Private P-12 Education, and Public P-12 Education (Career and Technical Training were not included because there were no respondents from this organization type). For example, if 4+ year Colleges reported informal ties with other 4+ year Colleges and Private P-12 Education, but not with 2-Year Colleges and Public P-12 Education, then the informal network intra-sector density for 4+ year Colleges would be 2 out of 4, or a density of 0.50. The inter-sector density for both networks for the Academic organizations were calculated based on the number of possible ties within the Business and Nonprofit sectors which included the organization types of Business with less than 50 employees, Business with 51-200 employees, Business with more than 200 employees, Charitable Foundations, Civic Organizations, Science Centers/Museums/Libraries, and Youth Serving Organizations (Faith Based organizations, Parent/Neighborhood organizations, Military, and Government

organizations were not included because of the absence of respondents from those organization types). For example, if 4+ year Colleges reported informal ties with Business with more than 200 employees, Charitable Foundations and Science Centers/Museums/Libraries, but not with the other Business and Nonprofit organization types, then the formal network inter-sector density for 4+ year Colleges would be 3 out of 8 or a density of 0.38.

Determining Structural Social Capital

The metrics of degree and betweenness centrality of each of the organization types represented by the respondents of the survey were utilized to measure structural SC. Degree centrality is a measure of the number of ties an actor has in the network and betweenness centrality is a metric based on how well an actor is connected to otherwise unconnected actors and holds an intermediary position between them. Using the adjacency matrix for the informal network, the degree centrality and betweenness centrality metrics were calculated using NodeXL (Smith, Ceni, Milic-Frayling, Shneiderman, Mendes Rodrigues, Leskovec, & Dunne, 2010). The metrics for each individual was then converted to a scoring system where the actor with the highest degree metric was given a degree score of 1, the actor with the next highest degree metric was given a degree score of 2, and so on. This scoring conversion was also completed for betweenness centrality metrics. Once each actor had a degree score and betweenness score, they were added together to determine the combined centrality score. Since the study utilized a small population, there were repeat degree centrality metrics. Ultimately, this study employed a scoring conversion and not a ranking system; therefore, these ties were conserved and several organization types received the same degree score, and then the scoring sequence continued with the next number. This process was then repeated for the formal network using Level 2 interactions rather than Level 1 interactions.

Results and Analysis

Population Demographics

There were 86 total surveys used in this analysis and respondents self-selected organization types to which they belonged. Figure 1 represents the number of respondents per organization type and Figure 2 represents the percentage of each stakeholder category represented by the respondents. The majority of respondents belonged to the Academic stakeholder category at 50% with the 4+ Year College organization type, having the most respondents at 27. The number of respondents in the 4+ year College organization type alone makes up 1/3 of the respondents of the entire survey. This large number of representatives from this organization type shows a strong engagement level from UNO.

The second most represented stakeholder category was Nonprofit, with 33% of the respondents. Within this category, Youth Serving Organizations had the most respondents with 10. The Business stakeholder category had the third largest representation with 15% of the participants who elected to complete the survey. Within this category, businesses with less than 50 employees represented the largest organization type with 8 respondents. There were no representatives who completed the survey within the following categories: Career or Technical Training, Parent/Neighborhood Organizations, Military, and Government.
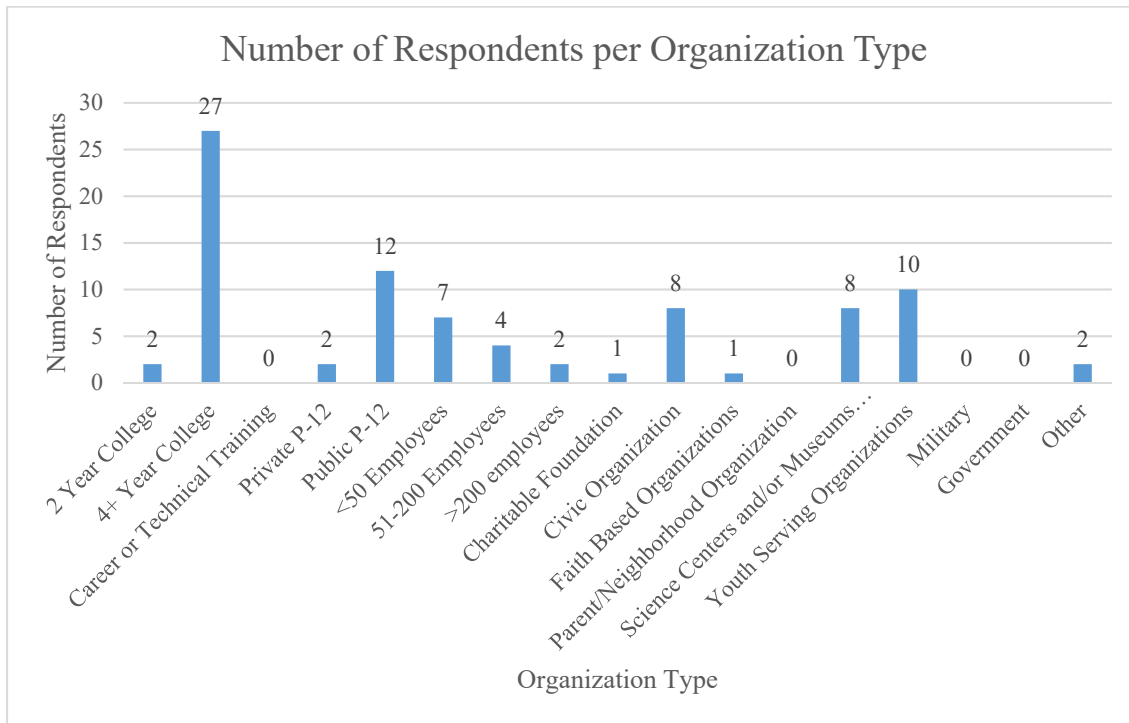
FIGURE 1. Percentage of respondents per organization type
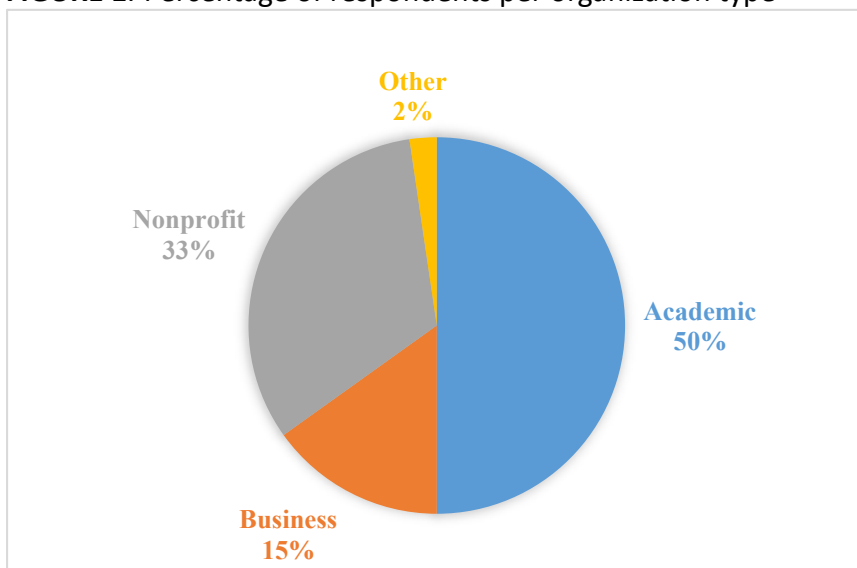
FIGURE 2. Percentage of respondents per stakeholder category

In order to determine relational SC, an adjacency matrix was initially developed that identified which ties were present. The data were used to identify formal and informal networks within the OSE based on the level of interaction actor one reported to have with actor two. Table 3 shows the adjacency matrix for the informal network where actor one is represented by the organization types in column 1 and actor 2 is represented by the organization types in row 1. When examining 4+ year Colleges (represented by 4yr), on average, they reported informal interactions with the following organization types: Two Year Institutions, Private P-12 Schools, Businesses with less than 50 Employees, Charitable Foundations, Civic Organizations, Faith Based Organizations, Science Centers/Museums/Libraries, and Youth Serving Organizations.

TABLE 3. Informal network adjacency matrix

	OSE Organization Types											
	2yr	4yr	Prv P12	Pub P12	<50	51-200	>200	CF	CO	FBO	SCML	YSO
2yr	0	0	0	0	1	0	1	0	1	1	1	1
4yr	1	0	1	0	1	0	0	1	1	1	1	1
PrvP12	1	0	1	0	1	1	1	1	1	1	0	1
PubP12	1	0	0	1	1	1	1	0	1	1	1	1
<50	1	1	1	0	0	1	1	1	1	1	1	0
51-200	1	1	1	1	1	0	0	1	0	1	1	1
>200	1	1	1	0	1	1	1	1	1	1	0	0
CF	1	1	1	1	1	1	1	1	1	0	0	0
CO	1	0	0	1	1	1	1	1	1	1	1	1
FBO	1	0	0	0	1	0	0	0	0	0	1	0
SCML	1	0	0	0	0	1	1	0	0	1	0	0
YSO	0	0	0	1	0	1	0	0	0	1	0	0

Figure 3 is the sociogram of the informal network and was produced through the Excel add-in NodeXL (Smith, et al., 2010). The actors (OSE organization types) were represented as the nodes and the reported relationships were the arcs (arrows). It should be noted that this is a directed graph, meaning that the arrows represent the "direction" of the interaction from actor 1 to actor 2. This means that there are unreciprocated ties represented in the graph, for example, there is a tie present between 4yr and CO even though CO did not report an informal relationship

on average with the 4+ year Colleges organization type. The organization types' nodes were represented by certain shapes and colors: Academic stakeholder category nodes were red squares; Business stakeholder category nodes were green circles; and Nonprofit stakeholder category nodes were blue triangles. This represented the organization types and their relative positions to one another based on their reported relationships. Refer to Table 1 for a list of the organization type abbreviations. There were no participants within the organization types of Career or Technical Training, Parent/Neighborhood Organizations, and Military, thus they are absent from the sociogram. The organization type of "Other" is also absent since it is a broad category for any respondents who felt they did not belong to any of the organization types listed.
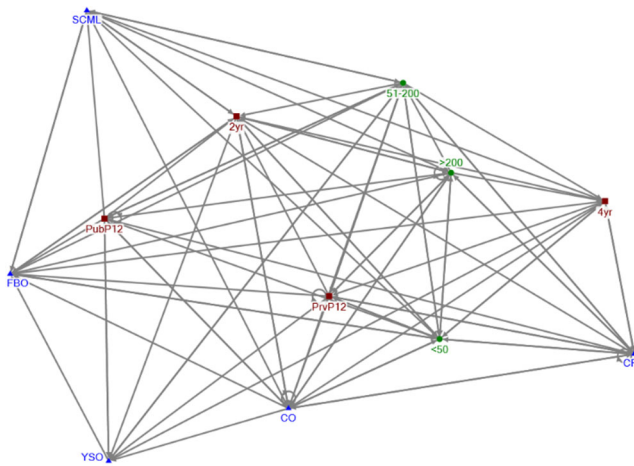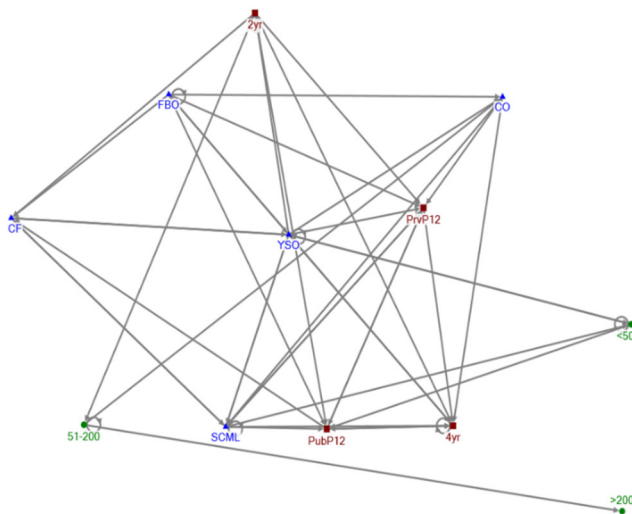

FIGURE 3. Sociogram of informal network

Table 4 shows the adjacency matrix for the formal network where actor one is represented by the organization types in column 1 and actor 2 is represented by the organization types in row 1. When examining 4+ year Colleges (represented by 4yr), on average, they reported formal interactions with the following organization types: 4+ year Colleges and Public P-12 Schools.

TABLE 4. Formal network adjacency matrix

					OSE Organization Types						
	2yr	4yr	Prv P12	Pub P12	<50	51-200	>200	CF	CO	FBO	SCML	YSO
2yr	1	1	1	1	0	1	0	1	0	0	0	0
4yr	0	1	0	1	0	0	0	0	0	0	0	0
PrvP12	0	1	0	1	0	0	0	0	0	0	1	0
PubP12	0	1	1	0	0	0	0	1	0	0	0	0
<50	0	0	0	1	1	0	0	0	0	0	0	1
51-200	0	0	0	0	0	1	1	0	1	0	0	0
>200	0	0	0	0	0	0	0	0	0	0	0	0
CF	0	0	0	0	0	0	0	0	0	0	1	1
CO	0	1	1	0	0	0	0	0	0	0	0	0
FBO	0	1	1	1	0	0	0	1	1	1	0	1
SCML	0	1	1	1	1	0	0	1	1	0	1	1
YSO	1	1	1	0	1	0	0	1	1	0	1	1

Figure 4 shows the sociogram of the informal network and was produced through the Excel add-in NodeXL (Smith, et al., 2010) and follows the same parameters as previously described for the sociogram in Figure 3.

FIGURE 4. Sociogram of formal network

Once the interactions were identified, the relational SC of the organization types were calculated using NodeXL (Smith, et al., 2010) and were determined by the density of each organization type's intra-sector and inter-sector ties for both network types, informal and formal (refer to Table 1 for each organization type's sector). The density of an actor's network is the degree to which the possible number of ties actually occur. If all possible ties occurred, the density would be 1, conversely, if none of the possible ties occurred, the density would be 0. This data is represented in Table 5.

TABLE 5. Intra-sector and inter-sector density by organization type

Organization Type	Intra-sector Informal Network Density	Inter-sector Informal Network Density	Intra-sector Formal Network Density	Inter-sector Formal Network Density
2 Yr	0.00	0.75	1.00	0.25
4+ Yr	0.50	0.75	0.50	0.00
Prv P12	0.50	0.88	0.50	0.12
Pub P12	0.50	0.88	0.50	0.12
Bus <50	0.67	0.78	0.33	0.22
Bus 51-200	0.33	0.78	0.67	0.11
Bus >200	1.00	0.67	0.00	0.00
CF	0.40	1.00	0.40	0.00
CO	1.00	0.71	0.00	0.29
FBO	0.20	0.29	0.80	0.43
SCML	0.20	0.43	0.80	0.57
YSO	0.20	0.29	0.80	0.57

H1. Within the informal network, the relational SC of 4+ year Colleges (UNO) is lower for intra-sector ties rather than inter-sector ties through the demonstration of network density.

The intra-sector relational SC of 4+ year Colleges within the informal network was 0.50, which means that 50% of the possible ties it could have with other Academic organizations were at the informal level. The inter-sector relational SC of 4+ year Colleges was 0.75, which means that 75% of the possible ties it could have with Business and Nonprofit organizations were at the informal level. This means that 4+ year Colleges possessed relatively more informal ties with organization types outside of its sector than within its sector as predicted by H1.

In addition, when looking at the informal network intra- and inter-sector ties of the organization types that belong to the Business sector, this pattern persisted. The organization types in the Business sector all show a lower intra-sector relational SC compared to their inter-sector

relational SC in the informal network. This pattern also persisted for the nonprofit organization types, except for Charitable Organizations.

H2: Within the formal network, the relational SC of 4+ year Colleges (UNO) is greater for inter-sector ties rather than intra-sector ties through the demonstration of network density

The intra-sector relational SC of 4+ year Colleges within the formal network was 0.50, which means that 50% of the possible ties it could have with other Academic organizations were at the formal level. The inter-sector relational SC of 4+ year Colleges is 0.00, which means that 0% of the possible ties it could have with Business and Nonprofit organizations were at the formal level. This means that 4+ year Colleges possess relatively more formal ties with organization types within its sector than without its sector, on average there were no formal ties reported between individuals from 4+ year Colleges types and any Business or Nonprofit organization types as predicted by H2.

In addition, when looking at the formal network intra- and inter-sector ties of the organization types that belong to the Business sector, this pattern persisted. The organization types in the Business sector all show a greater intra-sector relational SC compared to their inter-sector relational SC in the formal network, except for the organization type of Businesses with greater than 200 employees, which on average reported no intra- or inter-sector formal ties. This pattern also persisted for the nonprofit organization types, except for Charitable Organizations.

In terms of collaboration, the data supported the notion that relational SC is based on the history of interactions of the actors within a network and that on average, individuals from organization types that belong to similar sectors, such as Academic, Business, and Nonprofit, tend to bring with them formal ties with other individuals that belong to the same sector. The data also supported the notion that the individuals within a network on average will have informal ties or no ties to individuals who are in different sectors.

Structural Social Capital: Combined Centrality Score

The metrics of degree and betweenness centrality of each of the organization types represented by the respondents of the survey were utilized to measure structural SC. Degree centrality is a measure of the number of ties an actor has in the network and betweenness centrality is a metric based on how well an actor is connected to otherwise unconnected actors, and holds an intermediary position between them.

H3: Within the informal network, the 4+ year Colleges type (UNO) will possess a relatively low structural SC through the demonstration of one of the lowest combined centrality scores.

The combined centrality scores were calculated using NodeXL (Smith, et al., 2010) based on the degree and betweenness centralities for informal and formal networks, which are represented in Table 6 and 7, respectively. The top organization types with the best combined centrality scores for the informal network were Civic Organizations and Businesses with 51-200 Employees. This means that, on average, these respondents had both a large number of ties within the informal network as well as acted as intermediaries for otherwise unconnected organization types. The bottom organization types with the worst combined centrality scores were Science Centers, Museums, and Libraries, and Youth Serving Organizations.

TABLE 6. Informal network centrality metrics and scores by organization type

Organization Type	Degree Centrality	Degree Score	Betweenness Centrality	Betweenness Score	Combined Centrality Score
2 Yr	0.50	4	1.266	1	5
4+ Yr	0.67	3	1.030	2	5
Prv P12	0.75	2	0.577	6	8
Pub P12	0.75	2	0.887	3	5
Bus <50	0.75	2	0.647	5	7
Bus 51-200	0.75	2	1.266	1	3
Bus >200	0.75	2	0.647	5	7
CF	0.75	2	0.236	7	9
CO	0.83	1	1.266	1	2
FBO	0.25	6	0.831	4	10
SCML	0.33	5	0.111	8	13
YSO	0.25	6	0.236	7	13

When focusing on UNO, the organization type of 4+ Year Colleges had a combined centrality score of 5, which is the third highest score with a degree score of 3 and a betweenness score of 2 which contradicts H3. H3 was based on previous results presented from the OSE in 2016 and this demonstrates the dynamic nature of the OSE and how responses can change annually. UNO has a relatively high number of ties within the informal network, and these respondents can act as intermediaries connecting other network members. Further, UNO is in a position to foster these relationships and build upon them to generate more formal and lasting collaborations not only by developing partnerships with itself, but also by connecting organization types that aren't already connected. This also means that UNO's structural position allows it the possibility to somewhat influence the adoption rate of innovations within the OSE, as well as influence the scale to which an innovation is adopted through the informal ties it holds within the OSE.

TABLE 7. Formal network centrality metrics and scores by organization type

Organization Type	Degree Centrality	Degree Score	Betweenness Centrality	Betweenness Score	Combined Centrality Score
2 Yr	0.50	3	8.543	2	5
4+ Yr	0.17	5	1.210	8	13
Prv P12	0.25	4	1.210	8	12
Pub P12	0.25	4	3.467	5	9
Bus <50	0.25	4	0.143	10	14
Bus 51-200	0.25	4	10.250	1	5
Bus >200	0.00	6	0.00	11	17
CF	0.17	5	0.710	9	14
CO	0.17	5	8.167	3	8
FBO	0.58	2	1.126	7	9
SCML	0.67	1	3.126	6	7
YSO	0.67	1	5.050	4	5

H4: Within the formal network, the 4+ year Colleges type (UNO) will possess a relatively high structural SC through the demonstration of one of the highest combined centrality scores.

In the formal networks, the top organizations were 2-year Colleges, Businesses with 51 - 200 employees, and Youth Serving Organizations each with a combined centrality score of 5. This means that on average, these respondents had both a relatively large number of ties within the formal network as well as acted as intermediaries for otherwise unconnected organization types. The bottom organization types with the worst combined centrality scores were Businesses with less than 50 employees, Businesses with more than 200 employees and Charitable Organizations.

When focusing on UNO, the organization type of 4+ year Colleges had a combined centrality score of 13 which is one of the bottom 3 scores with a degree score of 5 and a betweenness score of 8 which contradicts H4. Again, H4 was based on data from the OSE survey in 2016. This demonstrates some of the limitations of this methodology, which will be further discussed in the conclusion. This means that UNO had a relatively low number of ties within the formal network, and these respondents typically cannot act as intermediaries connecting other network members. This reiterates the findings from the informal network because respondents could only select one interaction level, so if the majority of ties were informal, then the number of formal ties were fewer. Therefore, while UNO has some formal ties, there is room for growth within their formal network. Consequently, UNO's structural position within the formal network does not allow it to influence the scale and rate of adoption of innovations.

Conclusion

The purpose of this study was to determine how universities could use SNA to determine their structural position within MSCNs, as it is beneficial for an organization to identify their structural positions and understand the sphere of their influence of the SC and innovation within their network. Additionally, it is beneficial not only for an organization to identify and understand their own position, but to also identify others' positions within the network. This study demonstrated that SNA can be used to determine the structural positions of organization types within the OSE. Analysis was completed by averaging the interaction levels of the respondents within the organization types to determine interaction levels. This information was then used to calculate the centrality metrics of density as the metric for Relational SC and combining degree and betweenness as the metric for Structural SC. After converting these metrics to a scoring system and adding them, each organization type received a combined centrality score that identified organization types that acted as both hubs and gatekeepers.

Limitations

One of the limitations of this study was that it was based on a self-reporting survey, which allows for biases, namely social desirability bias and reference bias. Social desirability bias occurs when respondents select options because they want to seem more "popular" (West, 2014), while reference bias occurs when respondents interpret the various options differently (West, 2014). The survey used in this study did attempt to minimize reference bias by providing explanation of each interaction level. Desirability and reference biases affect all self-reporting surveys and further research needs to be conducted to determine how to minimize these threats. The data were also limited by the inconsistent spread of the number of respondents per organization type. The frequencies for those organization types that had fewer respondents were heavily influenced by only those few as compared to a larger number of responses.

This study was also limited by the network analysis, as it was based on averaging the interaction levels of the individual members of the organization types and does not represent the whole network. Also, it was not possible to represent the whole network, as surveys were completed by individuals who elected to participate. Further, utilizing whole network analysis would have been too time-intensive, as respondents would be required to select an interaction level for 86 different individuals.

Discussion

Through studying the OSE, we were able to look at the differences in various forms of SC for UNO within a growing, dynamic MSCN. Breaking the members of the network into different sectors allowed us to further examine the network through intra- and inter-sector ties. We were

also able to disaggregate the ties into two different networks based on the strength of formal and informal ties. In this study, we determined that the majority of UNO's informal network ties were with organization types outside of the Academic sector, meaning that respondents from UNO had, on average, more informal ties with individuals from Business and Nonprofit organization types than with Academic organization types. We also determined that the majority of UNO's formal network ties were with organization types inside of the Academic sector, meaning that, on average, they had more formal ties with individuals from Academic organization types than with Business or Nonprofit organization types. In fact, they only had two formal ties in the network which included Four Year Institutions and P-12 Public Schools.

In terms of the structural SC, the results from this study did not support the proposed hypotheses. UNO possessed a relatively high structural SC in the informal network and a relatively low structural SC in the formal network, which directly oppose H3 and H4. UNO had the third highest combined centrality score for the informal network, which means UNO is in a position to foster these informal relationships and encourage more meaningful collaborations. However, UNO had one of the bottom three combined centrality scores for the formal network. When looking at the two networks from this perspective, it makes sense the UNO would have a low score for the formal network because they held an influential position in the informal network and respondents can only select one level of interaction. It also demonstrates room for growth for UNO in terms of developing their informal relationships into formal relationships and helping to facilitate this growth for others within the network. These interactions can be best fostered through frequent, energetic, and genuine face-to-face interactions, resulting in increasingly more meaningful and sustainable relationships (Pentland, 2015).

When combining the results of the Relational SC and Structural SC of UNO for both networks, there are several organization types with which UNO needs to strategically form relationships. On average, individuals from UNO recorded no relationships with individuals from Business organization types with 51-200 Employees and > 200 Employees. In particular, it would be beneficial for UNO to seek out partnerships with individuals from Businesses with 51-200 Employees as they are in structural positions of hubs and gatekeepers in the formal network and, on average, UNO recorded no relationships with any individuals from this organization type. Developing partnerships with individuals from the Businesses with 51-200 Employees would be advantageous for UNO because these individuals have many formal connections and can help UNO make new connections and be involved in formal collaborations.

UNO also has many informal relationships that they can build upon, particularly in the Nonprofit sector; one organization type within the Nonprofit sector that UNO should enhance its relationship with is Youth Serving Organizations. On average, individuals in these organization types hold positions of prominence in the formal network, and individuals from UNO already

have informal relationships with these individuals, which can help facilitate a more formal collaborative relationship.

Within research concerning cross-sector partnerships, SNA is being used to analyze and manage these collaborations. The role of urban universities within these MSCNs can be informed and enhanced through the use of SNA. Universities should strive to be prominent actors by holding positions of hubs and gatekeepers within their innovative MSCNs, because while they hold content expertise, having access to diverse perspectives is vital to the generation of creativity and insight (Pentland, 2015). This creativity and insight will be beneficial for both the university and the community as a whole.

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