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Abstract

The field of education has witnessed an increasing trend of inter-organizational and inter-departmental collaborations and forming of networks. Collaborative educational programs have been implemented in a variety of ways. This paper proposes to understand and study collaborative educational programs through the lens of complexity theory and to utilize nonlinear research methods. This paper also proposes to connect the dots in the literature among complexity theory, collaborative educational programs, program evaluation, and alternative nonlinear research methods.

1. Overview

Inter-organizational collaborations have been studied broadly on "the mechanism by which policies have been advocated, services delivered, and the public sector governed" (Mischen, 2015, p. 381). The literature also refers to the concept of organizations working together to achieve the same goals using a variety of names such as partnerships, strategic alliances, coalitions, cooperative arrangements, and collaborative agreements (Provan, Fish, & Sydow, 2007). Although different definitions are provided throughout the body of literature, this paper uses the definition provided by Ansell and Gash (2008), which sees inter-organizational collaboration as "a collective decision-making process that is formal, consensus-oriented, and deliberative and that aims to make or implement public policy or manage public programs and assets" (p. 544).

There are different conditions and benefits that encourage organizations to work together. In Management, scholars have studied collaboration for decades and summarized the benefits of collaboration. Built on a seminal work by Wood and Gary (1991), Thomson and Perry (2006) constructed an Antecedent-Process-Outcome model to describe collaboration. Antecedents of collaboration address the needs of different institutions working together, such as a high level of interdependence (Logsdon, 1991), the need for resources and risk sharing (Alter & Hage, 1993), and facing complex issues (O'Toole, 1996). Process of collaboration includes governance, administration, organizational autonomy, and other structure-related factors (Thomson & Perry, 2007). Outcomes of collaboration resonate the benefits for institutions working together: achievement of goals (Bardach, 1998;

Gary, 2000), self-governing collective actions on problem-solving (Ostrom 1990), and others (Thomson & Perry, 2007). In Public Administration, scholars also build models to understand collaborations. In a model of collaborative governance, both short- and long-term benefits have been discussed (Ansell & Gash, 2008). A short-term outcome is described as "small win" that is critical to feed back into the collaboration process and to encourage long-term efforts (Ansell & Gash, 2008).

The cost for organizations to work together comes with benefits. For example, organizations trying to work together usually find that they need to put a lot of effort into building trusting relationships with others (Ansell & Gash, 2008). As another example, since working together requires constant communication, organizations need to coordinate regular face-to-face dialogue (Ansell & Gash, 2008). Relatively high levels of commitment by organizations are critical to the success of collaborations (Ansell & Gash, 2008). To sum up, inter-organizational collaborations have multiple benefits and effects on the collaborating organizations, such as strategic effects, knowledge creation effects, and political effects (Hardy, Phillips, & Lawrence, 2003). Meanwhile, inter-organizational collaborations should develop the capacity to manage social capital, financial capital, and knowledge capital (Mischen, 2015).

Given all the benefits of inter-organizational collaborations, the field of education has witnessed an increasing trend of inter-organizational and inter-departmental collaborations and forming of networks (Kezar, 2005). In K-12 education, from collaborative efforts on building programs to formal collaboration relations to comprehensively integrated service delivery models, schools and community organizations work diligently to serve students. In higher education, collaborative efforts by administrators and campus departments are formed to serve students with a range of goals. In this paper, Collaborative Educational Program (CEP) is used to refer to a variety of formats of inter-organizational collaborations on service delivery for students in the field of education.

This paper proposes to study and analyze CEPs through the lens of complexity theory. Building on previous work analyzing the relationships between complexity theory and social network analysis (Mischen & Jackson, 2008), this paper aims to connect the dots among CEPs, complexity theory, program evaluation, and other advanced complex analytic methods. This paper argues that CEPs are complex systems and need complex analytic methods as tools to analyze and evaluate their effectiveness and outcomes.

2. What is a Collaborative Educational Program (CEP)?

This paper defines CEP using four criteria: involving a group of organizations, aiming at service delivery to students, working in any form of program, and addressing complex problems. According to this definition, a range of programs are

CEPs. For example, a successful summer enrichment program for urban low-income gifted students provides an effective program model which contains three key components: courses that match student interests; support to parents and families; and development of interpersonal relationships with mentors and peers (Kaul, Johnsen, Witte, & Saxon, 2015). A range of longitudinal effects on the participating students has been witnessed (Kaul, Johnsen, Witte, & Saxon, 2015). They are education and career effects, social relationship effects, personal effects, and generational effects (Kaul, Johnsen, Witte, & Saxon, 2015). By serving both students and their families, this program took both needs of students and the environmental factors, which are potential burdens for students, into account (Kaul, Johnsen, Witte, & Saxon, 2015). Aiming for a system-level change, this program would not have become successful without the coordinated efforts from the University, which the program is based, and a number of public and private school districts, which the students come from (Kaul, Johnsen, Witte, & Saxon, 2015). As another example, school-community partnerships have been increasingly formed, especially in rural areas, to serve students (Bauch, 2001). School-community partnerships are believed to contribute to student development by preparing them for college through community services and activities, providing information about possible careers and education, and providing a sense of identity and stability (Alleman & Holly, 2003).

Community schools, a more integrated model, are also formed as a format of CEP to serve students in need. The National Coalition of Community Schools gives the following definition: "A community school is both a place and a set of partnerships between the school and other community resources. Its integrated focus on academics, health and social services, youth and community development and community engagement leads to improved student learning, stronger families and healthier communities" (Coalition of Community Schools, n.d.). As an integrated model, community schools utilize resources from the community to provide a range of services in schools for students, especially those in poverty, to help them be successful. Services provided in school by community organizations include but are not limited to health and mental health services, extended learning opportunities, and family connections and support.

3. What is a Complex System?

Complexity theory as a body of theoretical framework provides a fundamental feature to understanding the world (Complexity Academy, 2015). Within the scope of complexity theory, there are a variety of approaches. For example, game theory and prisoner's dilemma are presented in Axelrod's (2006) book, *The Evolution of Cooperation*. There are a variety of strategies to choose from when deciding whether to cooperate or not. There is not, however, a single strategy that should be

implemented under all kinds of circumstances. Tit for Tat is the most appreciated strategy in the game, which requires the player to adapt according to the other player's choice every time. There is no one-size-fits-all strategy in the game. Another example is nonlinear dynamics. An important message conveyed by Schelling (2006) in his book *Micromotives and Macrobehavior* is that an individual's behavior is not isolated from his/her environment, and the aggregation of the interactive behaviors usually brings surprising yet undesirable outcomes. His work demonstrated that most social behaviors by humans could not be predicted by any linear model since the variables we are using are not independent at all from one another. Other approaches in complex systems include but are not limited to systems theory, collective behaviors, networks, evolution and adaptation, and pattern formation (Complexity Academy, 2015).

Complex systems are usually seen as having a group of components that interact with one another in an open system, thus allowing fluxes in and out (Limburg, O'Neill, Constanza, & Farber, 2002). Even though complexity theory contains different approaches, complex systems share common characteristics.

3.1 Agents

A complex system is composed of a large number of agents (Mischen & Jackson, 2008). Agents can be cells of the immune system in Biology, citizens in Political Science, and investors in Business and Marketing (Grimm et al., 2005). Agents can also be individuals within an organization or organizations within a network in Behavior Science (Mischen & Jackson, 2008). As the unit of a complex system, agents need a clear goal, be autonomous and able to make decisions during the process of achieving the goal, and have the capacity to adapt to the changing environment (Grimm et al., 2005).

3.2 Connectivity

Agents need to be connected in order to form a complex system (Mischen & Jackson, 2008; Mitleton-Kelly, 2003). The connectivity can be interactions among cells, citizens, investors, individuals, and organizations. Interactions among individuals within an organization or organizations in a network can be either relational, physical, or a combination of both (Limburg, O'Neill, Constanza, & Farber, 2002). For instance, building partnerships is relational interaction, and sharing resources is physical interaction. Another explicit way to understand the connectivity in Behavior Science is the communication among individuals and organizations (Mischen & Jackson, 2003).

Among all the features of a complex system, connectivity and interaction are the ones that determine the complexity (Limburg, O'Neill, Constanza, & Farber,

2002). These features make the agents both connected and interdependent (Mischen & Jackson, 2003).

3.3 Structure and hierarchy

Structure and hierarchy describe the ways in which agents interact with one another in a complex system. Using communication among employees in an organization as an example, formal and informal communication patterns usually have different structures. Formal communication patterns are usually bounded by organizational structure and hierarchy. Employees within the same department always tend to have more work-related communication compared to communication with employees from other departments. Employees also tend to communicate with supervisors on a regular basis, even if they do not communicate with other colleagues. Informal communication patterns, on the other hand, may not be influenced as much by organizational structure and hierarchy. Friendship networks, family networks, mentoring relationships, and other factors could have bigger impacts on informal communication patterns. Understanding the structures of interactions, specifically the differences between structures for different interactions, could contribute to understanding complex systems.

3.4 Feedback

Feedback is another important factor in complex systems. A feedback loop is a connection between cause and effect that results in a chain reaction that leads to either stabilizing (negative feedback) or destabilizing (positive feedback) (Mischen & Jackson, 2008). In Schelling's model of segregation (1978), for example, a feedback loop is created when an agent observes the environment and decides whether he or she is satisfied after each move. In a collaborative service delivery network, as another example, a feedback loop is developed when a member of the network understands the network-level outcomes of its behavior. Feedback is the precondition of adaptation in complex systems.

3.5 Adaptation

"Every social agent receives information about the world, processes it, and acts" (Miller & Page, 2007, p. 30). Receiving and processing information about the world represents feedback, and acting based on the information is the foundation of adaptation. Each agent adapts to its environment, which is composed of other agents in the system, thus forming an adaptive system. In Schelling's model of segregation (1978), the move after knowing the environment is the way each agent adapts to the environment. In a collaborative network, choosing whether to stay

within the network based on who else is on board is a way each organization adapts to the environment. Aggregating all the agent-level adapting movements to the system level is the source of adaptation in a system.

3.6 Self-organizing

As each agent follows its rules, the aggregate outcomes of the systems are not always predictable and sometimes surprising. Meanwhile, the outcomes are usually not planned by anyone and are unconsciously self-organizing (Waldrop, 1992). This feature of a complex system further determines the complexity. By interacting with one another and following certain rules, agents form a complex adaptive self-organizing system. With energy flowing into the system, agents within the system organize themselves without central coordination (Anderson, 1999; Kauffman, 1995).

3.7 Nonlinearity

Subjectively, two ways of thinking usually explain how humans view the world: linear and nonlinear. Objectively, in the meantime, only a few systems in nature work linearly, such as sound and light, while other systems are primarily not as linear such as economy and brains (Waldrop, 1992). In complex systems, one would not be able to predict the value of a dependent variable by simply knowing the values of independent variables. First, we cannot call the factors influencing the system outcomes independent variables. Complex systems are nonlinear since agents are not independent from the environment and feedback loops contribute to the adaptation process. And then, the aggregate of effects does not equal the sum of individual agents' effects (Waldrop, 1992). This is the nature of complex systems.

4. Why is CEP a Complex System?

CEPs, as complex systems, have all the aforementioned features.

In a CEP, at least two levels of agents exist: participating organizations and contact individuals. In order to provide needed services to students, schools, districts, community-based organizations, health and mental health department of the government (both local and state), and even businesses need to be involved. All these organizations assign contact individuals, such as superintendents, principals, teachers, program directors, and government officials. As customers, students and their environments—such as families, neighborhoods, and communities—are all service receivers. As a result, both organizations and individuals can be treated as agents in a CEP that compose the structures.

When constructing a CEP, key agents would decide on what structure to use that could make sure the effectiveness and efficiency of the CEP. Provan and Kenis (2008) proposed three models that govern collaborative networks. Shared Governance, usually used when there is not a large number of participants and a high level of goal consensus, asks all the participating organizations to take part in governing the network (Provan & Kenis, 2008). Lead Organization, usually used when there is a moderate number of participants and a relatively low level of goal consensus, requires one organization from the network to take the lead in governing the network (Provan & Kenis, 2008). Network Administration Organization (NAO) usually being used when there are many participants and a moderately high level of goal consensus (Provan & Kenis, 2008). In all three models, hierarchy plays an important role in the network structure. In NAO, for example, the administration organization has the highest position in the hierarchy, and other participating organizations need to follow the lead. As collaborative efforts, CEPs are bounded by structures which are usually hierarchies. Funding agencies, for instance, would fund through one organization in the collaboration, which takes the lead. The funded organization, either in a formal or informal way, has a high position in the collaboration structure.

"Ultimately, the study of complex systems is the study of agents interacting in networks." (Mischen & Jackson, 2008, p. 317). Working towards the same goals, agents in a CEP are connected with one another in a lot of different ways. Communication is an important connection in collaborative networks (Mischen & Jackson, 2008). Similarly, information sharing, power, friendship, personal support, and other connections contribute to the connectivity of a CEP as well (Cross & Parker, 2004). Research has shown that connectivity plays a significant role in the outcomes of collaborative governance (Ansell & Gash, 2008). Using trust relations as an example, when the overall trust level is high in a collaborative network, it is more likely that the network will have better outcomes (Lambright et al., 2010).

Agents within a CEP adapt to other agents' behaviors and the environment based on feedback loops. Deciding whether to join a CEP from an organization's perspective is influenced by a range of factors, such as whether the organizational goal lines up with the collaboration's goals and whether other similar organizations (competitors) are in the collaboration. Behaviors of other participants influence the behaviors of any specific participant and thus creating feedback loops. When all the agents within a CEP respond to the feedback loops and adjust their behaviors, the whole collaboration has a high level of adaptation and is likely to thrive in the changing environment.

Even though agents are bounded by certain structures and interactive relations among the CEP, each agent has discretion on its own behaviors and decisions in the CEP. Without central coordination, agents following similar logic come together as a self-organizing system. If one agent would join a CEP only if

there is at least one other similar agent in the CEP, the decision of this agent is predictable, knowing who is already in the CEP. Understanding the agent-level behavioral logic would contribute to the understanding of collaboration-level behaviors.

Given the complexity of CEPs, analyzing and evaluating CEPs need not only traditional program evaluation methods but also more sophisticated methods.

5. How Do We Study CEP: Program Evaluation

While both linearity and nonlinearity are reflected in the ways systems work and the way people think, research tends to treat nonlinear social problems with linear practical solutions. A typical example is how programs are being evaluated.

A typical way of evaluating programs follows an extreme linear model. Evaluating methods are usually linear, reflected by the step-by-step construction of plans. Four steps of evaluating programs are commonly used: design a plan, collect data, analyze data, and use the results (Wholey, Hatry, & Newcome, 2010).

While the evaluations follow a linear model, programs are usually nonlinear complex social systems that involve a variety of stakeholders, utilize different channels of resources, aim for impacts on multiple levels, and require plenty of facilitations and interactions. CEP, as a type of program, is usually treated the same way.

A linear model is used to evaluate a nonlinear program because it simplifies reality and allows evaluators to grasp relatively representative information with limited time and resources. Another reason is that most evaluations focus heavily on short-term outputs and long-term outcomes. When seeing the results as the most significant indicator, it makes sense to use the linear model. By following the handful of steps, the evaluation formulas compute the requested numbers.

Evaluating nonlinear programs using linear models and methods is problematic. First, it treats the programs as tools used to solve social problems, and it neglects that the programs themselves are complex social systems. Second, it emphasizes the observable results (Jacobs, 2003) and aims to find out whether the programs are using the funds effectively and efficiently (Wholey, Hatry, & Newcome, 2010). This approach easily leads to type two errors when the evaluation does not show significant effects by the program while the program actually has impacts in a variety of ways that are not measured by the evaluation (Jacobs, 2003). Third, it ignores the contexts and environments of the program (Jacobs, 2003). Without knowing the circumstances under which the program is implemented, it would be challenging for evaluators to see the big picture and come up with accurate measurements. To use an analogy to describe the problem, the popular program evaluation method is like using a ruler to measure a box. The ruler cannot reflect what is in the box, what material the box uses, and where the box is. As a

result, nonlinear methods are needed to evaluate programs in a more comprehensive way.

6. How Could We Study CEP as Complex Systems?

When studying complex systems, different methods can be used to measure the outcomes and not only grasp the linear effects. In this sector, Social Network Analysis and Agent-Based Modeling will be discussed as two examples of how to utilize nonlinear methods to study CEPs as complex systems.

6.1 Social network analysis (SNA)

Social Network Analysis (SNA) is a method examining relational rather than attribute variables (Wasserman & Faust, 1994). While SNA is not a new method in social science, utilizing it in program evaluation is not pervasive yet (Durland & Fredericks, 2005). The value of incorporating SNA in program evaluation lies in the fact that SNA captures relational outcomes. In a CEP, attribute outcomes such as increased GPA and more access to health care may need long-term implementation. Relational outcomes, on the other hand, which are not usually captured and emphasized in evaluations, contribute greatly to the attribute outcomes. In a high school program evaluation study, evaluators originally planned to measure academic and attitudinal achievement (Kochan & Teddlie, 2005). They found, however, the most important outcome of using SNA in measuring the communication patterns among high school faculties (Kochan & Teddlie, 2005). Relational outcomes matter as much as attribute outcomes for CEPs since they are collaborative programs. Desirable attribute outcomes would hardly be achieved without good connectivity and positive internal relations.

6.2 Agent-based modeling

Agent-Based Modeling is intended for researchers to understand macro-level social phenomena as emerging from micro-level behaviors and interactions (Agassi, 1960; Hodgson, 2007; Udehn, 2002; & Neal & Lawlor, 2016). Even though agent-based modeling is seen as different from traditional research methods, it could offer a more integrated view of social phenomena since it bridges individual level and ecological levels factors, and by relying on the most critical factors, it contributes to the understanding of behavior outcomes (Neal & Lawlor, 2016). In a CEP, it is easier to understand an organization's behavior in collaboration. It is more challenging, however, to understand the network-level behaviors and the potential outcomes of the CEP. Utilizing Agent-Based Modeling, stakeholders of a CEP, such as funders and administrators, would be able to understand the potential effects

and challenges before implementing the program. Thus, this method could contribute to making informed decisions. The idea of using Agent-Based Modeling is not to replace the traditional program evaluation method. Agent-Based Modeling could be a nice supplement to understanding CEPs in a more comprehensive way (Neal & Lawlor, 2016).

Linear research methods follow the epistemology of positivism. The nature of CEP, however, is not linear, which determines the need for supplemental methods of studying. Social Network Analysis, Agent-Based Modeling, and potentially other methods which help to understand the social context more in-depth, such as Latent Growth Curves and Community narratives (Jason & Glenwick, 2016), would be a strong supplement in evaluating CEPs. As complex social systems, studying CEPs could benefit from nonlinear complex research methods.

7. Conceptual Framework

To sum up the discussed statements, Figure 1 illustrates both the existing links within the literature and the proposed links in this paper. The primary argument of this paper is that Collaborative Educational Programs are Complex Systems that should utilize alternative nonlinear research methods to supplement the traditional program evaluation.

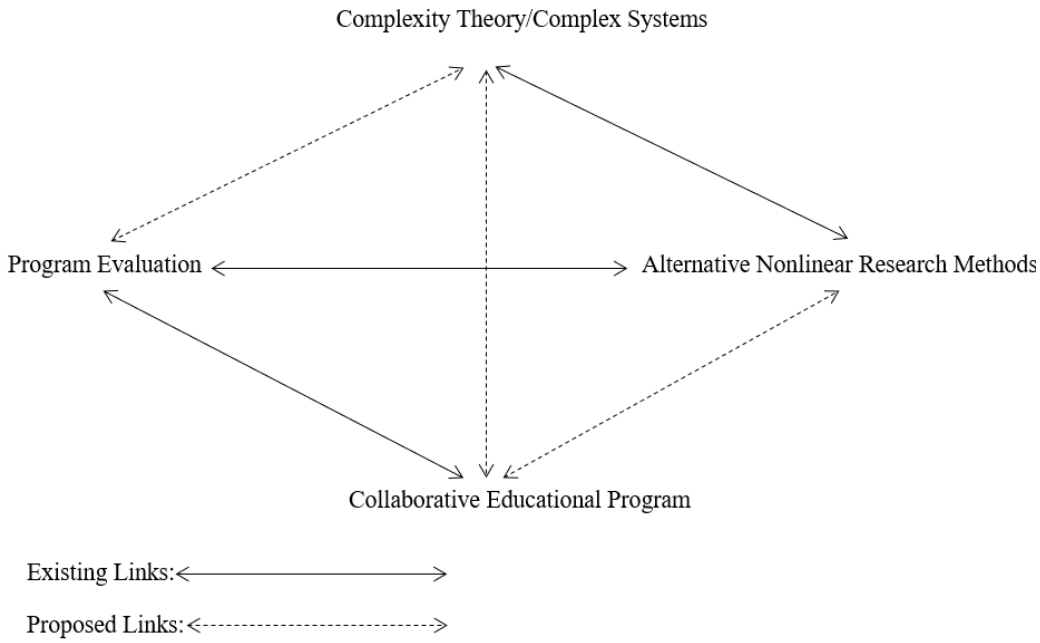

Figure 1. Existing and Proposed Links

8. Lessons Learned

Social problems are complex problems. For complex problems that exist within the field of education, different organizations are and should work together to address those problems. CEPs are complex systems when viewed from the lens of complexity theory. As a result, additional methods should be utilized to study and evaluate CEPs. Complexity theory has informed CEPs in both theoretical and methodological ways. Practically, complexity theory could also inform the implementation of CEPs. For example, founders and planners of CEPs need to recognize the complex nature of CEP. CEPs cannot be unchanged and need to adapt to the changing environment. By learning and building from the past, CEPs can evolve. Above all, complexity theory contributes to the understanding of CEPs and Program Evaluations.

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