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Extending systems thinking in planning and evaluation using group concept mapping and system dynamics to tackle complex problems

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ABSTRACT

Group concept mapping (GCM) has been successfully employed in program planning and evaluation for over 25 years. The broader set of systems thinking methodologies (of which GCM is one), have only recently found their way into the field. We present an overview of systems thinking emerging from a system dynamics (SD) perspective, and illustrate the potential synergy between GCM and SD. As with GCM, participatory processes are frequently employed when building SD models; however, it can be challenging to engage a large and diverse group of stakeholders in the iterative cycles of divergent thinking and consensus building required, while maintaining a broad perspective on the issue being studied. GCM provides a compelling resource for overcoming this challenge, by richly engaging a diverse set of stakeholders in broad exploration, structuring, and prioritization. SD provides an opportunity to extend GCM findings by embedding constructs in a testable hypothesis (SD model) describing how system structure and changes in constructs affect outcomes over time. SD can be used to simulate the hypothesized dynamics inherent in GCM concept maps. We illustrate the potential of the marriage of these methodologies in a case study of BECOMING, a federally-funded program aimed at strengthening the cross-sector system of care for youth with severe emotional disturbances.

1. Introduction

Recently there have been increasing calls for research, practice, programs, and policies to be grounded in systems thinking within the fields of evaluation (Patton, 2011; Williams & Imam, 2006) prevention science (Hassmiller Lich, Ginexi, Osgood, & Mabry, 2013), public health (Leischow et al., 2008; Luke & Stamatakis, 2012; Mabry, Marcus, Clark, Leischow, & Mendez, 2010; Mabry, Olster, Morgan, & Abrams, 2008), dissemination and implementation (Best et al., 2003; Burke et al., 2015; Hassmiller Lich, Frerichs, Fishbein, Bobashev, & Pentz, 2016; Powell et al., 2015), urban planning (Tozan & Ompad, 2015), and global health (Adam & de Savigny, 2012). Systems thinking can help stakeholders better understand how complex interconnections of multi-level factors influence public health, social, behavioral, or environmental problems (Hammond, 2009; Loyo et al., 2013; Mahamoud, Roche, & Homer, 2013; Proust et al., 2012; Senge, 2006; Sterman, 2006).

A variety of systems thinking methods have been applied to a range of issues relevant to evaluation and planning including, but not limited to, mental health service delivery, infectious disease control, and environmental planning. For example, group concept mapping (GCM) has been used to engage stakeholders to elucidate and synthesize factors shaping a wide range of systems problems and prioritize targets for action (Alafaireet et al., 2015; Bergeron & Levesque, 2014; Hatcher, 2010; Minh, Patel, Bruce-Barrett, & O'Campo, 2015; O'Campo, Burke, Peak, McDonnell, & Gielen, 2005; Vaughn, Jacquez, & McLinden, 2013). Causal Loop Diagramming (CLD) has been used to engage stakeholders to connect the complex cause-and-effect relationships influencing system outcomes in visual diagrams (Brennan, Sabounchi, Kemner, & Hovmand, 2015; Dyehouse, Bennett, Harbor, Childress, & Dark, 2009; Gillen et al., 2013; Hassmiller Lich, Minyard, Niles, Dave, & Gillen, 2014; Wittenborn, Rahmandad, Rick, & Hosseinichimeh, 2016). Systems science simulation modeling approaches, such as system dynamics (SD) or Agent-Based Modeling, have been used to

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quantify diagrammed relationships, inform evaluation targets, or compare intervention effects (Dray et al., 2012; Guo et al., 2001; Jones et al., 2006; Loyo et al., 2013; Mavrommati, Bithas, & Panayiotidis, 2013; Milstein et al., 2007; Perez et al., 2012; Riley & Ferguson, 2006; Riley et al., 2003; Stave, 2002, 2003; Tebbens et al., 2008; Thompson & Tebbens, 2012; Yonas et al., 2013).

Each of these systems thinking methods provides unique strengths that, when used together, can add value to program planning and evaluation by helping stakeholders explore systemic problems in different, but complementary, ways. We believe that there is no single "right" way to view a complex systems problem, and these methods can benefit from being used in conjunction with each other to advance learning. Through a case study of an initiative seeking to strengthen systems supporting transition-age youth with emotional and behavioral challenges in a community in the southeastern United States, we illustrate the potential benefits of integrating: (1) GCM – an approach for broadly soliciting input on factors affecting a complex problem; and (2) SD – an approach to enrich understanding of how identified factors interconnect to shape system-level outcomes over time. We describe the use of GCM in strategic planning, and then illustrate how SD inquiry might extend GCM results.

Systems thinking can help evaluation practitioners understand system complexity and plan with it in mind, which is necessary to overcome natural human tendency to simplify and resort to "Band-Aid" approaches that can be unintegrated or superficial, or to miss "unintended" consequences of actions (e.g., intervention, policy change) that undermine the effort over time (Sterman, 2006). While there are many approaches to systems thinking, one distinct approach grounded in SD directs practitioners to see problems from two vantage points – the forest and the trees (general and specific; patterns and events). SD projects often approach problems by attempting to understand complex dynamics (cause and effect relationships leading to observed outcomes over time) at a more detailed micro-level while maintaining clarity about how this detail fits within the broader system dynamics at the macro level. Practitioners are encouraged to embrace three thinking skills—"System as Cause Thinking, Operational Thinking, and Closed-Loop Thinking" (Richmond & Peterson, 2001). System as Cause Thinking pushes practitioners to identify system structure as the cause of problems rather than unchangeable factors imposed externally, perhaps requiring boundaries around investigation to be expanded. Operational Thinking drives us to describe the "plumbing" of systems in terms of stocks, flows, and other chains of variables determining change over time. Closed-Loop Thinking encourages us to identify the complex and often reciprocal interactions between influential variables, which lead to vicious/virtuous cycles (when an earlier change is reinforced within a system) or balancing forces (when the system counteracts change), and to evaluate or strategize with this feedback structure in mind. Together, this approach to systems thinking facilitates the development of solutions that are framed in this richer understanding of the sources of system behavior (e.g., limits to change, forces that seek to undermine or drive change for better and worse).

In this paper, we will explore the synergy of GCM (the focus of this special issue) and SD simulation—building off of a completed GCM project and illustrating how SD methods could be used to extend the work. GCM, more familiar to program planners and evaluators, can set the stage well for systems thinking as it offers an efficient method to broadly survey, organize, and prioritize factors contributing to an outcome (or set of related outcomes) under study with a broad and often diverse group of stakeholders. SD methods help a smaller group of stakeholders develop a more detailed, mechanistic hypothesis about how these (and perhaps other) factors interconnect to determine outcomes over time.

2. Supporting youth with SED: illustrating the integration of GCM and SD

Youth with SED transitioning to adulthood often face daunting challenges, including fragmented adult mental health services, loss of service entitlements, inadequate housing, and limited educational and job opportunities that are frequently further limited by substance use and/or criminal system involvement (Davis, Banks, Fisher, & Grudzinskas, 2004; Davis & Sondheimer, 2005; MDC, 2008). In late 2010, the Substance Abuse and Mental Health Services Administration (SAMHSA) funded a 6-year demonstration project that sought to improve support for transition-age youth aged 16–21 living in Durham, North Carolina who have SED (the term used for minors) or serious mental illness (the term used for adults) and who have become disconnected from supportive systems such as schools, family, mentors, and/or employment (Friedman, Katz-Leavy, Manderscheid, & Sondheimer, 1996).

The initial investment of over $5 million in one community's initiative, Building Every Chance of Making it Now and Grown Up (BECOMING), continues to support efforts to identify and address important gaps in fragmented local systems of care supporting youth transitioning into adult systems and independent adulthood. Evidence suggests that coordinated community approaches can help these high-risk youth (Burns, Schoenwald, Burchard, Faw, & Santos, 2000; Haber, Karpur, Deschênes, & Clark, 2008). Yet, communities lack guidance about how to select and implement such initiatives. Strategic planning to support this broad and important mission was critical, and planners turned to GCM to ensure priorities across stakeholder groups were heard.

2.1. Community-engaged strategic planning using GCM

Standard concept mapping methodology was employed (Kane & Trochim, 2007) including: (1) Preparation: generating the focus prompt, determining participants, and setting the project schedule; (2) Generation: brainstorming statements in response to the focus prompt; (3) Structuring: sorting statements for similarity, and rating statements on the dimensions of importance and feasibility; (4) Analysis: multivariate statistical analyses to represent ideas graphically through maps; (5) Interpretation: analysis of results in a facilitated session; and (6) Utilization: using results to address the intent of the project.

2.1.1. Sample

BECOMING leadership identified and recruited youth/young adults and parents/caregivers to participate in this study through email, flyers, and word of mouth. A total of 14 youth participated in the Generation phase and 28 participated in the structuring phase, with 22 youth completing both the importance and feasibility ratings. A total of 8 caregivers participated in the generation phase and 17 participated in the structuring phase. Neither youth nor caregivers participated in sorting. Agency staff were recruited to participate during BECOMING's "Full Partnership" planning meeting. Approximately 100 agency staff attended the meeting, and four additional facilitated sessions were held for the generation phase. A total of 31 agency staff participated in the structuring phase, with 18 agency staff completing the sort, and 20 agency staff completing importance and feasibility ratings. A total of 5 researchers also participated in the structuring phase, all of whom completed sorting only. The total number of participants in the structuring phase of the study was 81. A total of 23 participants completed the sorting, 61 participants completed the importance ratings, and 61 participants completed the feasibility ratings. Due to incomplete or repetitive responses, a total of 2 sort ratings, 8 importance ratings, and 6 feasibility ratings were not included in analyses.

2.1.2. Procedure

Brainstorming sessions involved asking participants in group settings to respond individually to the prompt: "For youth involved in BECOMING, one thing that affects successful transition to adulthood is . . . " Agency staff participated in five facilitated sessions in June 2011 and generated a total of 609 statements. Two additional sessions were held with youth participants in February 2012 and March 2012. Youth generated 134 statements. Lastly, two different sessions with caregivers were held in February 2012 and April 2012. Caregivers generated a total of 87 statements.

Across all brainstorming sessions, participants generated a total of 830 statements. The statements were edited by research team members to remove duplicates (Brown, 2005; Kane & Trochim, 2007). The initial statement set was analyzed using the KWIC (Keywords in Context) software program developed by William M. Trochim. An audit trail was created to track the evolution of the statement synthesis; indicating how the statements were merged; edited; or deleted and established transparency for the synthesis process (Brown, 2005).

To verify that the final set of 97 statements adequately represented the initial brainstormed set, a youth, a caregiver, two agency staff, and three researcher participants from the generation phase reviewed the statements. Each reviewer received a list of the 97 statements comprising the final statement set, as well as a unique set of 97 randomly generated statements that were drawn from the 830 original brainstormed statements. The reviewers were instructed to read through both lists and note whether the final set adequately captured all of the statements in the random list. The reviewers did not note any discrepancies, but did suggest a few minor changes in wording that were made to improve clarity of the final statement set.

After the generation phase, participants were invited to participate in the structuring phase in both in-person and electronic formats. Five in-person sessions were held for all participant groups to complete the structuring phase, and members of the research team were present to facilitate the data collection process. Three sessions took place at an agency setting, one at a library, and another at the Durham Public School's Staff Development Center. Agency staff and researchers had the option of completing the sorting and rating electronically using the Concept Systems Global MAX Software. Agency staff and researcher participants sorted the statements based on their perceptions of conceptual similarity. Youth, caregivers, and agency staff rated each statement using a 5-point Likert scale on the dimensions of perceived importance (1 = "relatively unimportant"; 5 = "extremely important") and feasibility (1 = "relatively unfeasible"; 5 = "extremely feasible").

2.1.3. Analysis and interpretation

Structuring data were analyzed using Concept Systems Global MAX. Together with one representative from each of the stakeholder groups, the research team engaged in a facilitated interpretation session held as a webinar. A five-cluster solution was selected and the following cluster labels were generated:

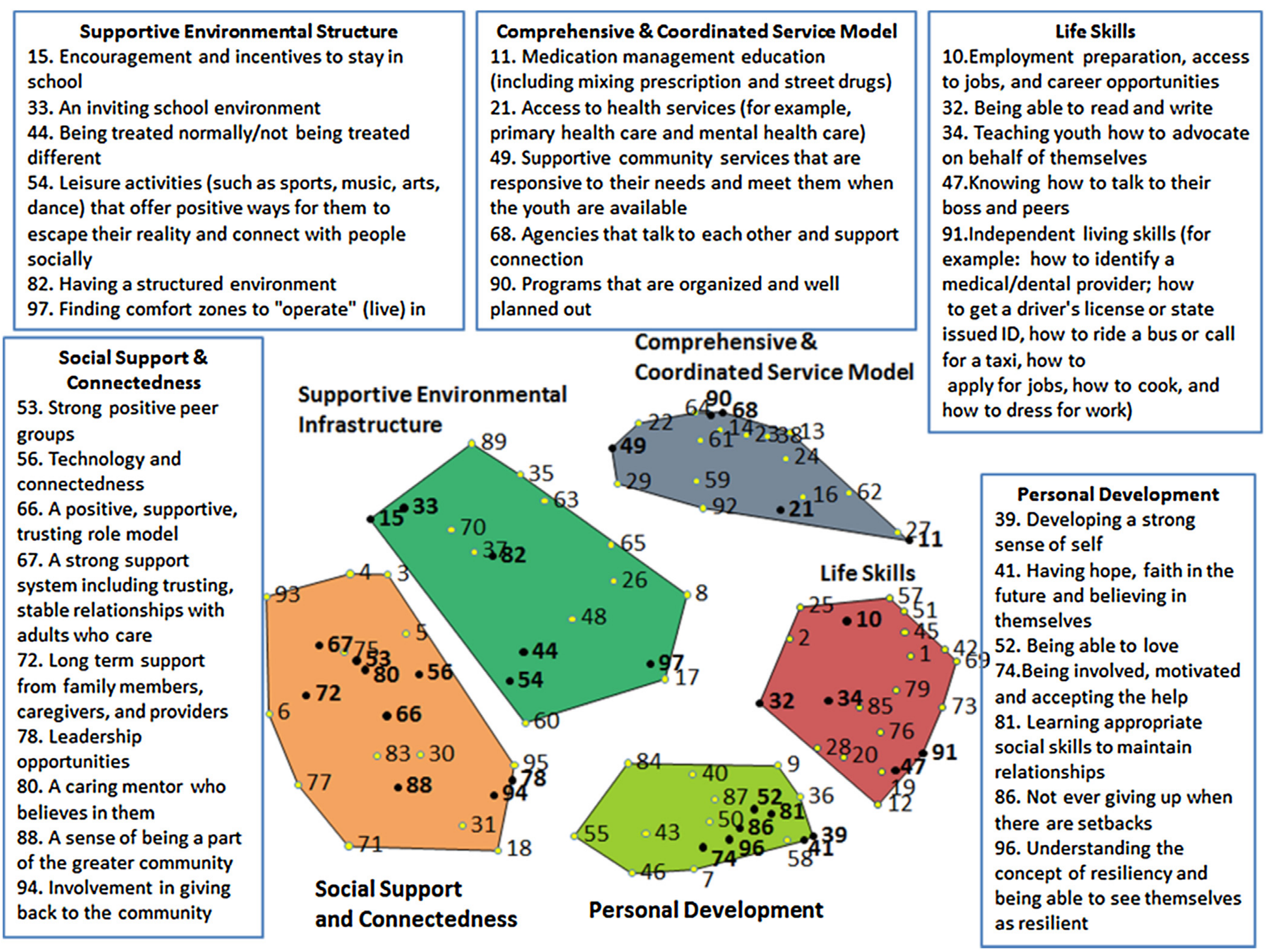

Fig. 1. BECOMING Concept Map: a five-cluster solution with statements rated above average in both importance and feasibility.

Comprehensive and Coordinated Service Model, Life Skills, Personal Development, Positive Social Support and Connectedness, and Supportive Environmental Infrastructure. Fig. 1 presents the final cluster solution overlaid on the point map (each point and corresponding number represents one of the 97 final statements). Statement numbers in bold were rated above average in both importance and feasibility, and are listed in text boxes within each cluster.

2.2. Enhancing GCM with SD

GCM provides a structured method for engaging large, diverse groups (i.e., hundreds of individuals participated in this project) using both synchronous (in-person) and asynchronous (CS Global Max) approaches. As an evaluation and planning tool, the strength of GCM is that it models diverse stakeholder perspectives and converges them into several core components in the form of concept maps. GCM also assures that differences in priorities between diverse and potentially marginalized stakeholders are appreciated (Urban, 2008). GCM offers an opportunity to quickly engage a large group of stakeholders to “see the forest” and begin to engage in Systems as Cause Thinking. Concept maps help stakeholders see the broad landscape around the issue under study, set priorities, and inform the boundary around an issue being studied.

GCM, however, provides limited engagement of Operational Thinking and Closed-Loop Thinking, which would inform understanding of how identified factors interconnect to shape system-level outcomes over time. Without this understanding, it can be hard to estimate accurately how alternate interventions under consideration actually change outcomes in the short-, medium-, and long-term (for example, GCM importance ratings might be erroneous or lack a common timeframe). Furthermore, convincing decision makers might require a more robust and mechanistic explanation for why prioritized actions are selected.

SD methods offer a systematic approach to enrich understanding of complex causal relationships between constructs illuminated in GCM. Diagrams can be tested, iterated, and quantified using available data. Quantified models, taking the form of dynamic computer simulation models, are often used to help a group of stakeholders – including people who live in, work in, are affected by, and make decisions about a system under study – learn what works best and why in the context under study.

SD was first introduced by Jay Forrester (Forrester, 1961) with a focus on engineering and business decision making, for example improving control of a complex supply chain. Since, it has been applied in a number of contexts to increase understanding of problematic complex system behavior and to support planning for more effective change (Homer & Hirsch, 2006; Hovmand et al., 2012; Sterman, 2000). SD offers a rigorous, well-described (scripted), stakeholder-engaged approach to uncover individual mental models, to support stakeholder discussion and synthesis of these in the form of explicit system diagrams, and to quantify, simulate, and test hypotheses in the form of SD models to determine their consistency with data (Sterman, 2000). While implementation of SD methods in practice is iterative, the general steps include: (1) defining the problem and system boundary; (2) creating an explicit (diagrammed) explanatory dynamic hypothesis about the system structure and causal linkages driving change in the system over time; (3) converting the qualitative dynamic hypothesis into a quantified simulation model, and testing the model against data and expert opinion; and finally, (5) using the model to facilitate learning about how the system behaves and how to impact it positively over time (Sterman, 2000).

To demonstrate the complementary value of SD in the BECOMING GCM project, our team created an SD diagram and model. Because we want to illustrate all steps in the SD process, we have generated a plausible (but not real) scenario with hypothetical data to test the emerging model. The model and data are available to the interested reader (see https://kristenlich.web.unc.edu/supphassmillerlich2016epp/). This model could also serve as a “concept model” (distinct from a GCM concept map); SD concept models are often used to help a group of stakeholders quickly learn about the SD approach while offering an existing but incomplete and/or wrong model to react to and improve (Richardson, 2013).

2.3. SD step 1: defining the problem and system boundary

The first step to building an SD model is to narrow the system boundary and identify a specific and achievable objective that will

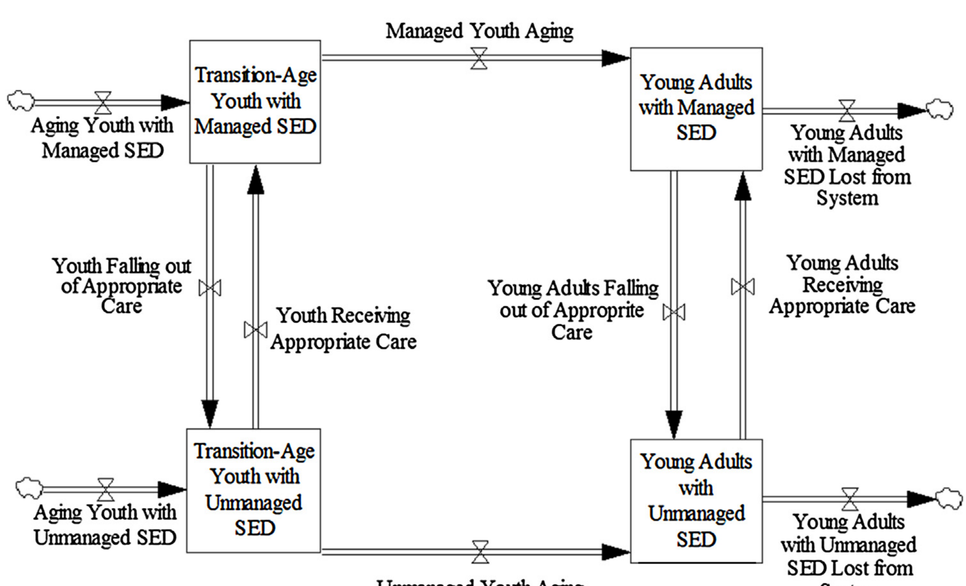

Fig. 2. Stock (boxes) and Flow (pipelines) Model: an operational system structure of managed and unmanaged transition-age youth and young adults with serious emotional disturbance (SED).

offer focus to the work and set expectations about what will be achieved. A first step is to engage in Operational Thinking—to describe (verbally and/or diagrammatically) the "plumbing' of the system.

A natural starting point in the BECOMING project involves documenting how transition-age youth with SED move in and out of having their mental health well managed through use of various supportive services over time. Given that supports are generally different for children (age 16–17) and young adults (18–21), we separate model stocks by age and the quality of management of the mental health condition. Stocks are variables that accumulate over time; stock variables are named and represented inside boxes in Fig. 2. Fig. 2 is a stock and flow diagram, indicating how transition-aged youth within BECOMING's target population might flow from one stock to another over time (flows are represented as double-lined arrows). The rate of flow, depicted with a valve on each pipeline, quantifies the number of units (youth) flowing over a fixed unit of time (e.g., week, month, year). New youth age into the transition-age youth stocks, emerging from a cloud indicating factors influencing management of younger youth are outside the boundary of the model. Similarly, young adults leave the system over time, either because they age out or completely disengage from monitoring. Clouds here indicate that these young adults are not tracked; they are also outside the model boundary as specified.

We enhanced the stock and flow model in Fig. 2 by adding the clusters identified through the GCM process (grey shaded boxes in Fig. 3). Single-lined arrows are used to define cause and effect relationships between these clusters and other variables or rates of flow within the model. Arrows from clusters in Fig. 3 explicitly indicate how either strengthening or degrading factors within each cluster are believed to most significantly alter flows among transition-age youth over time. The direction of the arrow indicates the hypothesized direction of an effect, from a variable that, if changed, triggers change in the connected variable. The plus or minus sign indicates the nature of the effect. A plus indicates that the two variables move in the same direction—an increase (or decrease) in the first leads to an increase (or decrease, respectively) in the second. A minus sign indicates that the two variables move in opposite directions—an increase (or decrease) in the first leads to a decrease (or increase, respectively) in the second. As changes ripple through systems, sometimes variables that are initially driven up will later be driven back down (for example, if a balancing feedback loop is involved). As such, it is important to realize that cause and effect linkages in SD diagrams can be read with change occurring in either direction. For example, there is a causal connection with negative polarity between 'social support and connectedness' and "youth falling out of appropriate care." An increase in social support and connectedness will trigger a decrease in the rate of youth falling out of appropriate care, dampening the deleterious effect of a flow from "youth with managed SED" to "unmanaged SED." The inverse is also true—a decrease in social support and connectedness will trigger an increased flow of youth falling out of appropriate care (and an increase in "unmanaged SED"). As another example, there is a causal connection with positive polarity between "comprehensive and coordinated service model" and "youth receiving appropriate care," implying that, along with other positive influences on this model, an increase in comprehensive and coordinated services would lead to an increase in the number of youth receiving appropriate care—drawing youth with unmanaged SED into the well-managed stock (and the inverse if the initial change in "comprehensive and coordinated service model" is in the opposite direction). This explicit diagram can be shared with stakeholders to validate the model or to identify evidence supporting modification and to create a shared mental model that connects GCM themes to outcomes. The macro thinking embodied in this model also allows one to discuss and hypothesize where, within this broad SD diagram, a work-group should focus their efforts to enhance desirable flows and mitigate undesirable flows to improve overall outcomes. An objective in our work was to further explore the GCM cluster of social support and connectedness and hypothesize how the flow of transition-age youth with SED into the "managed" state can be enhanced.

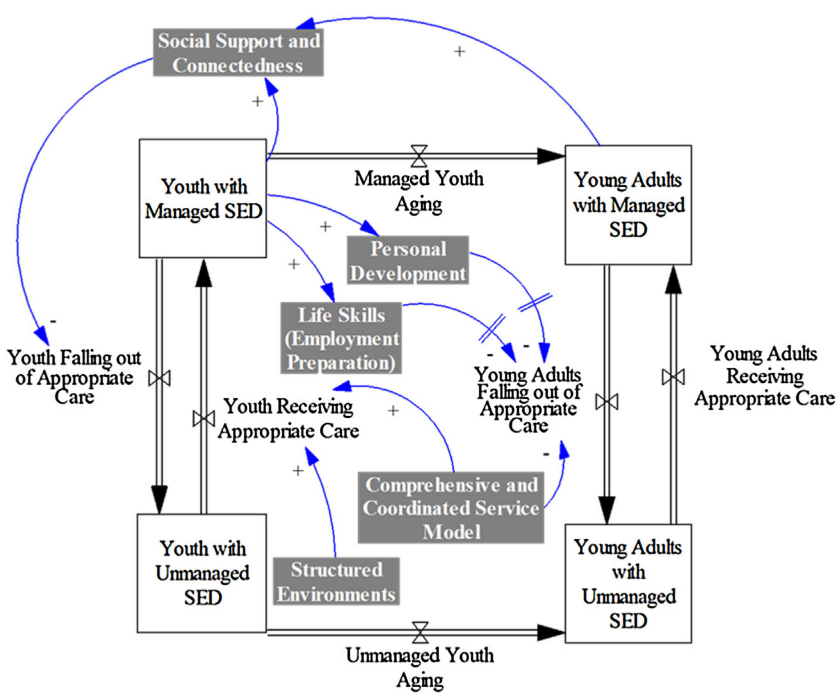

Fig. 3. Stock and Flow Model: key connection between GCM clusters (grey shading) and operational system structure.

2.4. SD step 2: creating a dynamic hypothesis

A dynamic hypothesis is an SD diagram that is developed to explain observed or speculated trends over time. For example, reinforcing feedback loops produce exponential growth or decay, balancing feedback loops create movement toward a steady state (desirable or not), and complex combinations of different loops and variables might produce more complex dynamics such as S-shaped curves or oscillation. Suppose BECOMING sought to explain trends in the number of transition-age youth with managed SED over time, as illustrated in the left side of Fig. 4 (hypothetical data). If stakeholders felt that change was concentrated around the construct of social support and connectedness, statements within this GCM cluster might be used to create a dynamic hypothesis to explicitly describe how social support and connectedness influences SED management among youth in the community. Important GCM statement-level constructs such as peer support and mentoring can add language and more detailed insights. The stock and flow diagram in the lower right of Fig. 4 presents one hypothesis about the system structure producing observed trends, adding detail to Fig. 2. Recall that a single-lined arrow connecting two stocks, rates, or variables indicates that a change in the first (the trigger) will lead to a change in the second (the effect).

Social support and connectedness can come in many shapes and sizes. In the example presented in Fig. 4, social support and connectedness comes from peer mentors. The number of peer mentors is a function of the number of “transition-age youth with managed SED” and the “percent of transition age youth who provide mentoring.” Arrows between these variables in the diagram indicate that an increase (or decrease) in either of these two variables will lead to an increase (or decrease) in social support and connectedness. Similarly, the number of “youth falling out of appropriate care” is a function of the social support and connectedness variable (the number of mentors), the “number of transition-age youth each mentor serves,” and the reduction in risk of becoming unmanaged that mentoring confers, quantified in this model as 1 = complete risk reduction, 0 = no effect. There is a + on the arrow connecting the number of managed transition-age youth to the rate of youth falling out of care, indicating again that an increase (or decrease) in the number of youth susceptible will lead to an increase (or decrease) in the number of youth falling out of appropriate care. All other variables have an inverse relationship with the rate of youth falling out of care (−); as the number of mentors, potential mentees, or risk reduction of falling out of appropriate care for mentored youth increase (or decrease), the rate of youth falling out of appropriate care decreases (or increases).

While stock and flow models encourage Operational Thinking about how people (in this case) flow between stocks over time and what affects rates of flow, sometimes another type of SD diagram – causal loop diagrams (CLDs) – are used to simplify diagrammatic documentation of system behavior and encourage Closed-Loop Thinking. These diagrams include variables, causal linkages, and feedback loops, but omit the stock and flow structure. This can be particularly useful when an SD initiative is trying to better understand or design actions to improve a component of the larger system, and is focused on impacting the force of relevant closed (reinforcing and balancing) loops, perhaps considering which loops dominate system outcomes or are amenable to intervention. Cause and effect are seldom completely direct and linear and feedback loops illustrate real world complexity when chains of cause and effect circle back to affect a variable earlier in the sequence. When triggered, a reinforcing loop amplifies changes and can drive exponential growth or decay in variables within the

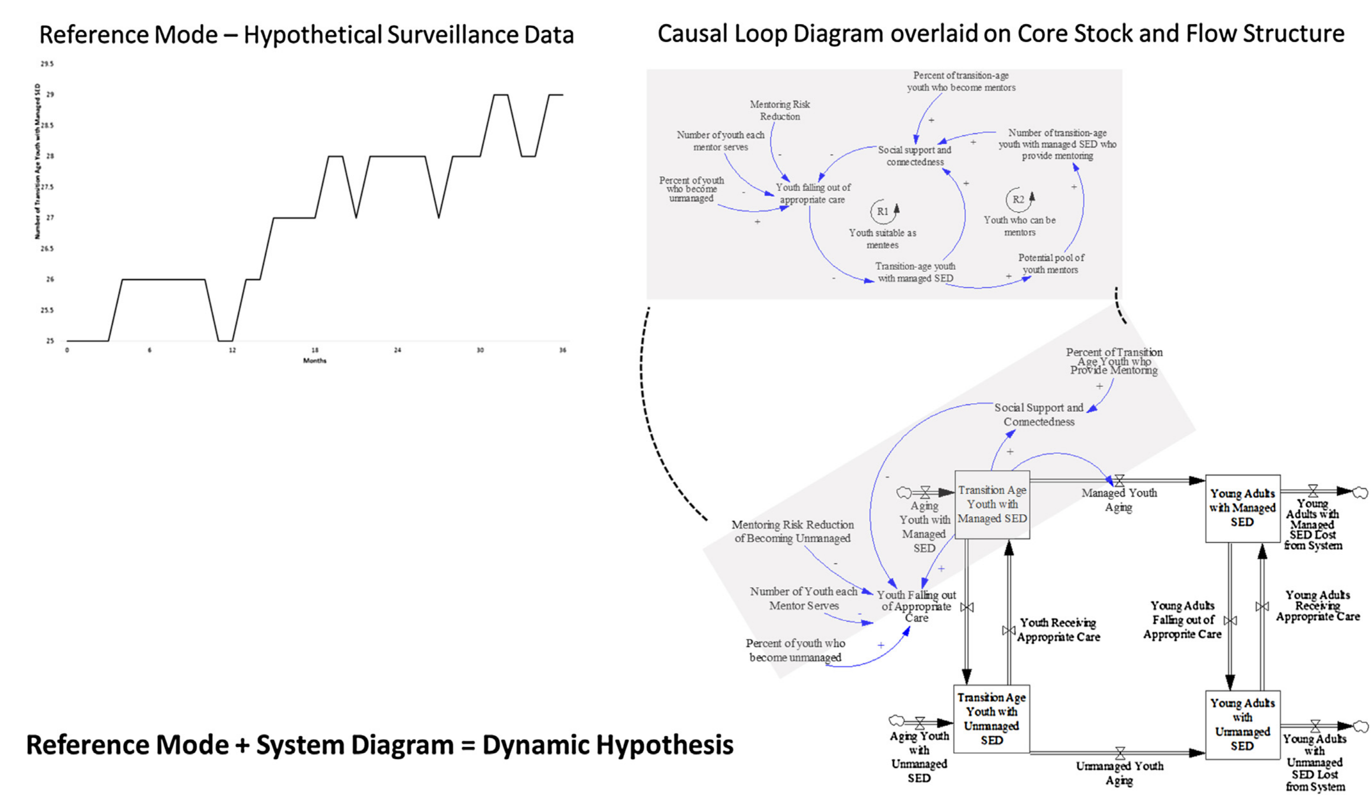

Fig. 4. Hypothetical Dynamic Hypothesis: Hypothetical data and corresponding SD diagrams explaining how social support and connectedness affect the number of transition-age youth with managed SED over time. The hypothesized dynamics of a mentoring program for youth with serious emotional disturbance (SED) diagrammed in the bottom right are placed on top of core stock and flow structure (boxes and pipelines, from Fig. 2) to illustrate operational system structure. A causal loop diagram is used to simplify dynamics to support Closed-Loop thinking (top right).

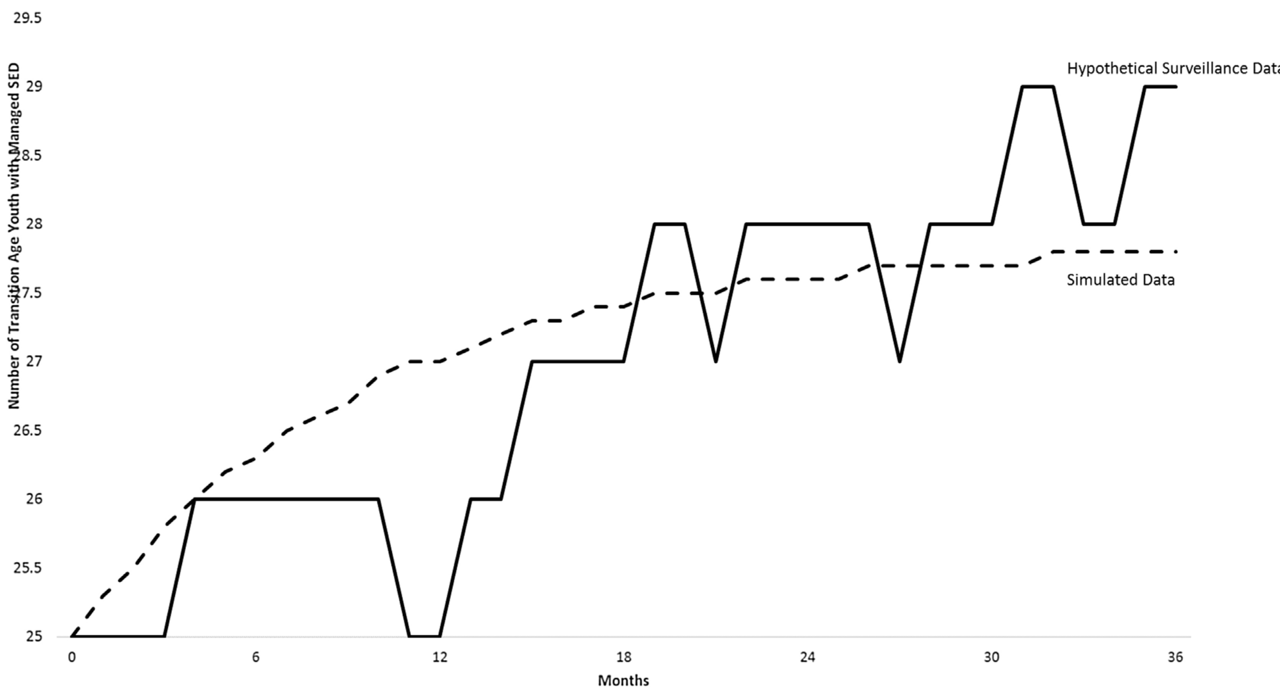

Fig. 5. Behavior over Time Graph to Assess Consistency between Simulated and Actual Data: Predicted number of transition-age youth with managed SED under the best-fitting (calibrated) model scenario (dashed line) based on Fig. 4 compared to hypothetical surveillance data (solid line). In the best-fitting scenario, 24% of transition-age youth provide mentoring (2 mentees each), which confers a 75% reduction in the monthly risk of becoming unmanaged.

loop. A balancing loop, on the other hand, dampens earlier change. Two reinforcing loops in Fig. 4 describe how increasing (or decreasing) the number of transition-age youth with managed SED increases (decreases) both the level of social support and connectedness among youth – both driving up (down) the number of managed youth that might be mentored (R1) and mentoring others (R2). As long as these loops dominate, mentoring programs will be somewhat self-sustaining – both creating their own pool of future mentors and retaining youth sufficiently engaged in supportive services to consider being mentored. While this is good, it also means that expecting peer mentoring to be an ongoing part of a high-functioning program is important.

2.5. SD step 3: developing a simulation model

Converting diagrams into quantified computer simulation models allows dynamic hypotheses to be tested, and explore the degree to which the model be made consistent with available data. We used the SD simulation software program, Vensim DSS for Windows, Version 6.3D Double Precision (www.vensim.com), to convert the stock and flow structure depicted in Fig. 4 into operational model equations. We include a Vensim model file and description of parameter values used in an online Supplement (see https://kristenlich.web.unc.edu/supphassmillerlich2016epp/). The interested reader can download a free trial of Vensim, on which the model will run (http://vensim.com/free-download/).

To illustrate, assume stakeholders sought to test the dynamic hypothesis in Fig. 4 using surveillance data on the numbers of transition-age youth and engaged young adults with managed and unmanaged SED over time. We could compare surveillance data against our simulation model output to refine the model and estimate unknown parameters. Regarding unknown parameters, it is common to have incomplete data when building SD simulation models. Common practice is to obtain best estimates from additional data, scientific literature and/or expert opinion and then to calibrate, or fine tune, these parameters to maximize consistency between simulated and actual trends. The trend lines in Fig. 5 present hypothetical surveillance data (solid line), and the simulated equivalent for the best-calibrated version of the model (dashed line).

Fig. 5 illustrates the extent to which the dynamic hypothesis presented in Fig. 4 can be made consistent with data; it reflects the scenario where 24% of transition-aged youth served as mentors, each mentor mentored 2 youth at a time, and mentored youth exhibited a 75% monthly reduction in the risk of becoming unmanaged. If BECOMING sought to test such a model, stakeholders would need to question whether mentoring at this level is happening. If not, additional changes in the model would be needed. It might also be worth investigating what additional changes occurred between months 6 and 15–the period of greatest divergence between simulated and surveillance data.

2.6. SD step 4: using the model to facilitate learning

A common objective of both GCM and SD initiatives is strategic planning. Using SD allows a better understanding of system behavior and local context so that planners can engage with the resulting GCM and SD models to develop specific targets for action ("leverage points") that result in high-impact change. Once confidence is built in the model's accuracy, the simulation model is used to assess the likely impact of various actions (intervention scenarios) to inform decision-making about which to investment in.

One objective of BECOMING is to learn how to leverage existing supportive services and resources in the community to increase and sustain youth support. A facilitator might ask the group to pose "what if" questions to learn how changes in the model would impact outcomes as compared to the simulated current context ("base case"). Considering the social support and connectedness example (Fig. 4), BECOMING stakeholders might wonder whether increasing the number of peer mentors has an impact on reducing the number of youth who go from managed to unmanaged SED. Stakeholders could develop several scenarios specifying different values for the percent of youth who act as mentors, potentially

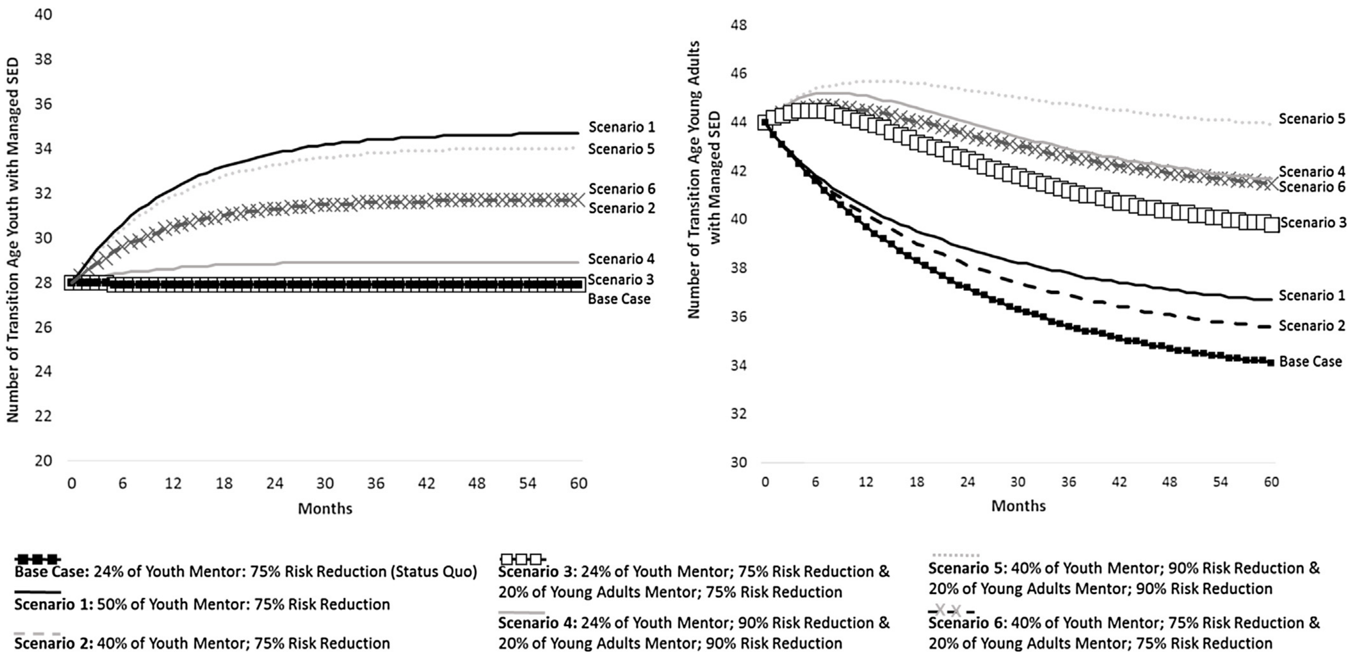

Fig. 6. Behavior over Time Graph to Project Relative Effects of Different Intervention Scenarios: The number of transition-age youth (at left) and young adults (at right) with managed SED under a hypothetical base case and six alternate intervention scenarios, generated with a System Dynamics simulation model built from Fig. 4 and available for the interested reader to run (see Supplemental files 1 and 2 for the model and parameter values used in each scenario, respectively, available at https://kristenlich.web.unc.edu/supphassmillerlich2016epp/).

adding young adult mentors, and their effectiveness (i.e. risk reduction of mentored youth becoming unmanaged) and use the simulation model to test mental models/understand outcomes. For example, Fig. 6 presents results from simulating a series of six scenarios compared to the base case, i.e., no additional intervention. The six scenarios vary: (1) the percent of youth who mentor from 24%, the current level, up to 50%, (2) the percent of young adults who mentor from zero, the current level, up to 20%, and (3) the mentored youth's monthly reduction in the risk of becoming unmanaged from 75% (the current value) to 90%. Simulating scenarios can help the group learn which targets for change confer the most substantial improvements over time While scenario 1 (increasing youth mentors) improves the number of transition-age youth that are well-managed most substantially, it does not have a very substantial impact on the number of well-managed young adults. Scenario 6, which has a comparable increase in mentoring (split between transition-age youth and young adults) has a larger total effect across age groups.

Strategic decisions are not typically made based on impact alone. With simulation results in hand the group might also engage in a discussion about the feasibility of alternate scenarios and how they may (or may not) leverage current strengths in the community. This enables a richer conversation about the relationship between resources required and improvement in outcomes across scenarios than is possible without quantitative impact estimates. The simulation model could be used to estimate how much change in the number of mentors (youth and/or young adults) or effectiveness of current mentors would need to be made for a fixed number of additional youth and/or young adults that are well-managed, to facilitate comparison.

GCM statement-level results could once again illuminate variables to include in SD simulation scenarios. For example, leadership opportunities and youth/young adults' sense of being a valuable part of the greater community were rated as highly important in GCM (Fig. 1). Fig. 7 documents, in the form of a CLD building off of Fig. 4, the hypothesis that if youth who serve as mentors are empowered appropriately and guided to re-envision mentoring as an opportunity to be community leaders, their own feelings of connection to the community will increase, which will lead to a decrease in their own chances of falling out of appropriate care. Being a mentor in this case more substantially supports mentors (not just mentees) engagement and outcomes. BECOMING stakeholders would be asked to estimate changes in specific model parameters driven by the enhanced mentoring program. For example, they would need to estimate the extent to which engaged mentors will be less likely to disengage from supportive services, whether there would be spillover effects on their mentees, and resource requirements. All of these parameters could be estimated (with plausible ranges) to learn about the potential impact on outcomes. Or, a small study could be implemented to estimate these parameters directly.

Sessions using SD models to guide learning can range from single day "action labs" (Hassmiller Lich et al., 2014; Loyo et al., 2013; Luna-Reyes et al., 2006; Minyard, Ferencik, Ann Phillips, & Soderquist, 2014; Stave, 2002, 2003) to shorter meetings spread out over time. However, intense interaction with a model coupled with facilitation ensuring that a systematic scientific method is applied to scenario development and mental model testing (Mass, 1991; Sterman, 2006) can be quite impactful (Loyo et al., 2013).

3. Conclusion

Thinking in causal linkages and feedback loops is a new way of understanding reality for people used to thinking of systems in terms of their components and linear relationships between parts (e.g., logic models or flow charts). Both GCM concept maps and SD models integrate and visually depict people's mental models of systems in terms of relevant variables/constructs and cause-and-effect relationships between them. Discussing and integrating results from these methods could help BECOMING stakeholders develop shared mental models of the elements and the interaction of those elements in the system affecting transition-age youth.

While there is tremendous potential in linking GCM and SD for strategic planning or evaluation, there are barriers. Integration

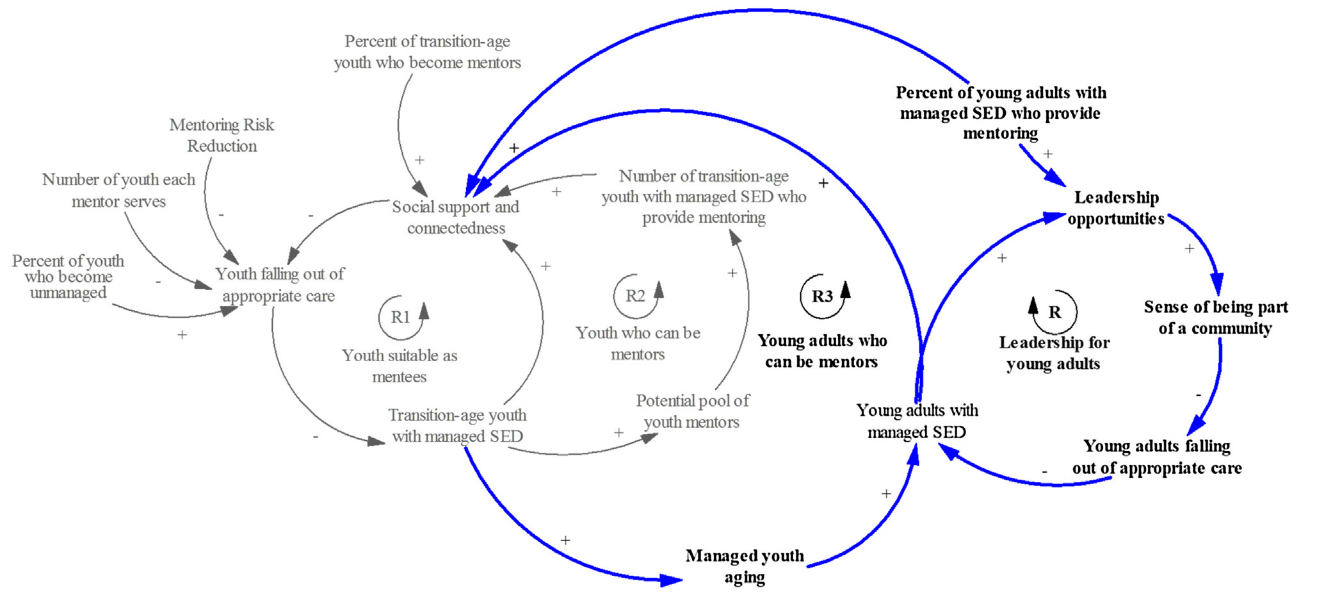

Fig. 7. Causal loop diagram (CLD) expanding Fig. 4, which described the effects of peer mentors on increasing engagement among mentees, to include additional important and feasible constructs from GCM that could strengthen the effects of mentoring programs (R1 and R2 in light gray were previously described; R3 and R4, indicated with heavy arrows, are new). This diagram represents a complexity-aware theory of change, documenting a larger set of interconnected leverage points at which synergistic intervention could be targeted and evaluated during strategic planning.

requires introducing another method and engaging stakeholders in model building, hypothesizing and testing. And like GCM, SD imposes a response burden on participants to acquire sufficient understanding of the process and devote the necessary time for this effort. From the standpoint of the evaluator, integrating SD with GCM means having sufficient expertise on both methods and having access to the specialized software necessary for both methods. In spite of these limitations the integration of SD and GCM addresses a need for practice change, programs, policies, and assessments to be grounded in systems thinking.

Some of the suggestions explored in this paper require little additional data for a group to undertake (informing SD focal problems and model boundaries via GCM, identifying SD variables via GCM), while others will require substantial extension of GCM analysis with previous or new participants. While a full introduction to SD was outside the scope of this article, we have tried to refer to seminal resources. There is an emerging movement to "script" or describe discrete activities that could be woven together to build up a full SD project (Ackermann, Andersen, Eden, & Richardson, 2011; Hovmand et al., 2012; Hovmand, Rouwette, Andersen, & Richardson, 2015). But, we would be remiss not to note the steep learning curve required to become an expert SD modeler, and the value of collaborating with more experienced modelers as you are learning.

While SD offers an approach to "connecting the dots" between GCM constructs, several other cautions are important for teams preparing to use the method. Stakeholders become quite adept at the kind of thinking SD espouses (Hovmand, 2014), but it takes careful effort and teamwork (Richardson & Andersen, 1995). The time investment required for stakeholders to be meaningfully engaged (a minimum of 4 h) and the limit imposed on group size to assure effective group process (Vennix, 1996) can impede an SD initiative's ability to engage a breadth of stakeholders in deep, mechanistic, systems thinking. SD projects can also be resource intense and require considerable time to produce, test, and iterate useful quantitative decision-support models.

Both SD and GCM recognize the value of engaging a variety of diverse stakeholders and the importance of garnering their support and commitment to address complex problems. Both methods seek to broaden stakeholders' understanding of problems, though each approach is distinct and we believe, complementary. To sum, GCM can be used to enhance SD by providing a platform for engaging a large and diverse group of stakeholders in developing an understanding of important factors in a complex system. SD can be used to enhance GCM by guiding stakeholders in connecting GCM statements and constructs within hypotheses in the form of diagrams about how key factors interconnect to determine outcomes over time. These SD diagrams can be quantified and simulated to test understanding of the hypothesized dynamics inherent in the resulting concept map. GCM could be used again, after an SD component of a project, to further brainstorm, sort, and prioritize inputs reacting to the emerging model (for example, more broadly brainstorming missing variables from dynamic hypotheses or additional action ideas for change).

We encourage users of GCM to explore the potential of using SD to extend their systems thinking activities. While SD simulation can be resource intense, diagramming can be readily learned and can push your Operational and Closed-Loop Thinking, enriching your team's understanding of the interconnected set of factors affecting outcomes over time. Doing so can help you understand the ways in which the system contributes to undesirable outcomes (System as Cause Thinking) – expanding potential targets for action and informing potentially more impactful and sustainable system change (Meadows & Wright, 2008).

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