Integrating Systems Science and Community-Based Participatory Research to Achieve Health Equity

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Unanswered questions about racial and socioeconomic health disparities may be addressed using community-based participatory research and systems science. Community-based participatory research is an orientation to research that prioritizes developing capacity, improving trust, and translating knowledge to action. Systems science provides research methods to study dynamic and interrelated forces that shape health disparities. Community-based participatory research and systems science are complementary, but their integration requires more research. We discuss paradigmatic, socioecological, capacity-building, colearning, and translational synergies that help advance progress toward health equity. (*Am J Public Health*. 2016;106:215–222. doi: 10.2105/AJPH.2015.302944)

Despite a research emphasis on addressing health disparities, there are persistent and widening gaps in health outcomes.[1] Research evidence has led to recognizing that interactions among biology, behaviors, socioeconomic status, and environments over time give rise to health disparities in a manner not easily understood or addressed using reductionist approaches (e.g., regression, randomized controlled trials).[2] There is a critical need for new research approaches that can improve knowledge about forces shaping health disparities and advance the translation of knowledge into action in real-world systems.

Community-based participatory research (CBPR) is recognized for its capacity to effectively engage with communities suffering from health disparities.[3] CBPR includes the participatory and equitable involvement of community members and researchers, colearning processes and local capacity building, systems development that builds on community strengths, and empowering processes that achieve a balance between research and action.[4] This approach has produced many benefits, including improved research quality, increased dissemination, the implementation of interventions, and enhanced community and academic research capacity.[5] Minkler states, "CBPR is not a research method, but an orientation to research."[6(pS81)] CBPR not only acknowledges complexity and the need to engage diverse perspectives,[6,7] but it also draws tools from other disciplines to understand or analyze the complex forces shaping health disparities.

Systems science is an interdisciplinary field that involves a diverse array of theories and methodologies with the purpose of improving our ability to understand complex problems.[8] Complex problems are composed of heterogeneous and interacting parts that influence the overall behavior of the system in ways that cannot be easily reduced to a single (or even several) mechanism.[9] Systems science methods provide both structured qualitative and computational techniques to navigate complex systems. Qualitative techniques integrate relevant theory and experiential "mental models" to support transdisciplinary learning and collaboration. Computational techniques provide analytic tools to improve understanding of characteristics of complex problems, including changes over time, delays between cause and effect, nonlinear relationships, and feedback (i.e., "ripple effects" that are reinforced or balanced).[8] Although systems science is known for its potential to understand complexities associated with health disparities,[2] most systems science research in public health does not meaningfully focus on developing community capacity to address health challenges over time.

CBPR and systems science have seldom been considered for their combined potential to address health disparities.[2,3] The fit between these diverse, but likely synergistic, approaches has been recognized with limited application to community development issues.[10–12] Public health can benefit from these efforts and advance the use of an approach that integrates CBPR and systems science. We introduce systems science and highlight its prospective synergy with CBPR.

SYSTEMS SCIENCE

Systems science is an interdisciplinary field that is conceptually grounded in a concern with "interrelationships between parts and their relationships to a functioning whole."[13(p539)] Overall, the field seeks to improve clarity about boundaries of and relationships within systems. Systems science approaches belie simple categorization, but they range from qualitative problem structuring to quantitative computational methods. Problem-structuring methods contend with problems that are ill-defined or in disagreement across system stakeholders and focus on developing a shared understanding of the

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This article was accepted October 8, 2015.
doi: 10.2105/AJPH.2015.302944

system influencing an issue. To do this, problem-structuring methods use structured group facilitation, which often involves visual diagramming techniques.[14] Computational methods focus on the development and use of statistical or simulation models to understand well-defined problems related to a system of interest.

In public health, systems science applications have largely been focused on computational methods.[8,15–17] Although these approaches are highly relevant for their ability to improve the understanding of social and spatial interrelationships related to health disparity issues, problem-structuring methods have received less attention than have computational methods. Problem-structuring methods can address health disparities, especially when mechanisms contributing to and solutions for addressing them are under debate, unclear, or difficult to quantify. Furthermore, problem-structuring approaches arose (in part) from the recognition that greater stakeholder involvement and commitment was needed to address relatively subjective issues[18]—making them well suited for CBPR.

Although public health has not emphasized using systems science problem-structuring methods, there are exceptions and emerging examples (e.g., Gillen et al.[19]; Kitson et al.[20]). Furthermore, disciplines such as community operations research[10,12] and community-based system dynamics[11] exemplify the potential of systems science and CBPR integration to address health issues. Researchers and community draw from both problem-structuring and computational methods to collaboratively define issues, explore system influences, and implement actions, throughout which, attention is given to trust and power dynamics. Yet, more work is needed to advance this type of integration in public health. We have highlighted a few key system science approaches with health disparity–related examples that describe both computational methods most often used in public health[21–23] and problem-structuring approaches[24,25] (summaries of these and additional approaches[26,27] are available as a supplement to the online version of this article at http://www.ajph.orgtable).

Soft Systems Methodology

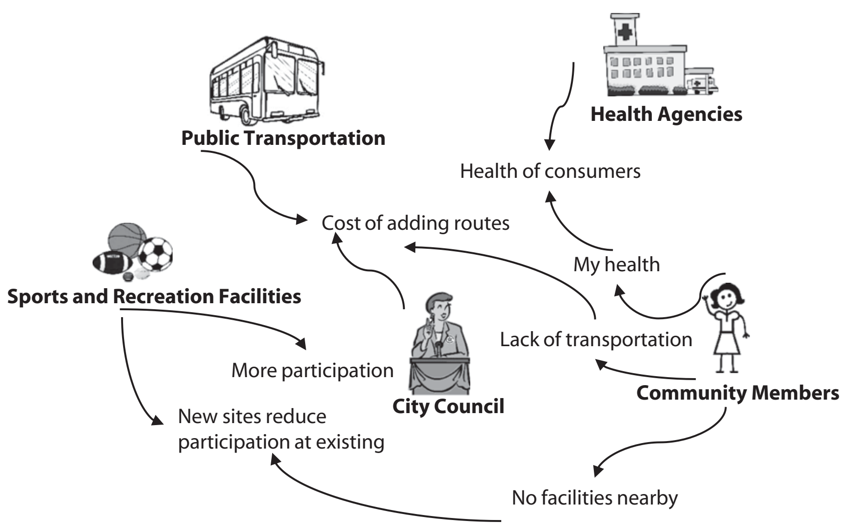
Soft systems methodology is a problem-structuring approach used when the problem is not readily apparent, is evolving, or is perceived differently among system stakeholders (Figure 1). Stakeholders participate in creating visual models called "rich pictures" that are used to guide action-oriented processes to consider system changes.[24] Often the process is purely qualitative: as changes are implemented, the real-world process and results are compared with the rich pictures, which are subsequently refined and used to guide additional system changes. Researchers sometimes combine soft systems methodologies with computational or other quantitative analyses.[29–31]

A recent study integrated soft systems and geographical information systems analysis to explore and map socioeconomic disparities in physical activity and determine locations for a new recreational facility.[31] The researchers held a series of interviews, discussions, and workshops with stakeholders (e.g., public transportation providers, recreational services staff) in which they used a rich picture to explore recreational sports participation from each stakeholder's perspective and to relate and integrate these perspectives. The researchers then used geographical information systems analyses to identify locations for a new recreational facility that would achieve balance from the stakeholders' perspectives and promote use among lower-income communities.

System Dynamics

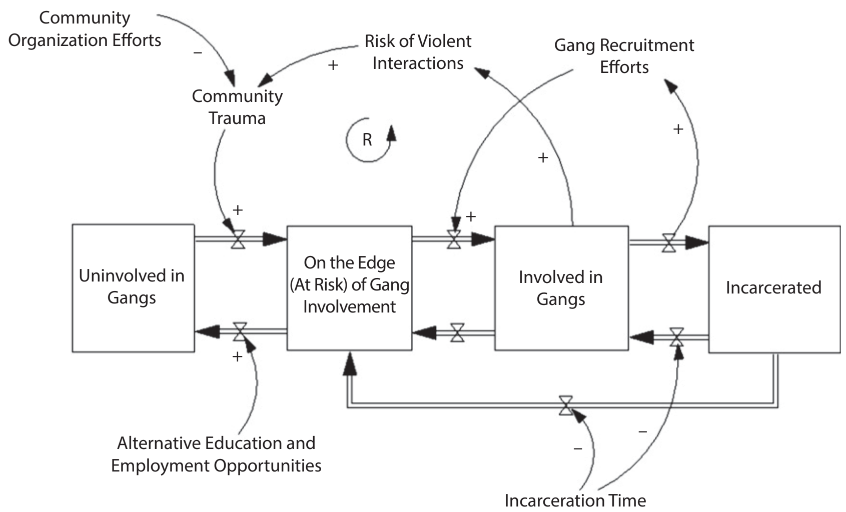
System dynamics is an approach that uses a range of problem-structuring and computational methods to understand and analyze the behavior of complex systems over time (Figure 2).[23,32,33] System dynamics involves a diagramming language that is amenable to moving from qualitative visual diagrams to quantitative models to hypothesize the cause and effect relationships leading to observed system behavior. For example, models involve components called stocks (i.e., variables that accumulate or depreciate over time, e.g., people, diseases, or currency) and flows (i.e., rates that change these stocks, e.g., births, disease incidence, or interest rates) that can be first diagrammed visually (on paper or electronically). The visual diagrams can be translated and built in computer software, quantified and calibrated with data, and used to simulate the impact of possible policies and interventions.

Computational modeling is foundational to system dynamics, but the importance of stakeholder engagement is recognized.[34,35] Some researchers have noted the power of



Source. Figure is inspired by Taylor et al.[28] but is intended to illustrate methods only. Please see Taylor et al.[28] for information on specific research processes, methods, and outcomes.

FIGURE 1—Example Soft Systems Model (Rich Picture): Stakeholder Views of Recreational Facility Use



Source. Figure is inspired by Bridgewater et al.[32] but is intended to illustrate methods only. Please see Bridgewater et al.[32] for information on specific research processes, methods, and outcomes.

FIGURE 2—Example System Dynamics Model: Youth-Related Gang Violence

stakeholder engagement throughout the modeling process to aid communication, learning, and commitment to action.[25,35] Thus, group model building arose as a participatory process to qualitatively define system problems, build visual and quantitative models, and interpret simulation results. In system dynamics, the use of group model building varies, but it is central to community-based system dynamics,[11] and examples of community-engaged and participatory health research using system dynamics have emerged in the literature.[36–39]

Bridgewater et al.[37] developed a system dynamics model by engaging with community stakeholders (e.g., gang-involved youths, violence prevention programs) to understand gang-related violence in an urban community. In the model, stocks included youths uninvolved in gangs, associated with gang members, "on the edge" of becoming a gang member, involved in gangs, and incarcerated. Flows between the stocks represented the transition of youths into and out of gang involvement, which was influenced by variables such as community trauma, risk of violent interactions, and gang recruitment efforts. The final model was simulated to test the impact of intervening at various flows (i.e., transition points into and out of gangs). For example, simulations tested whether reducing the recruitment of on the edge youths into gangs (i.e., the rate of transition between on the edge to gang member stocks) or increasing incarceration rates (i.e., the rate of transition between gang member to incarcerated stocks) resulted in the greater reduction in youth-related violence over time.

Agent-Based Modeling

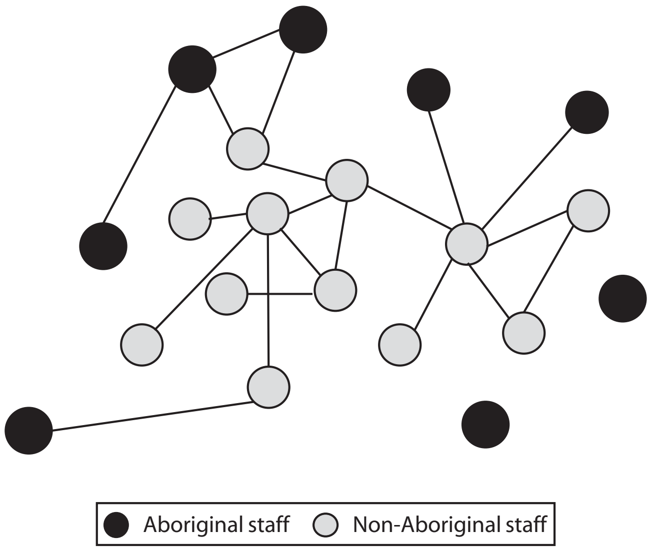
In the health field, agent-based modeling typically involves creating artificial societies (Figure 3).[21] These artificial societies contain individual entities: agents that represent, for example, people, organizations, or objects. The agents are given spatial or network locations and assigned characteristics and rules for how they interact with each other and their environment over time. Agent-based models are simulated to understand how the agent-level details lead to emergent system behavior. Agent-based modeling has been applied within community-engaged environmental sustainability and agriculture research,[40–43] but there are fewer examples within community-engaged health research.

Auchincloss et al.[44] used an agent-based model to explore the role of residential segregation and food resource distribution in shaping socioeconomic disparities in dietary behaviors. Agents in the model included food stores (assigned as healthy or unhealthy) and households (assigned as low, medium, or high economic status). Model rules governed where households shopped, where stores were located, and the types of food sold. For example, model parameters and functions shaped where households chose to shop on the basis of food preferences and geographical proximity, where stores chose to locate, and the

Note. Computational model formulations create interactions of food stores and households that determine the attributes of each food store and household at every time step.

Source. Figure is inspired by Auchincloss et al.[40] but is intended to illustrate methods only. Please see Auchincloss et al.[40] for information on specific research processes, methods, and outcomes.

FIGURE 3—Example Agent-Based Model: Dietary Inequalities in the Context of Residential Segregation



Source. Figure is inspired by Fuller et al.[45] but is intended to illustrate methods only. Please see Fuller et al.[45] for information on specific research processes, methods, and outcomes.

FIGURE 4—Example Network Analysis Model: Care Coordination Networks of Health Care Providers

types of food they sold (i.e., healthy or unhealthy) on the basis of customer demand. The simulations indicated that residential segregation reinforced disparities and interventions needed to address food preferences and access to inexpensive healthy foods to improve diets among low-income populations.

Network Analysis

Network analysis focuses on relationships among entities within a system, which can be individual people, organizations, places, or job tasks (Figure 4).[22] Researchers typically create quantitative models (although qualitative approaches to network mapping are possible) by capturing data about the system entities and their interconnections. Connections might reflect many links, such as communication, collaboration, data sharing, influence, assignment, or trust. This information is used to visualize and analyze network structure and properties and answer questions such as "Are there certain individuals more highly connected to others?" and "How do connections influence behaviors?" Network analysis has been increasingly applied in community-based health research.[45–47] For example, several health coalitions have used network analysis to understand and analyze how connections among organizations and agencies influence their efforts.[48–51]

In Australia, Fuller et al.[46] used participatory network analysis to engage with clinic staff to understand health service delivery to underserved Aboriginal populations. The researchers surveyed staff from a health service system—which included traveling clinics for Aboriginal communities and a central coordinating clinic—regarding their links to other staff when exchanging information and coordinating care. They diagrammed the survey data, which revealed important information about the structure and delivery of care.

SYNERGIES BETWEEN SYSTEMS SCIENCE AND CBPR

We identified 5 areas of synergy between systems science and CBPR:

1. paradigmatic,
2. socioecological,
3. capacity building,
4. colearning, and
5. translational (data available as a supplement to the online version of this article at http://www.ajph.org as Figure S1).

The synergies highlighted are not dichotomies; that is, the insight and tools from one approach are not wholly unfamiliar to the other. Rather, the approaches often overlap and emphasize complementary aspects of research that make integration advantageous.

Paradigmatic Synergy

Both systems science and CBPR trace their roots to paradigmatic shifts in scientific thinking away from reductionist, positivist paradigms. For systems science, origins are often traced to general systems theory,[52] which arose from concern that reductionist thinking was losing sight of phenomena that could not be broken down into component parts.[53] CBPR is grounded on critical and constructivist paradigms, which argue that reductionist thinking does not appropriately consider the potential for ever-changing, multiple, and socially constructed realities.[7] Both systems science and CBPR acknowledge that different theories and methodologies are needed depending on research problems and contexts,[7,18,54] and both use a mixture of deductive and inductive logic (and quantitative and qualitative methods) to understand and address complex problems.

Systems science and CBPR paradigms frame research in complementary ways with the capacity to generate better quality and more comprehensive information about health disparities. Systems science recognizes the importance of understanding systems as a whole (e.g., how transactions across system components give rise to outcomes over time). CBPR recognizes the importance of social and cultural context and community-developed research perspectives. For example, their integration could benefit research focused on healthy eating. Systems science could compel the exploration of how "food systems" that involve transactions among policy, food availability, and community norms and beliefs relate to changes in eating behaviors over time. A CBPR approach would engage community stakeholders to frame research questions that improve the understanding of their perceptions and experience of food (e.g., considering variable definitions of healthy food over time).

Socioecological Synergy

A socioecological approach (i.e., the consideration of multiple levels of influence) is inherent in both systems science and CBPR. Systems science recognizes that important variables in systems lie and interact across levels and must be integrated to better understand disparate health outcomes and design more significant interventions.[17,19,55] CBPR often involves efforts that target factors at multiple levels, including individual, social, and policy levels.[6,56]

Systems science and CBPR produce complementary information about multilevel systems with the potential to improve identifying the optimum set of strategies to address health disparities. CBPR identifies and develops interventions that build on strengths at multiple levels within a community (e.g., individual leaders, organizations)—a facilitator of successful policy and environmental change.[6] However, complex problems such as health disparities can exhibit policy resistance because views of system influences are too narrow and complex problem characteristics (e.g., delays between cause and effect) are not intuitively understood, which often results in well-intentioned efforts with limited or even negative effects.[34,35] Systems science methods help overcome these challenges by widening system views and simulating models to understand the impact of interventions.[34,35]

For example, school suspension and expulsion policies are criticized for exacerbating academic deterioration and subsequent problems (e.g., substance abuse).[57] Social network analysis can elucidate important relationships that underpin students' problematic behaviors (e.g., peer or family networks exerting negative social influence) and alternative programs (e.g., interventions that aim to shape positive support networks). This type of analysis can be complemented with a CBPR approach that focuses on community strengths, which would help identify community organizations where such interventions may be ideally situated.

Capacity-Building Synergy

Both systems science and CBPR rely on processes to generate and build knowledge iteratively to improve capacity. Across the range of systems science approaches, initial models (conceptual or computational) are built, tested against the real world, and refined to improve systems thinking capacity.[23] CBPR is an ongoing colearning effort in which researchers and the community work collaboratively to gain knowledge and build the capacity to address health issues.[58]

Systems science and CBPR both gain and use knowledge in ways that, when used together, hold potential to accelerate progress toward addressing health disparities. CBPR often focuses on using knowledge to identify community training and education needs.[3,59] In systems science, early models of small pieces of a system have been found to yield important insights, such as information about gaps or redundancies in how an issue is being addressed.[11] Exemplifying such integration, community-based system dynamics engages communities continually with both problem-structuring and computational methods to identify actions and needed training and to improve a community's systems thinking capacity over time.[11]

For example, an early visual model of cardiovascular disease could lead an engaged health clinic to initiate regular screening and counseling for tobacco use. Subsequently, clinic data could be used to build and simulate a model to understand the impact of targeting different subgroups with enhanced or tailored counseling. Throughout the model-building process, CBPR principles would guide continual stakeholder engagement and training needs, building local capacity to make identified changes and understand new problems from a systems perspective.

Colearning Synergy

Equitable community and researcher participation is a central tenet of CBPR.[58] Participatory processes are inherent in some systems science approaches (e.g., soft systems, community-based system dynamics, systemic intervention)[11,24,25,60] and are emerging in others (e.g., network analysis, agent-based modeling).[61,62]

Systems science and CBPR both have the ability to elucidate new information about mechanisms that influence health disparities. CBPR places the focus on involving community members in the research process to define an issue from their perspective. For example, CBPR has extensively used photovoice, in which communities visually document issues from their perspective in ways that counteract stigmas and stereotypes.[63] Systems science recognizes that stakeholders hold a wealth of information in their mental database (e.g., relationships between system components, decision points in a system).[23] Thus, systems science researchers have developed formal facilitation strategies (e.g., group model-building scripts)[64] to help researchers engage with stakeholders to understand and extract data from stakeholders' mental databases to build system models.[35] Combining participatory processes from CBPR and systems science may improve the depth and breadth of colearning that occurs.

For example, previous research has found that experiencing racial discrimination increases health risks, yet the mechanisms and pathways through which this occurs remain poorly understood.[65] A CBPR data collection tool, such as photovoice, has the potential to uncover important perceptions of influences and outcomes of racial discrimination. Participatory system science methods, such as group model building, provide formal strategies with the ability to improve understanding about explicit connections between these influences, outcomes, and health.

Translational Synergy

Finally, there is a key translational synergy. Systems science emphasizes improving knowledge of complex problems, and some approaches have a specific focus on action-oriented approaches. Conversely, CBPR emphasizes translating knowledge into action, and practitioners often seek to determine system-oriented actions.[66,67] The enhanced integration of systems science and CBPR can improve both knowledge of optimal strategies and their translation to programs and policies to address health disparities.

Community-based system dynamics, which advocates collaboratively building and learning from and acting on the basis of modeling efforts in the long term with a community, exemplifies this potential synergy.[11] As another example, the ReThink Health initiative followed this type of process, integrating system dynamics group model building with participatory action planning.[68] This initiative built a system dynamics model with local communities that allowed them to define, test, and determine actions on the basis of a model that simulated the effect of 25 possible interventions in health outcomes. This type of process provides important opportunities to inspire the translation and adaption of multicomponent, multilevel interventions that are mutually reinforcing.

KEY CONSIDERATIONS FOR INTEGRATING SYSTEMS SCIENCE AND CBPR

The synergies we have highlighted provide a rationale for integrating systems science and CBPR. In a long-term CBPR partnership, multiple systems science methods could be used as questions unfold and information is gained. Problem-structuring methods are apt for early efforts without a strong consensus on priorities and may illuminate more specific questions that require computational methods. For example, soft systems' rich pictures highlighting stakeholder views on community health care services might uncover a need for network analysis to understand organizational relationships and their influence on access to care. Which approach to use, and when, involves many decisions and factors (e.g., resources, expertise available). Methodology and frameworks from community operations research may provide apt guidance.[12] For example, the systemic intervention methodology involves a process of community-engaged critique, judgment, and action to reflect on and determine how to combine multiple theories and methodologies to address research questions.[60] This methodology has been successfully used to understand concerns and improve services for homeless youths in 1 community.[69]

Considering the system problem and social contexts can also inform decisions.[70] For example, system problems range from simple to complex, and social contexts can range from agreement among stakeholders to coercive situations with substantial power dynamics. Highly complex problems and coercive situations may merit a long-term resource-intensive combination of high community participation that draws from both problem-structuring and computational approaches. Conversely, if a community is in general agreement about an issue but is exhibiting high complexity, fewer problem-structuring and more computational approaches are likely required.

There are several challenges in integrating systems science and CBPR. Integrating systems science approaches may increase the significant time and resources already committed to CBPR. Additionally, both systems science and CBPR require training that is not often provided together or in the same educational structures.

Another key consideration is balancing power between researchers and community members. Computational system models have been criticized for their lack of transparency, which can exacerbate power dynamics.[71] For example, researchers working with a low-income housing cooperative had to pay special attention to formulating and communicating technical aspects of a computational financial model that would inform the community's decisions about issues such as sales policies and rent increases.[72] However, thoughtful consideration of the expertise each group brings and implementation of innovative communication strategies can make models accessible and universally utiliatarian.[39,72,73]

Finally, the use of participatory approaches with systems science methods can raise ethical considerations. For example, network analysis is inherently personal in nature, and maintaining confidentiality would be especially important if community members participate in data collection, analysis, and interpretation. Thus, highly sensitive issues may require additional human participant safeguards or may not be well suited to participatory processes. However, participatory network analysis has been emerging, and 1 study found that the system-focused nature of the method made the problem structural rather than personal.[46]

RECOMMENDATIONS AND CONCLUSIONS

Efforts have successfully integrated systems science and CBPR to address a range of health concerns, but more can and should be done. Their integration can create a shift to transdisciplinary research frames that widen the consideration of potential social and economic determinants and produce a stronger translation of "knowledge to action" through optimal combinations of individual, social, policy, and environmental changes. To continue to progress, expanded efforts are needed to explore integration in terms of process and impacts; these efforts should be carefully evaluated to direct practice toward the most effective and efficient methods.

Integrating systems science and CBPR will require inter- and transdisciplinary work that includes teams from diverse backgrounds. Researchers who have training and expertise in CBPR will likely need to reach across disciplines (e.g., business, engineering) to find systems science researchers and to provide time for meaningful exchange to learn from and balance each other's strengths and weaknesses. For example, systems science researchers may not have significant participatory research experience and so may require training in engaged scholarship and guidance to adapt methods for community acceptability. Systems science researchers will need to provide training to both community and CBPR researchers in methodology such as diagramming languages.

Academic and research institution policies and resources are needed to foster integration development. A program of research would require studies that range from developing and testing new integrated methods to assessing multilevel outcomes across communities that undertake such integrated efforts. Overall, problem-structuring methods merit more attention, especially for issues in which computational modeling alone may be fruitless if fundamental beliefs about systemic influences diverge across stakeholders.

Problem-structuring methods should be examined for their ability to achieve a shared understanding of issues that are historically contentious and include diverse perspectives. Also, participatory applications of agent-based modeling have been limited, and new approaches to structure problems and help participants visualize agent-based models may be needed.[74] Real-world applications and experiences provide the best opportunities for learning. This requires resources and funding opportunities that expand the ability of researchers to explore integration in natural settings. In complex and dynamic community settings, funding that favors natural experiments with rigorous mixed methods may produce more valuable information than do controlled and randomized experiments.

The match between CBPR approaches and systems science to address health disparities is compelling. Systems science can help widen our understanding of health disparities and advance our knowledge of the complex forces shaping them. By engaging the community, CBPR can enhance the quality and utility of systems models and the translation to action. CBPR is an approach already known for using a diversity of methods, and although challenges cannot be ignored, adding systems science to the CBPR methodological toolbox could result in accelerated progress in achieving health equity. AJPH

CONTRIBUTORS

L. Frerichs conceptualized and led the study. K. Hassmiller Lich, G. Dave, and G. Corbie-Smith contributed to critical revisions and approved the final version of the article.

ACKNOWLEDGMENTS

This work was supported by the National Institutes of Health (grants K24 HL105493 and UL1TR0011111).

The authors would like to thank the 3 anonymous peer reviewers for their insightful feedback and helpful comments, which helped improve and strengthen this article.

HUMAN PARTICIPANT PROTECTION

No protocol approval was necessary because no human participants were involved in this study.

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