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The Application of Systems Science in Nutrition Related Behaviors and Outcomes Implementation Research: A Scoping Review

A Review

Abstract Word Count: 148

Manuscript Word Count: 4131

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Financial support: This study was funded by West Virginia Agricultural and Forestry Experiment Station (WVA00689 and WVA00721).
Abstract

Use of systems science can improve the dissemination and implementation (D&I) process. However, little is known about use of systems science in nutrition D&I research. The purpose of this article is to synthesize the ways in which systems science methodology is applied in nutrition D&I research. Scoping review methodology involved searching six academic databases for full-text, peer-reviewed, English articles between 1970-2020 that employed systems science within nutrition D&I research. Data extraction included intervention type, population, study aim, methods, theoretical approach, outcomes, and results. Descriptive statistics and qualitative thematic analysis preceded. Thirty-four retained articles qualitatively identified benefits (successful planning and organization of complex interventions) and challenges (limited resources, trainings, and lack of knowledge) to utilizing systems science in nutrition D&I research. Future research should work towards building knowledge capacity among nutrition practitioners by increasing available trainings and resources to enhance the utilization of systems science in nutrition D&I research.

Teaser Text

Systems science can enhance development of complex nutrition interventions. This scoping review summarizes current use of systems science in nutrition behaviors and outcomes dissemination and implementation research and suggests that capacity building trainings should be developed in this area.
Introduction

Dietary patterns describes the frequency, proportions, variety, and combination of different foods, drinks, and nutrients in the human diet (1). The current dietary patterns in the United States are associated with four of the ten leading causes of death: heart diseases, some types of cancer, stroke, and type 2 diabetes (2). For example, many American do not consume enough fruits and vegetables (3) and overconsume added sugars, saturated fats, and salt (4), which can increase the risk of obesity and carries with it an increased risk for these chronic diseases (4-7). Luckily, nutrition interventions including education, programs, and policies can lead to positive changes in an individual’s dietary behaviors, which may lower the risk of chronic diseases and enhance health (2).

Nutrition interventions describe any combination of strategies designed to motivate and facilitate the adoption of nutrition-related behaviors that encourage health and well-being (2). Current research shows that nutrition interventions such as i-COOK 4-H (8, 9) and Homestyles (10-13), which address childhood nutrition, the GetFRUVED(14, 15) intervention that encourages college student health behaviors (16-27), a mental health recovery and nutrition program, M4R2 (28, 29), and a culinary medicine educational program to improve health professional nutrition-related knowledge (30-32), can positively support healthy lifestyle changes. Despite the noted positive influences on health and well-being, current reviews evaluating the effectiveness of nutrition interventions on health behaviors have identified areas for improvement in implementation. There is a need to address the sustainability (33), replicability and adaptability (34) of interventions, methodological issues, lack of large-group interventions (35-37), and unclear identification or integration of the multiple interrelated factors that impact nutrition and dietary patterns (34, 38, 39).

D&I research seeks to understand and overcome barriers to adoption, sustainability, and methodological issues of interventions that address complex problems (40). Health issues are increasingly
recognized as complex problems embed within our society, with multiple interacting components and undefined behaviors (40, 41). For example, implementation of a nutrition intervention to promote healthy dietary patterns in adults without consideration of the mix of factors that influence food consumption including biological factors, cultural and social preferences, physical health, food access, and emotional and psychological well-being may have limited impact. Solutions to complex problems often require intervening at many different levels, using multiple strategies, and engaging numerous actors and organizations (40), which may require new methodological approaches that address complexity with the implementation of nutrition interventions.

Systems thinking is a perspective that aims to interpret how things are connected to each other and within a larger system (42). A system is a set of elements or factors that are organized and interconnected and ultimately produce complex and dynamic behaviors that can evolve over time (43). Dynamic, complex, and interrelated are key terms among these definitions that inform many components of systems thinking and systems science methods. Methods of systems science, including systems dynamic modelling (SDM), network analysis (SNA), agent-based modeling (ABM), soft-systems approaches, cognitive and concept mapping, and other simulations have been developed to understand and identify between the system’s structure and behavior over time (44). Systems science methods are increasingly used to explain or predict real-world outcomes of large-scale interventions (42). In recent years, public health practitioners are applying systems science and thinking to identify the factors that influence intervention efficacy and real-world application (45). Further, D&I research utilizes systems science to understand complex factors influencing successful interventions and to identify challenges (44). Current research for systems science and D&I research predominately focus on patient safety and the medical field (46-54), tobacco research (55, 56), obesity with a focus on planning and quantifying interrelated factors, (57-60) and policy change (61-65). Although current evidence provides positive insights from using systems science in D&I health research, little is known about the utilization within nutrition. However, interest for the use of systems science in nutrition implementation research is
increasingly recognized. For example, recent calls have been made to organize knowledge and interest in implementation science in nutrition (66-68) including the developing of the Society for Implementation Science in Nutrition (68), yet there is a lack of reviews of the current state of research. Therefore, more research is needed to inform nutrition practitioners in order to lead to a greater capacity for factors that influence complex issues and interventions to enhance the health and well-being of communities (1, 40).

Thus, the purpose of this article is to synthesize the ways in which systems science methodology is applied in nutrition D&I research.

Methods

Scoping reviews formulate research questions of interest, based on what is known or not known from the literature (69). A scoping review is particularly useful when a topic has not yet been extensively reviewed or is a complex issue (70), making it an ideal approach to map the application of systems science in nutrition D&I research. The methodology of this scoping review followed the guided framework developed by Levac and colleagues (71) and adapted by Arksey and O’Malley (72) which identifies 6 key guidelines including: identifying the research question, identifying relevant studies, study selection, charting the data, collating, summarizing, and reporting results and consultation. Step six is optional and was not applied in the current review.

**Step 1: Identify the Research Questions**

1. How are systems science methods and systems thinking applied to nutrition D&I research?
2. What are the benefits and challenges of systems science and systems thinking within nutrition D&I research?

**Step 2: Identify Relevant Literature**

The search strategy was approved by two authors (AW & MDO) and involved a search of peer-reviewed, English literature was completed in July 2020 within six primary literature databases: PubMed, CINAHL, Web of Science, ProQuest, Scopus, and Agricola. MeSH terms and key words that were
mapped to subject headings were used to define the search’s scope to best capture relevant articles. Since the language of D&I research and systems science is complex, key words consisted of relevant concepts related to systems science of systems thinking, diffusion of innovation or dissemination, implementation or interventions, and nutrition behaviors and outcomes, and food. A full electronic search strategy is presented in the supplemental material table for replicability.

**Step 3: Select the Literature**

Identified articles were screened for inclusion by one author (AW). Inclusion criteria included full-text, peer-reviewed, English articles between 1970-2020 describing studies that employed systems science within nutrition D&I research. Preliminary exclusion criteria sought to identify articles that were non-English articles, articles without an abstract or articles with only an abstract, and articles that did not address nutrition and nutrition-related D&I using systems science in some capacity through an intensive initial analysis of titles, keywords, and abstracts. Secondary exclusion primarily focused on if an article did or did not mention systems science or thinking, systems analysis (i.e. network analysis, agent-based modeling, systems dynamic modeling or conceptual modeling), or systems vocabulary (i.e. complexity, interrelated and complex relationships) within nutrition D&I research. PRISMA flow chart guides were used to display the exclusion methodology and approved by a secondary reviewer (MDO) to ensure the search strategy was implemented with fidelity.

**Step 4: Chart the Data**

The primary researcher (AW) extracted the data using a structured table adapted from Armstrong and colleagues (69) in accordance with the research questions identified in step one. Study descriptions of interest included: title, authors, year of publication, study location, study population, organization of articles (systems methods and modeling or systems framing and language, aims, methodologies, context, theories, models or framework utilized, intervention type (i.e. planning, evaluation, implementation, dissemination), outcomes and results to inform qualitative analysis. The final chart and study
characteristics were reviewed collaboratively between the primary researcher (AW) and by a secondary researcher (RW). Any discrepancies between the two researchers were identified and adoptions were mutually agreed on.

**Step 5: Collate, Summarize, and Report Results**

Descriptive statistics including frequency counts of study description categories including: systems science methods, tools, and ideologies, intervention types (i.e. planning, evaluation, implementation, dissemination), and explicitly mentioned theory, models, and frameworks used in the included articles’ study design were calculated using JMP Pro 14 (73). Qualitative data analysis, which is used to examine themes or patterns to organize, describe, and interpret a dataset(74) was conducted to identify and interpret themes from the study description categories including articles aims, methods, outcomes, and results using NVivo Pro 12 (75). The benefits and challenges were assessed by analyzing specifically mentioned benefits and challenges by the authors of the included articles and independently identified by researchers. The qualitative data analysis was conducted by two trained researchers (AW & RW), one who generated initial codes that informed a coding dictionary and then developed themes to generate summative content. Then independent researchers discussed the coding dictionary to identify discrepancies and collectively agree upon themes.

**Results**

**Publication and Article Characteristics**

A total of 1,854 articles were retrieved, of which 34 met inclusion. Figure 1 shows the PRISMA flow diagram (76) of included and excluded studies. Most of the included articles were published in 2015 (20%) and 2018 (20%). The data sets described in the 34 articles employed seven different research designs, in which reviews including systematic, literature or a scoping review (37%) and case study analysis (20%) were more prominent. Most studies conducted research in locations within the United States (55.9%) and 44.1% of research was conducted within a global lens (i.e. multiple locations at once
including in Africa, Europe, the United Kingdom, Australia, Canada and low- and middle-income countries).

**QUESTION:** How are system science methods applied in nutrition behaviors and outcomes D&I research?

*Additional articles were located through a reference list search of key articles to ensure an exhaustive scope.

+The reasons for exclusion include: exclusion was based on if the article followed search strategy MeSH or subject headings terms, did not mention systems thinking or science, systems analysis, or systems vocabulary within D&I research (interventions, innovations, dissemination or knowledge translation), if the paper just provided an abstract and articles had to include diet or food-related outcomes, behavior, or promotion as the primary health focus (education, promotion, programming).
Articles were grouped into two categories based on their utilization of systems science. Systems modeling (44.1%) included articles that employed systems dynamics, network analysis, agent-based modeling. Systems framing and language (55.9%) described articles that depicted and identified elements of systems thinking including complexity, interrelated relationships, and systems-related frameworks. Additionally, articles were sorted into their D&I intervention type or process including planning and organizing (29.4%), scope of implementation (29.4%), utilization and adoption of an intervention (20.6%), knowledge translation or dissemination (17.6%); training or curriculum development and implementation (2.94%), and implementation evaluation (2.94%). Lastly, articles were reviewed and classified for their nutrition topics including: 23.5% nutrition-related behaviors and outcomes (i.e. hypertension, smoking, physical activity, obesity, diabetes, Body Mass Index); 11.7% food, health, and nutrition policy; 11.7% health and nutrition education; 38.2% knowledge translation; 8.82% described interventions methods; and 5.88% health and food access.

Qualitative Analysis

Eight key themes emerged from the deductive qualitative thematic analysis of the 34 included articles that describe how systems science methods and framing were applied in nutrition D&I research. Each theme will be defined and highlight key aspects of systems science that should be addressed by individuals that are involved in nutrition implementation science. Further, the benefits and challenges and future research were analyzed from the qualitative data.

1. Engagement and leadership are defined as having strong strategic support to provide appropriate leadership that will promote nutrition and health related partnerships and to enhance engagement with key community members that will be a part of the intervention. Engagement and leadership were key themes in eight articles analyzed in this scoping review (57, 77-83). Six articles (57, 79-83) all expressed the involvement of key leadership encouraged the commitment and
empowerment of other key stakeholders, which contributed to the success of systems science methods and framing in the analyzed articles.

2. Strategies for sustainable interventions are defined as practices that explicitly set out to improve nutrition behaviors and outcomes by outlining clear strategies and goals. Several (9/34) articles demonstrated that applying systems science to nutrition implementation had an effect on program effectiveness (84), the planning and organizing process (85), wide-scale adoption and scalability of interventions (86), evaluation and assessment (63), organizational relationship building (78), and assisted in developing complex interventions (57, 60, 87).

3. Conceptualizing systems components is the recognition of the complex nature of nutrition D&I research including the acknowledgment of the interacting and evolving elements of the complex adaptive system. Articles (18 of 34) clearly conceptualized and discussed the systems components within their research. Many articles identified and employed a systems-approach methodology, which improved the recognition that nutrition and diet-related interventions are complex and dynamic (59, 79, 85, 88-92). Other articles acknowledged that linear ways of thinking hinder the nutrition implementation process, and that systems science demonstrates complexities, structure, and interrelated relationships, which are important aspects in intervention design (93-95).

4. Interaction and Dynamic Relationships are methods or actions of specific activities to develop and maintain relationships among individuals and organizations. Articles identified relationship factors that influence implementation by applying systems science methods. Acknowledged factors included: contextual and organizational structures, and intervention and individual behavioral characteristics that impact nutrition D&I goals, plans, and sustainability (59, 85, 89, 94, 96-99).

5. Innovation and Education defines systems science approaches to support and encourage the development of strategies to address complex nutrition behaviors and outcomes in D&I research. Articles identified that situating education and innovations within systems-oriented frameworks
or theories assists stakeholders with design, evaluation, and self-efficacy in nutrition D&I research (59, 85, 98). Furthermore, the development of more trainings and curriculums that focus on applying systems science in nutrition D&I research are needed to enhance knowledge capacity and educational support among practitioners to increase utilization (78, 83, 86, 92, 94, 100, 101). The capacity building theme elaborates more on increasing available resources and information for innovation and education.

6. **Capacity building** is increasing nutrition resources, education, support, and information within a system to encourage change among communities and organizations. Many articles discussed the need for capacity building among organizations to utilize systems science in nutrition D&I research (84, 89, 92, 94-96, 102). Likewise, articles identified that insufficient capacity was a major barrier to systems-oriented nutrition D&I research (63, 77, 79, 81, 92). Other articles referenced the need to address knowledge capacity gaps to increase self-efficacy in systems science and nutrition D&I research (57, 81, 84, 92, 103). Further, the communication and knowledge translation theme below elaborates on additional capacity building barriers that influence self-efficacy in systems science and nutrition D&I research.

7. **Communication and Knowledge Translation** are mechanisms and processes that support communication of evidence-based information and practice among stakeholders within the system. Twelve articles reported the importance of effective communication (88) and community engagement (79, 102) in nutrition implementation research. Further, the application of systems science resulted in articles identifying the differences in knowledge translation among diverse populations (83, 90, 103). Lastly, articles noted minimal translation and understanding of systems science and D&I theories, models, or frameworks in different settings, which resulted in low self-efficacy and ultimately persisting the evidence-based information practice gap in health (77, 102).

8. **Monitoring and Evaluation** describes articulated methods to provide continuous feedback into the system to enhance effectiveness of nutrition D&I research. Articles cited utilizing a systems
science approaches to monitor and evaluate nutrition D&I research including process evaluation (89), systems dynamic modeling (79), network analysis (95), conceptual models (85), and agent-based modeling (81). However, many researchers cited the gap in the current literature for monitoring and evaluating nutrition D&I research including: designing and planning systems-oriented interventions (78); addressing scale-up approaches (77, 86), developing distinct health systems monitoring and evaluation methods (63, 96), development and evaluation of effective systems science competencies and tools (80, 84, 92, 100, 101), and fidelity of nutrition D&I interventions (57, 84, 85, 102, 104).

**Benefits and Challenges of Systems Science in Nutrition D&I Interventions**

The 34 included articles were analyzed for the benefits and challenges, specifically stated by the authors and synthesized by research team, of utilizing systems science in nutrition and diet-related behavior D&I research that are briefly described below. Table 2 provides a simple summary of the benefits and challenges from the qualitative analysis. Articles identified systems science methods as useful tools to strengthen D&I planning and predicting, organizing, communicating and knowledge translation, design, and implementation (78, 79, 85-88, 92, 94, 95, 97-100, 103, 105, 106). Many key challenges included capacity and resources for complex interventions (57, 84, 95) especially in rural contexts (102), and lack of training in systems science and nutrition D&I research (90-92, 95). Articles concluded that future research needs to predominately focus on educating nutrition researchers and practitioners through trainings and curriculums to enhance systems science in nutrition D&I research (57, 91, 95, 97, 100).
Discussion

Relatively few articles examined systems science in D&I research that focused on addressing nutrition behaviors and intervention methods, and most are recent; therefore, these results suggest an emerging area that deserves more attention. Furthermore, most papers identified by the inclusion process were reviews which included commentaries, calls for application, or systematic reviews, but did not use systems methodologies. Additionally, the categorical analysis highlighted that systems science is more likely to be theoretically framed rather than utilized within research methodology, which are similar to findings from another systematic review (107), and suggest that prevention science, which includes nutrition interventions, has still yet to take full advantage of these analytic approaches (108).

However, the articles that did use systems science methodologies and framing to implement an intervention, highlighted numerous key benefits in applying systems science to nutrition implementation including planning and organizing potential policies and programs; predicting behavioral outcomes; and visualizing complexity of implementation. These findings reflect previous research by Burke and colleagues (44), which discuss the many implementation successes of three case studies that utilized the different models of systems science methods (SNA, SDM, and ABM). Furthermore, the qualitative findings from this review suggest that systems science framing and methods improved key aspects of nutrition D&I process and research such as conceptualizing systems components, methods of monitoring and evaluating, strategies for interventions, relationships and leadership, which echoes similar positive implications outlined by Riley and colleagues (40) and Luke and colleagues (109).

While current research supports that systems science improves many aspects to health D&I research (40, 44, 109), our review found capacity building barriers for systems science in nutrition implementation including knowledge translation of D&I theories, models, and frameworks as well as
limited available educational trainings for nutrition researchers hinders systems science application in the field of nutrition D&I research. Therefore, the remainder of this discussion will reflect more deeply on how to build capacity among nutrition D&I researchers to apply systems science in the implementation process.

Current nutrition implementation researchers emphasize the importance of utilizing implementation science in nutrition interventions (66, 68, 110-113). Koorts and colleagues reported a strong consensus among nutrition and physical activity academics that D&I research was important to reduce research practice gap among patients and communities and increased real-world implications of their own research (114). Nonetheless, a lack of D&I training and expertise, and misunderstanding on how to achieve real-world impact with D&I science hindered individuals’ involvement (114). To achieve desired real-world changes, Warren and colleagues suggest that nutrition strategies need to invoke systems thinking during the implementation process (68). Similarly, Burke and colleagues argue that successful health implementation cannot take place without acknowledging the complexity of real-world situations and that the tools from systems science are needed to model these interrelated factors (44).

However, to utilize systems science in nutrition interventions, capacity building, including increasing resources and knowledge are needed (115), which are similar findings to our review. Additionally, research suggests that a lack of training and expertise in D&I science among nutrition researchers, are barriers to utilization (68, 114), again reflecting the present study’s findings.

Existing evidence demonstrates effectiveness of D&I trainings among graduate students, postgraduate, and professionals in public health fields including mental health and cancer. These studies reported significant increases in knowledge of D&I skills (116), demonstrated capability to incorporate D&I into research practice (100), improved understanding of implementation challenges in healthcare (117), and enhanced understanding of relevant D&I theoretical approaches (117). These results suggest that D&I trainings for graduate, postgraduate, and professionals positively influence knowledge and understanding of D&I science, which are important implications to address our review results of current
capacity barriers among nutrition researchers and practitioners. Likewise, a National Institutes of Health convened panel recognized that D&I trainings should teach trainees to employ methods and strategies from the field and equip them to draw on methods from other areas such as systems science (118). Our results reflect this emerging viewpoint of incorporating other disciplinary methods, such as systems science, within implementation science. Therefore, a nutrition-specific D&I training that incorporates systems science modeling and perspectives would benefit current and future nutrition researchers’ and practitioners’ implementation self-efficacy, skills, and motivations for real-world intervention effectiveness.

In regard to the structure of the proposed nutrition-specific D&I training, current higher education intuitions systems science curriculums in health show positive adult learning outcomes through active learning strategies (85, 100, 101, 119). Active learning techniques ask participants to engage by practicing skills, solving problems to complex programs, propose solutions, and explain ideas (120). Current research displays advantages to active learning strategies such as scenario-based case studies in teaching systems science in health implementation research including an increased understanding of barriers to care (101); improved knowledge and skills of systems science in health (119); and acquisition of knowledge to apply systems science frameworks and theory to frame implementation process (85, 100). Additionally, many researchers discuss the need for mentorship (116) and faculty engagement (100) to act as translators when simulating active learning techniques, which is similar to a collaborative learning approach (121). A collaborative learning approach describes the joint intellectual effort by students and teachers to acquire knowledge (122). Current curriculums teaching systems science employing collaborative teaching strategies report that students are able to critically examine the complex challenges within food, nutrition, and health programs (123). Chambers and colleagues encourages implementation science training programs moving towards problem-solving and activity style learning (124) Thus, to enhance learning outcomes among current and future adult nutrition researchers
and practitioners, should incorporate active learning strategies and collaborative learning approaches to acquire knowledge and skills in the application of systems science in implementation.

In terms of population for the proposed capacity building training, it is important to start to train future nutrition researchers and practitioners. Highly selective training programs limit the amount and type of people able to receive the education (118). Additionally, training should be available for people in a variety of implementation roles, including predoctoral, early career and experienced practitioners (118). Therefore, the proposed curriculum should be available to a variation of nutrition practitioners including university nutrition and public health students, registered dietitians, and established researchers. To incentivize current students and future registered dietitians to complete the proposed curriculum, course developers should build courses from previously identified D&I competencies (125) and from the Society of Nutrition Education competencies (126) to help with validation and to institutionalize the proposed curriculum for future nutrition degree recipients. Lastly, additional incentives could include receiving continuous educational credits for completion of this course and for funders to highlight emerging issues such as capacity building in nutrition through targeted strategies (e.g., funding announcements, training programs, or support for new research teams) (127).

Limitations

However, this study is not without limitations. First, only one author was involved in the screening process. While the search strategy, inclusion/exclusion criteria, and data analysis were reviewed and approved collaboratively, the screening process was done during the initial COVID-19 pandemic lockdown, which made collaborating for the inclusion process challenging. While the researcher who led the inclusion process, is proficient in nutrition D&I research and systems thinking, the article screen process was done independently, which is a limitation of this scoping review. Further, the inconsistencies and adapting language surrounding the interdisciplinary fields D&I and systems science challenged the development of key terms, inclusion criteria, and influenced the databases chosen. Given these challenges, this review aimed to be exhaustive, however the complex nature of this subject matter may
have excluded some research. Furthermore, not all databases used MeSH terms, key terms, or subject headings, which could influence the types of articles retrieved. Lastly, indexing of articles sometimes takes up to a year, which could have potentially impacted article retrieval and inclusion analysis.

Conclusions and Practice Implications

This study demonstrates that systems science provides positive implementation approaches to design and translate nutrition behaviors and knowledge into practice. However, capacity building barriers for systems science in nutrition implementation including limited available educational trainings for nutrition researchers hinders systems science application in the field of nutrition D&I research. Therefore, our results suggest that an active and collaborative teaching method for a nutrition-specific D&I curriculum for university nutrition and public health students, registered dietitians, and established researchers is likely to enhance systems science skills, which aligns well with current literature implications. It is also important to note that capacity needs to be built at a higher level (e.g., funding announcements, training programs, or support for new research teams) as well to support the development of said curriculums and to incentivize participation.
Acknowledgements

Author Contributions: AW designed the study, conducted the search, screened for inclusion, extracted data, synthesized the literature, and drafted the manuscript. RW contributed to data analysis, study refinement and revisions to draft manuscript. MDO verified data extraction, inclusion and exclusion criteria, and contributed to study refinement and revisions to draft manuscript. All authors read and approved final manuscript.

Acknowledgements: The authors would like to acknowledge Susan Arnold for her contributions to the development of the search strategy.
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| First Author, Year (reference number) | Study Aims | Category | Intervention Type | Nutrition Topic | Data Collection | Theoretical Perspective |
|--------------------------------------|------------|----------|-------------------|-----------------|-----------------|-------------------------|
| Shelton RC, 2018 (96)                | To examine and discuss conceptual and methodological issues in studying sustainability. | Systems Framing or Language | Scope of Implementation | Interventions methods | Review | Dynamic Sustainability Framework |
| Krystyna A Stave 2015 (97)           | To explain and demonstrate the system dynamics approach for examining food systems closely | Systems Modeling (SDM) | Planning and Organizing Interventions | Agriculture policy, nutrition education, communication, and behavior. | Modeling | Whole Systems Approach |
| Brownson RC 2018 (92)                | To aid practitioners in building organizational level capacity and assist researchers in conducting participatory research. | Systems Framing or Language | Planning and Organizing Interventions | Methods to translate health information | Review | n/a |
| Erasmus E 2016 (63)                  | To investigate the scope of health and systems education among partners in the organization. | Systems Framing or Language | Scope of Implementation | Food and health policy and systems | Cross sectional | Social Science theory |
| Yamey G 2012 (77)                   | To understand how to scale up health tools in low to middle income countries. | Systems Framing or Language | Scope of Implementation | Health and food access | Qualitative Study | Diffusion of Innovation |
| Glegg SMN, 2019 (106)               | To comprehensively map ways social network analysis are used in D&I. | Systems Modeling (SNA) | Dissemination | Methods to translate health knowledge/information | Review | Whole Systems Approach |
| Hammer JM 2012 (78)                 | To improve the understanding about what reasonably to expect from large group interventions and how best to design them. | Systems Framing or Language | Planning and Organizing Interventions | Health and Nutrition Education | Case Study | Large Group Intervention theory |
| Hitzinger M 2018 (99)               | To improve the integration, governance, and coordination of implementing the One Health framework | Systems Framing or Language | Utilization/adoption of an evidence-based practices (EBP) | Methods to translate health knowledge/information | Case Study | One Health framework |
| Author  | Year (ID) | Aims/Objectives | Methodology/Approach | Intervention Area | Study Type | Theory/Framework |
|---------|-----------|----------------|---------------------|------------------|------------|-----------------|
| Zhang J | 2015 (93) | To build an agent-based model (ABM) of adolescent body mass index (BMI) and tested the impact of social influence on combined overweight and obesity prevalence in the population. | Systems modeling (ABM) | Body Mass Index (BMI) and obesity (nutrition-related) | Secondary data analysis | Social Learning theory |
| Kalim K | 2006 (88) | Aims to describe systems thinking and illustrates its value in understanding the complexity of the diabetes national service framework. | Systems Modeling (SDM) | Diabetes (nutrition-related disease) | Qualitative Study | Systems Thinking/Systems theory |
| Johnston LM | 2014 (59) | To explore the utility of the intervention level framework. | Systems Framing or Language | Obesity Policy | Review | Intervention Level framework |
| Limbani F | 2019 (89) | To report the relationships, benefits and challenges of process evaluation and complex interventions. | Systems Framing or Language | Hypertension (nutrition-related disease) | Case Study | n/a |
| Loyo HK | 2013 (79) | To align prevention efforts and maximize the effect of limited resources; to pioneer an innovative, systems-oriented approach to understand the dynamic dimensions of health protection policies. | Systems Modeling (SDM) | Chronic Disease/Obesity Policy (nutrition-related diseases) | Modeling | Whole systems approach |
| Luig T | 2018 (57) | To explore implementation strategies using the interactive systems framework. | Systems Framing or Language | Methods to translate health knowledge/ information | Qualitative Study | Interactive Systems framework |
| McGlashan J | 2016 (60) | To explore the application of | Systems Modeling | Obesity (nutrition-related) | Modeling | Whole Systems Approach |
| Author                  | Year | Title                                                                 | Methodology          | Scope of Implementation             | Interventions                                                                 | Language        | Approach                           |
|-------------------------|------|------------------------------------------------------------------------|----------------------|--------------------------------------|-------------------------------------------------------------------------------|-----------------|------------------------------------|
| Widener MJ              | 2013 | To contribute to the current discourse on food deserts by presenting an agent-based model (ABM) that tests several spatial and aspatial interventions. | Systems Modeling (ABM) | Planning and Organizing Interventions | Health and Food access                                                          | (SNA & SDM)     | Whole Systems Approach              |
| Nianogo RA              | 2015 | Aimed to review studies that used agent-based modeling (ABM) to study noncommunicable diseases as well as their risk factors in the context of public health. | Systems Science Modeling (ABM) | Scope of Implementation             | Physical activity, diet and diabetes (nutrition-related)                      | (ABM)           | Whole Systems Approach              |
| Buchthal OV             | 2015 | To identify communication and collaboration patterns among organizations involved in nutrition education within a diverse community. | Systems Modeling (SNA) | Dissemination                        | Methods to translate health knowledge/ information                              | (SNA)           | Whole Systems Approach              |
| Peterson H              | 2018 | To describe the importance of implementation science in health.       | Systems Framing or Language | Scope of Implementation             | Methods to translate health knowledge/ information                              | (SNA)           | Active Implementation framework/ Interactive and Synergistic framework |
| Phillips W              | 2006 | To investigate multilevel networks and their impact on diffusion of innovation. | Systems Framing or Language | Dissemination                       | Methods to translate health knowledge/ information                              | (SNA)           | Systems of Innovation               |
| Ramaswamy R             | 2019 | To develop an interdisciplinary practice-focused curriculum to teach Masters’ of Public Health (MPH) students | Systems Framing or Language | Curriculum Development              | Health and Nutrition Education                                                  | (SNA)           | Kirkpatrick’s model of Learning Evaluation |
| Author                  | Year | Aims/Goals                                                                 | Systems Framing or Language | Scope of Implementation | Interventions Methods | Methodology                  | Review                  | CAS/Complex Adaptive Systems |
|-------------------------|------|-----------------------------------------------------------------------------|-----------------------------|-------------------------|-----------------------|-----------------------------|--------------------------|-----------------------------|
| Resnicow K              | 2008 | Aims to provide a summary on chaos and complex adaptive systems (CAS) use in public health. | Systems Framing or Language | Interventions methods   | Review                | Chaos theory/Complex Adaptive systems |
| Riley B                 | 2012 | To integrate the lessons emerging from the literature with those of identified leaders in public health; to begin to identify useful principles to help public health better understand, assess and shape the creation and use of EBP. | Systems Framing or Language | Utilization/Adoption of EBP | Review                | Complex Adaptive systems   |
| Hammond RA              | 2014 | Reexamine a “follow the average” hypothesis to test whether the central insight from the original model holds and explore what new insights can be gained from a more detailed and complex model. | Systems Modeling (ABM)      | Planning and Organizing Interventions | Review                | Whole Systems Approach     |
| Smith T                 | 2016 | To explore how communities, translate evidence-based and promising health practices to rural contexts. | Systems Framing or Language | Utilization/Adoption of EBP | Methods to translate health knowledge/ information | Case Study                | Interactive Systems Framework |
| Theobald S              | 2018 | Aims to provide key features in implementation research in low/middle income countries. | Systems Framing or Language | Scope of Implementation | Methods to translate health knowledge/ information | Case Study                | n/a                       |
| Wang Y                  | 2015 | To review current strategies used to model health-related issues by using systems science. | Systems Modeling (SDM)      | Scope of Implementation | Review                | Systems Thinking/Systems Theory |
| Williams J              | 2016 | The aim of this study to explore how systems | Systems Framing or Language | Utilization/Adoption of EBP | Review                | ABCD Model                 |
thinking might be used to guide state officials in developing a research-based evaluation plan for training programs and improve the understanding of the relationships and dependencies among units in an organization.

| Author | Year | Aims | Methods | Evaluation Plan | n/a |
|--------|------|------|----------|-----------------|-----|
| Woltering L | 2019 (86) | To demonstrate the problems underlining successful scalability of the sustainable development goals. | Systems Framing or Language | Scope of Implementation | Interventions methods | Review | n/a |
| Li Y | 2015 (81) | Aims to use ABM to help understand the potential impact of implementing lifestyle interventions. | Systems Modeling (ABM) | Utilization/Adoption of EBP | Lifestyle intervention (smoking, overweight, diet and physical activity) | Qualitative Study | Whole Systems Approach |
| Yousefi-Nooraie R | 2015 (82) | We tested whether engagement of staff in the intervention and their behavior were associated with being chosen as information source. | Systems Modeling (SNA) | Dissemination | Methods to translate health knowledge/information | Longitudinal | Transactive Memory Principles/Whole Systems Approach |
| Yousefi-Nooraie R | 2012 (103) | A quantitative social network analysis designed to understand how the staff of one health department in Canada turned to peers to seek information regarding research evidence to inform practice-based decisions. | Systems Modeling (SNA) | Dissemination | Methods to translate health knowledge/information | Cross-Sectional | Whole Systems Approach/Social Capital theory/Social Influence theory |
| Yousefi-Nooraie R | 2014 (83) | Aims to model how managers and professional consultants seek information to | Systems Modeling (SNA) | Dissemination | Methods to translate health knowledge/information | Cross-Sectional | Whole Systems Approach |
| Zenni E. | 2006 (101) | To implement and evaluate the effectiveness of scenario-based learning in enhancing medical residents competencies of systems thinking to address patients. | Systems Framing or Language | Evaluation | Health and Nutrition Education | Case Study | Systems Thinking/Systems Theory/Adult Learning Theory |
Table 2: Benefits and Challenges to Systems Science Methods in Nutrition D&I

| Benefits                                           | Challenges                                                                 |
|----------------------------------------------------|---------------------------------------------------------------------------|
| Provides methods for D&I planning and predicting   | Methodological and conceptual challenges of measuring sustainability       |
| Provides frameworks and models to organize and    | Inconsistent knowledge translation in nutrition and diet research         |
| design implementation                              |                                                                           |
| Helps to understand and predict knowledge and     | Capacity building and resources to implement complex interventions        |
| communication patterns                              |                                                                           |
| Systems science assisted in visualizing and       | Limited “real-world” interventions and implications                      |
| modeling the complexities of nutrition D&I research|                                                                           |
| Useful in understanding barriers for nutrition    | Inconsistent and varying language within D&I and systems science           |
| education and interventions                        |                                                                           |