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A comparison of linear and systems thinking approaches for program evaluation illustrated using the Indiana Interdisciplinary GK-12

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ABSTRACT

Logic models are based on linear relationships between program resources, activities, and outcomes, and have been used widely to support both program development and evaluation. While useful in describing some programs, the linear nature of the logic model makes it difficult to capture the complex relationships within larger, multifaceted programs. Causal loop diagrams based on a systems thinking approach can better capture a multidimensional, layered program model while providing a more complete understanding of the relationship between program elements, which enables evaluators to examine influences and dependencies between and within program components. Few studies describe how to conceptualize and apply systems models for educational program evaluation. The goal of this paper is to use our NSF-funded, Interdisciplinary GK-12 project: Bringing Authentic Problem Solving in STEM to Rural Middle Schools to illustrate a systems thinking approach to model a complex educational program to aid in evaluation. GK-12 pairs eight teachers with eight STEM doctoral fellows per program year to implement curricula in middle schools. We demonstrate how systems thinking provides added value by modeling the participant groups, instruments, outcomes, and other factors in ways that enhance the interpretation of quantitative and qualitative data. Limitations of the model include added complexity. Implications include better understanding of interactions and outcomes and analyses reflecting interacting or conflicting variables.

1. Introduction

Too often educational program development and evaluation focuses on the simple end-point relationship between interventions and outcomes. Chen (2005) refers to this common approach as an input–output or ‘‘black box’’ evaluation: things go in and things come out, but what happens in between is a mystery. While useful in identifying program merits, the black box evaluation cannot capture the ‘‘transformation processes that turn interventions into outcomes’’ (p. 231) and thus, evaluation findings often lack robust explanatory power. What is needed is evaluation that considers the details of what occurs in ‘‘the black box,’’ based on models that underlie that rationale for proposing that the interventions will result in the desired outcomes. The function of the evaluation model is to make clearer the system and allow for more explicit analysis of the program through analysis of the components of the system, which is the promise of a ‘‘white box’’ approach. Furthermore, this type of analysis of the inner components and the logic of the system can enable needed analyses leading to improvement of theoretical models.

The purpose of the current paper is to provide an example of how to uncover some of these system details and express the components of a program using a systems thinking approach.

1.1. A traditional approach to program evaluation—logic models

Logic models are widely used to model program evaluation in educational settings and provide one approach to representing program theory. All logic models provide a graphical representation of program elements (inputs, activities, outputs, outcomes, and impacts) and the logical relationship between components. While the model can be represented in a variety of ways, the framework proposed by the Kellogg Foundation (2004) is easily understood, widely used, and therefore provided as an example here. The logic model consists of the following elements:

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- *Inputs/resources*. Inputs are program resources (e.g., funding, personnel, facilities, materials, time, consultants, transportation and other resources). Program implementation is dependent on adequate inputs.
- *Activities/processes*. Activities are the action components of the program and include transformational processes aimed at attaining desired results for the participants (e.g., training sessions, workshops).
- *Outputs*. Outputs include tangible evidence of program delivery (e.g., number/type of participants, products or materials developed). Outputs are tied to and dependent on the program activities and are circumscribed by the inputs supporting the program.
- *Outcomes*. Outcomes are directly related to the outcome objectives of the program and describe the anticipated results of program implementation. Outcomes can be considered short-term objectives (such as knowledge, awareness, attitudes, skills) and medium-term objectives related to anticipated changes in behavior (e.g., increases in positive behaviors and practices, decreases in nonproductive behaviors).
- *Impacts*. Impacts are those outcomes that might be expected long term (e.g., institutional changes, social changes).
- *Context/environment*. The context/environment includes factors that may interfere with the planned delivery of the program. If it is not possible to work around contextual constraints, the understanding of how these factors influence program outcomes can be invaluable in extending program theory and increasing program benefits through formative evaluation processes.
- *Assumptions*. Assumptions provide the basis for inferring that program elements will result in anticipated outcomes or impacts (i.e., derived from developmental, social, or learning theory).

The function of the logic model is to make clearer the system and allow for more explicit analysis of the program through analysis of components of the system. Fig. 1 is an example of a logic model using two of the GK-12 program goals.

Logic models represent a linear perspective of a system, whereby inputs are linked to activities and outcomes. A drawback of a one-dimensional map, however, is a limited ability to discern multiple influences on participant change. For example, observational data may describe not only the actions of a participant, but also the interaction between other participant groups and the environment. Subsequent analyses that do not account for such interactions may fail to show the manner and degree to which outcomes are dependent on several interacting variables. Thus, while logic models serve as an initial step for understanding a system, systems thinking and associated models can provide a more realistic (complete and dynamic) representation of the processes within a system than a logic model.

1.2. A systems thinking approach to program evaluation

Unlike logic models, systems thinking provides a means to conceptualize the interaction of the multiple components that make up complex programs. Systems thinking encompasses a wide variety of research and fields of study, including general systems theory (GST), system dynamics, complexity science, and systemics (Midgley, 2007). Cabrera, Colosi, and Lobdell (2008) emphasized the construct of systems thinking as an understanding of the patterns that connect various systems ideas, methods, theories, or models. Although systems thinking is often confused with systems theory, which takes a holistic perspective, systems thinking focuses on the whole as well as the parts to form a more complete understanding of the system (Cabrera, 2006). Cabrera et al. (2008)

Goal 1: Provide training and mentoring for graduate student ***fellows*** to develop their ability as future STEM faculty or industry professionals.

Goal 2: Provide professional development for middle school ***teachers***, enhancing offerings and inquiry-based education in STEM disciplines.

Inputs/ Resources	***Activities Processes?***	***Outputs?***	***Outcomes?***	***Outcome Measures?***	***Impacts***
All NSF Funding Purdue Faculty Professional Staff	***Fellows*** Maymester Course Workshops Classroom Participation	***Fellows*** # learning teams # meetings # lesson plans	***Fellows*** Increased teaching self-efficacy Increased knowledge of pedagogy	***Fellows*** STEBI-B Attitudes and Beliefs Survey *Quantitative* Concept maps *Qualitative*	***Fellows*** Cadre of scientists able to communicate scientific understandings to a broad audience
Graduate Assistants Purdue Facilities Middle School Facilities Technology & Curricular Materials	***Teachers*** Teacher-Fellow Team Meetings Graduate Fellow Mentoring Co-development of Science Units	***Teachers*** # schools # hrs engaged # sessions # instructional units	***Teachers*** Increased knowledge of scientific inquiry Increased teaching self-efficacy	***Teachers*** Program Survey *Quantitative* Focus Group *Qualitative*	***Teachers*** Teachers who are confident and effective in engaging learners with current scientific content

Fig. 1. GK-12 logic model.