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Utilizing program theory and contribution analysis to evaluate the development of science teacher leaders

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ABSTRACT

This paper illustrates how theory of change coupled with contribution analysis assisted in delineating the role each aspect of a teacher professional development program contributed to the expected outcomes. Using a mixed methods evaluation based upon the theory of change, data was gathered on 12 teacher leaders over three years. Findings indicated that not only did the teachers continue to develop as leaders over the three year project but also that the interventions designed to provide professional development to the teachers did indeed contribute to the attainment of project outcomes. By combining stakeholders' theory of change with contribution analysis, evaluators can develop an understanding of program intentions and design an evaluation that enhances the validity of findings.

Educational research has taught us that systemic change in schools requires a broad-based team working in concert toward a common goal (Sockett, DeMulder, LePage, & Wood, 2001). Teacher leaders (TLs) are especially poised to facilitate lasting positive change in the educational system because of the integral part they play in both development and delivery of educational reform (Ballek, O'Rouke, Provenzano, & Bellamy, 2005; Teacher Leader Exploratory Consortium, 2012). TLs provide the expertise needed to improve teaching and learning, school/classroom culture, and instruction through interactions (both formal and informal) with peers or colleagues that will culminate in greater student learning (York-Barr & Duke, 2004). TLs are best able to influence others when they merge strong content knowledge with both strong pedagogical knowledge and strong leadership skills (Hofstein, Carmeli, & Shore, 2004). However, even when TLs are well versed in pedagogical content knowledge such as inquiry-based instructional theory and strategies, fidelity of implementation is inconsistent (Pitman & Romberg, 2000). Roehrig (2004) identified five constraints that inhibit the implementation of inquiry based instruction: a lack of understanding of the nature of science, limited content knowledge, limited pedagogical content knowledge, personal teaching beliefs, and concerns about student and classroom management. Additionally, due to increased emphasis on standardized testing, teachers believe they do not have time to teach inquiry-based science due to assessment demands (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012).

A National Science Foundation Math Science Partnership (Award DUE-0927996), designed to improve science education by making it relevant to students through the incorporation of Project-Based Science (PBS) (Krajcik & Czerniak, 2014) linked to the renewable energies industry and its environmental impacts, utilizes TLs to provide long term (minimum 3 years) K-12 science teacher professional development to their respective school districts (6 TLs per district). In spite of a broad literature base that supports the effectiveness of the teacher leader, there is little evidence that districts have adopted and supported teachers as educational leaders (Helterbran, 2010). Because the attribution of intervention components to overall success can be arbitrary when an evaluation plan does not clearly sort and assess impact (Mayne, 1999), a contribution analysis based upon theory of change was employed to delineate the role each aspect of the professional development program contributed to the expected outcomes. This evaluation examined whether participation in a professional development program that included rigorous content, PBS strategies, and leadership skill development contributed to the evolution from teacher to teacher as a leader in science education.

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Background: LEADERS program overview

The transition to a globalized world has led to unforeseen market trends resulting in both favorable and unfavorable outcomes for the United States. In response to the realization that other nations have surpassed the US in innovative scientific and technological discovery and potentially economic prosperity, public decision-makers have lobbied to make science and mathematics education a top priority. Over the last decade, national priorities have evolved from influential policy reports demanding comprehensive changes in science teaching and learning. Most recently, *A Framework for K-12 Science Education* (National Research Council, 2012) and the *Next Generation Science Standards* (http://www.nextgenscience.org) posit that children learn science by actively engaging in the practices of science. Thus, teachers are urged to *blend* core science ideas, crosscutting concepts and science and engineering practices. However, for many teachers this requires a shift in practices away from one that covers primarily content (oftentimes for large scale assessments) to one that has children conduct investigations or complete projects that may not have a predetermined "answer."

Leadership for **E**ducators: **A**cademy for **D**riving **E**conomic **R**evitalization in **S**cience (**LEADERS**) is a partnership that gathers and merges the expertise of four essential entities (K-12 school districts, higher education, the renewable energy industry, and informal science education sites) in the economic revitalization of the Great Lakes Region. TLs and district level support personnel from area public and parochial schools collaborated with university and industry partners in the development of PBS curriculum relating to renewable energy. The professional development of the TLs was a three-year process that included graduate level content courses (part of the university's renewable energy minor) and three graduate level education courses on teacher leadership delivered during an intensive summer institute. Academic year follow up included monthly meetings to develop and provide professional development sessions to district teachers. Participation extended beyond the project-sponsored three years as the TLs continued to develop and deliver teacher professional development that utilized PBS within their respective districts once active participation was complete. This section explains the details of the TL professional development.

Participant selection

Selection of TLs was based on the following criteria: previous leadership roles within the district (e.g., department chair, special projects team leader, participation as a new teacher mentor), state or national recognition (Presidential Awardee or National Board Certification), participation in other teacher leader projects (such as prior or current federally or state funded projects), strong science background, respect among peers, experience with adult learners, and commitment to the National Science Education Standards which were the most current at the time of selection (National Research Council, 1996).

The selected TLs included one second grade teacher (7–8 year old students), one fifth grade teacher (10–11 year olds), three sixth grade teachers (11–12 year olds), two teachers teaching science grades 5–8 (ages of students range from 10 to 14), five high school teachers (14–18 year olds), and two administrators. One principal who participated in all the courses eventually joined the group of TLs.

Professional development (intervention)

The three-year summer institute plan of instruction can be seen in Table 1. It included a balance between renewable energy advanced content, a PBS course, and leadership courses. The PBS and leadership courses continued throughout the year as the TLs implemented PBS science in their classrooms and delivered professional development sessions for their district science teachers.

Table 1
LEADERS plan of study.

Term	Course	Credit
Summer I	Physical principles of energy sources for humans	3.0
	Principles of solar and wind energy	3.0
	Project-based science	3.0
	Leadership	
AY 1	Leadership (cont.)	3.0
Summer II	Chemical aspects of sustainable energy	3.0
	Earth technologies	3.0
	Climate change	30.
	Leadership	
AY 2	Leadership (cont.)	3.0
Summer III	Earth systems science	3.0
	Alternative energy: sources, applications and economics	3.0
	Leadership	3.0

Note: AY, academic year.

Content courses

University scientists teaching courses pertaining to renewable energy on the undergraduate level at the university were selected to develop advanced content courses for the project. The model made use of a team pairing each scientist with a science educator to blend the PBS course content with the science and engineering content courses. Lessons in the courses followed a learning cycle where participants explored science phenomena, concepts were explained (teachers' science content knowledge was extended), and opportunities to extend the learned concepts were provided. Specifically the model used the 5 E Learning Cycle Model: (1) *Engagement* where instructors tap prior knowledge and spark interest in the concept/topics under study; (2) *Exploration* where participants develop and use inquiry skills through concrete, hands-on experiences; (3) *Explanation* that provides participants the opportunity to learn key scientific concepts; (4) *Elaboration* where the concepts are applied again, but in a new and contextualized way; and (5) *Evaluation*, which includes assessment opportunities along with the examination of related state achievement standards (Bybee and Landes, 1988).

Project-based science

TLs learned about PBS through both reading about PBS (Krajcik & Czerniak, 2014) and engagement in a project studying the transformations of energy. The instructor was an experienced teacher who used PBS principles every day in her junior high school science classroom. Investigating and Questioning the World through Science and Technology (iQWST) and Project Based Inquiry Science (PBIS) curriculum materials (Energy unit) developed through an NSF-funded project were included as examples of model PBS curricula (Krajcik, McNeill, & Reiser, 2008). Through the building of Rube Goldberg devices (O'Connor, 2003), the teacher leaders explored and explained the energy transformations of the devices they created. Each TL developed a project-based unit for his/her classroom.

In the fall, TLs implemented the PBS units designed in the summer in their own classrooms. The TLs drew upon their experiences implementing PBS when planning and creating their