

**Abstract Title:** Understanding Student Success in the Science Learning through Engineering Design (SLED) Partnership

**MSP Project Name:** Science Learning through Engineering Design (SLED) Partnership

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**120 word summary:**

The aim of the SLED Partnership is to increase grade 3-6 student learning of science by developing Indiana's first integrated, engineering design-based approach to elementary school science education. We hypothesize that authentic engineering learning tasks are more likely to hold the attention and interest of students and lead to deeper levels of science engagement and advance teacher understanding of a broader range of engineering practice. Students will gain and share new scientific knowledge with others to form a productive community of practice. Attention is given to innovative approaches including context mapping, word associations, and think-aloud protocols as a means of effectively capturing student learning and, furthermore, exploring the fidelity of teachers' instructional implementations of engineering-design based science lessons.

## **Section 1: Questions for dialogue at the MSP LNC**

As new members of the MSP Learning Network, the *Science Learning through Engineering Design (SLED) Targeted Math Science Partnership* research team seeks to learn more about measuring student success in science at the elementary/intermediate school level. We posit the following questions:

1. What are effective ways of measuring elementary school students' science conceptual understanding and application when using the engineering design process?
2. In what ways can researchers account for variation in teacher implementation of instructional practices (in our case, the engineering design process) and its impact on student success?

## **Section 2: Conceptual framework**

The SLED Partnership will answer the overarching question: Given the necessary tools and resources, cross-disciplinary support, and instructional time, could elementary/intermediate teachers work as a community of practice and effectively improve elementary school students' science achievement through a standards-based, design-oriented, integrated curriculum built around the use of the *engineering design process*? Engineering, science, technology, and education faculty from Purdue University will work directly with 200 elementary /intermediate

inservice teachers, 100 preservice elementary teachers, and 5,000 students in the four partnering Indiana school districts.

### **SLED Definition of Student Success**

We define student success in the following manner. Students who engage in SLED engineering design-based science lessons demonstrate growth and/or improvement in how they: a) conceptualize the design process; b) apply design- and inquiry-based skills; c) learn and use scientific concepts to solve problems productively; d) connect and transfer individual scientific concepts and design skills to new situations; and e) perform on standardized tests.

### **Context of the work within the STEM education literature and within your MSP Project**

During the past decade, there has been a surge of interest in engineering design activities as a means to promote science learning (Benenson, 2001; Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004; Kolodner, 2002; Lewis, 2001; Puntambekar & Kolodner, 2005). Design challenges provide a motivating context for students to learn science conceptual (content) and procedural (processes) knowledge (Crismond, 2001). As students engage in an iterative process of asking questions, developing plans, designing prototypes or models, evaluating, and redesigning, they also have the opportunity to confront their understandings and misunderstandings of science concepts (Fortus, et al., 2004; Puntambekar & Kolodner, 2005).

While empirical research validates the use of engineering design at the secondary school level, such efforts are almost nonexistent for the elementary school classroom. Studies indicate that elementary and intermediate school teachers (defined as grades 1-6 and 3-6, respectively) teach science in isolation and grapple with barriers such as insufficient subject matter knowledge, inadequate instructional time, and limited access to or awareness of curriculum resources that blend disciplines (Abell & Lederman, 2007; Meier, Nicole, & Cobbs, 1998).

SLED researchers draw on the construct of situated learning theory (Lave & Wenger, 1991) where learners become part of a community of practice in which they learn from others through an apprenticeship approach and advance from simple tasks to more complex ones until becoming full-fledged participants of the community. Learners must engage in authentic learning tasks in which they can relate to their own experience inside and outside of school; the tasks are ones that an experienced practitioner would undertake (Brown, Collins, & Duguid, 1989; Bruner, 1996; Lave & Wenger 1991). In the SLED partnership, teachers will integrate various curricular activities grounded in the engineering design process and the work of professional engineers while simultaneously merging these ideas, concepts, and skills with children's use of everyday technology, children's ideas of current science issues and topics, and children's abilities to work collaboratively in a social setting modeling the engineer's workplace.

### **Claim(s) or hypothesis (es) examined in the work**

We hypothesize that authentic engineering learning tasks are more likely to hold the attention and interest of students and lead to deeper levels of science engagement (Fortus, et al., 2004; Roth, 1996; 1997; 1998) and advance teacher understanding of a broader range of engineering

practice. Students will gain and share new scientific knowledge with others to form a productive community of practice.

### **Section 3: Explanatory framework**

The SLED Partnership is guided by the following research questions related to student success:

1. How do elementary/intermediate school students conceptualize and learn design?
2. How do elementary and intermediate school students utilize and learn science when engaging in engineering design-based tasks?
3. What new science content knowledge do students construct when engaging in engineering design based tasks?
4. How do students connect individual scientific concepts together in the context of an engineering design-based task and how enduring and accurate are these connections?

#### **Measures of Student Success**

The following measures will be taken to ensure that members of the SLED research team can adequately assess student success. More specifically, we propose that measures, such as, context mapping, word associations, and knowledge assessments (i.e., knowledge tests, ISTEP) will elicit students' knowledge and conceptual understandings. Other measures, such as think-aloud protocols, will reveal gaps in students' conceptual understandings as students transfer knowledge from one design task to another. Additional measures including student interviews, classroom observations and supporting documents will convey students' formative and summative conceptions of the design process and descriptive, first-hand accounts of learning before and after engaging in the engineering design-based activities.

*Pre- and Post-Instructional Engineering Knowledge Tests:* Student learning of science-related content in each unit is assessed before and after each unit is enacted by pre- and post-tests. Tests are constructed in collaboration with SLED teachers using their respective curriculum maps and SLED team-generated assessments. The tests are composed of developmentally appropriate multiple-choice and open-ended items that probe for different levels of comprehension using low, medium, and high cognitive demand items.

*Indiana State-wide Test of Educational Progress (ISTEP):* The Indiana Statewide Testing for Educational Progress-Plus (ISTEP+) measures what students know and are able to do at each grade level. There are six Indiana Standards for Grade 4 Science and seven standards in Grade 6 Science, and they are divided into six categories for reporting student achievement. Age-appropriate concepts are assessed within each category. SLED researchers use data generated from the ISTEP to determine science content achievement.

*Student Participant Interviews:* Semi-structured interviews identify individual students' conceptualizations of design and how they reflect on their engagement in the design process. Students also share descriptive accounts of learning before and after engaging in the engineering design-based activities. Student interviews will allow SLED researchers to employ the following

methods to probe students' understanding of science and design concepts: 1) Context maps and word associations, and 2) Think-aloud method.

Context maps and word associations: SLED researchers utilize two complementary approaches to assess students' progression in their conceptual understanding of science: 1) eliciting knowledge with the use of *word associations* and *context maps* and 2) assessing persistence and accuracy of students' understanding by treating students design as a writing activity. Word associations are a well-established means to assess linkages between different concepts (Cachapuz & Maskill, 1989; Gunstone, 1980), and context maps are a more age appropriate variation of concept maps and they provide a more global view of students' conceptual understanding (Bloom, 1995).

Think-aloud method: Using a "think-aloud" protocol method (Ericsson & Simon, 1993; Kruger & Cross, 2001; van Someren, van de Velde, & Sandberg, 1994) students are asked to verbalize their design thoughts as they work through a transfer problem similar to the SLED design problems. The data from the protocol identify common cognitive strategies employed by the students and identify gaps in the students' application of science concepts.

Classroom observations: Classroom observations allow SLED researchers to examine, in real time, how design tasks are implemented and how students engage in these respective tasks. Observations allow us to assess the fidelity of the treatment (i.e. do teachers implement activities as expected). We also expect to observe evidence of students working in teams, using design-informed language and/or vocabulary, and attempting to apply scientific concepts.

Supporting documents: Supporting documents such as students' design notebooks and artifacts are analyzed because students' project work, their designs, and notebooks are a "writing" activity and speech act, meaning that students do not just solve a problem, their designs and notebook entries explicitly communicate their understanding of science.

### **Key insights (prospective for newer projects) that have value for the Learning Network**

The SLED expects to generate: 1) a new line of research on the understanding of how teachers teach science through the engineering design process and how young students learn science through design-based activities; 2) a library of tested, design-based curricular materials to support teaching science in grades 3-6; and 3) a prototype for high quality teacher professional development in engineering design for preservice and inservice elementary educators.

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