Learning science through engineering design: An effective approach to STEM integration at the elementary school level

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SLED
Science Learning through Engineering Design

How do we characterize STEM?

- Instructional approaches that explore teaching and learning between and among any two or more STEM subject areas, and/or between a STEM subject and one or more school subjects
- In the SLED Partnership, we use the ***engineering design process*** as a mechanism to facilitate and improve students' learning of science and mathematics at the elementary school level (grades 3-6)
- Proficiency in this practice supports a better understanding of how scientific knowledge is produced and how engineering solutions are developed.

SLED Partnership

Science Learning through Engineering Design (SLED) is a partnership project of Purdue, four Indiana school districts, and community partners designed to help improve students' science learning in grades 3-6.

SLED

Science Learning through Engineering Design

SLED Partners

Purdue University

- Colleges of Education, Engineering, Science, and Technology
- Discovery Learning Research Center

School Partners

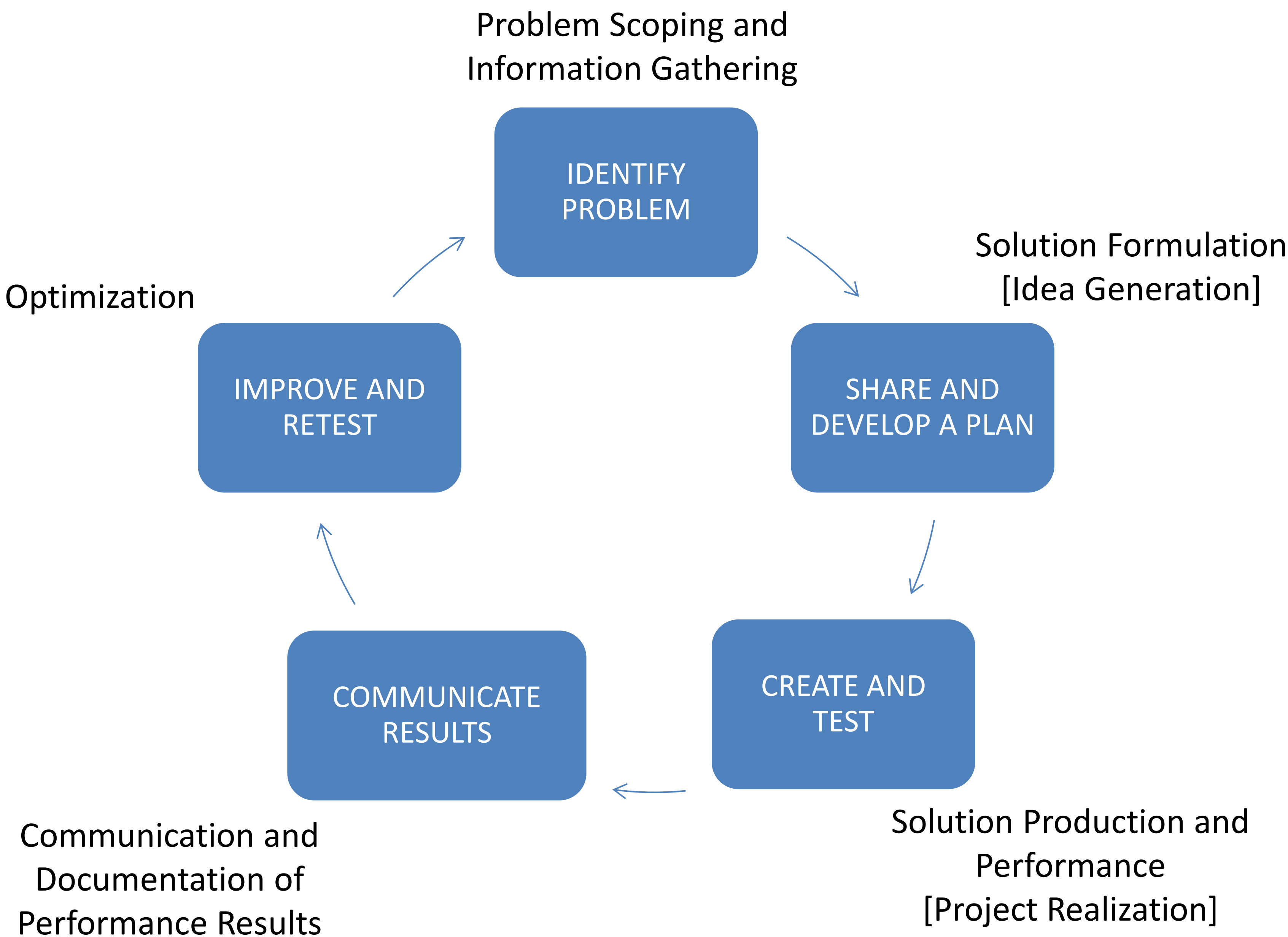
- Lafayette & Tippecanoe Schools
- Plymouth Community Schools
- Taylor Community Schools

Community Partners

- Subaru of Indiana Automotive
- RoadWorks Manufacturing
- Delphi Automotive
- Plymouth Foundry
- Caterpillar Inc.

Question guiding the SLED Partnership

If given the necessary tools and resources, cross-disciplinary support, and instructional time, could elementary/intermediate school teachers (grades 3 – 6) effectively improve students' science achievement through an integrated curriculum based on the use of the *engineering design process*?


Problem Scoping and
Information Gathering
IDENTIFY PROBLEM
Solution Formulation
[Idea Generation]
SHARE AND DEVELOP A PLAN
CREATE AND TEST
Solution Production and
Performance
[Project Realization]
COMMUNICATE RESULTS
Communication and
Documentation of
Performance Results
IMPROVE AND RETEST
Optimization

Design Challenge

Can you design a better candy bag?

Identify the problem

- What is the problem?
- Who is the client and what are the client's needs?
- What are the constraints?

Develop and create a plan

- Draw a diagram & make a list of materials
- Create your better candy bag

Testing, Evaluating, and Redesigning

- How could you test your bags?
- Which science concepts could be introduced or applied?
- How would you evaluate the performance of your design compared to another team's design?
- How would you foster redesign?
- As a teacher, how and what would you assess?

Teacher Challenges

First-order challenges

- Time
- Resources
- Space
- Classroom management

Second-order challenges

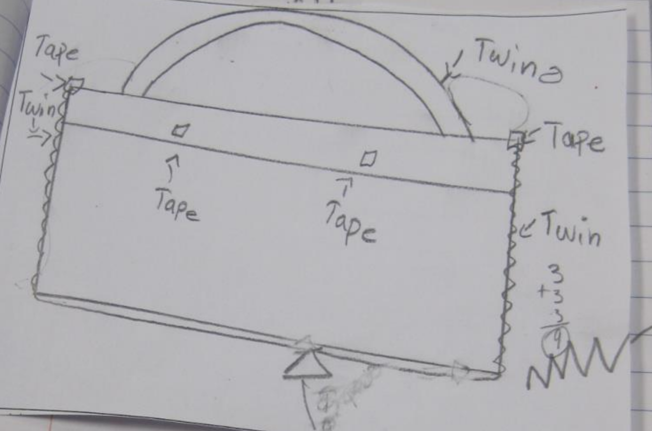
- Assessment
- Mental to physical models
- Testing

Presenting our designs & findings

Share your designs

- *What worked?*
- *What did not work?*
- *If you could improve on your design, what would you do?*

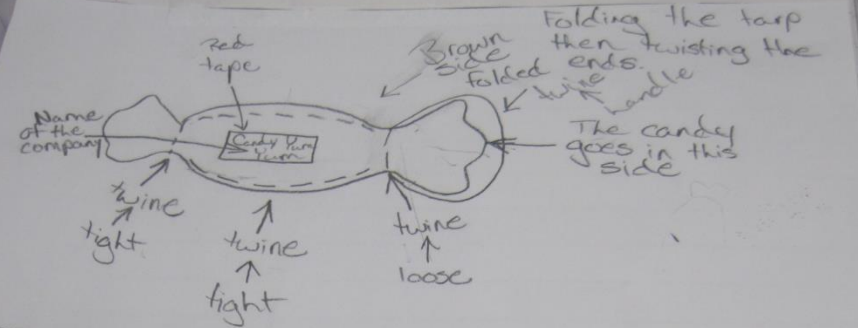
Big Plan



Mass the bag can hold

g ______

Kg ______



Two big strips of twine and two small strips of twine. One piece of red tape.

...d: 3 piece of red tape, 5 strips of twine, 1 tarp.

...e wieght the bag can hold: 5,000 grams


PURDUE
6


Stop your craving
7

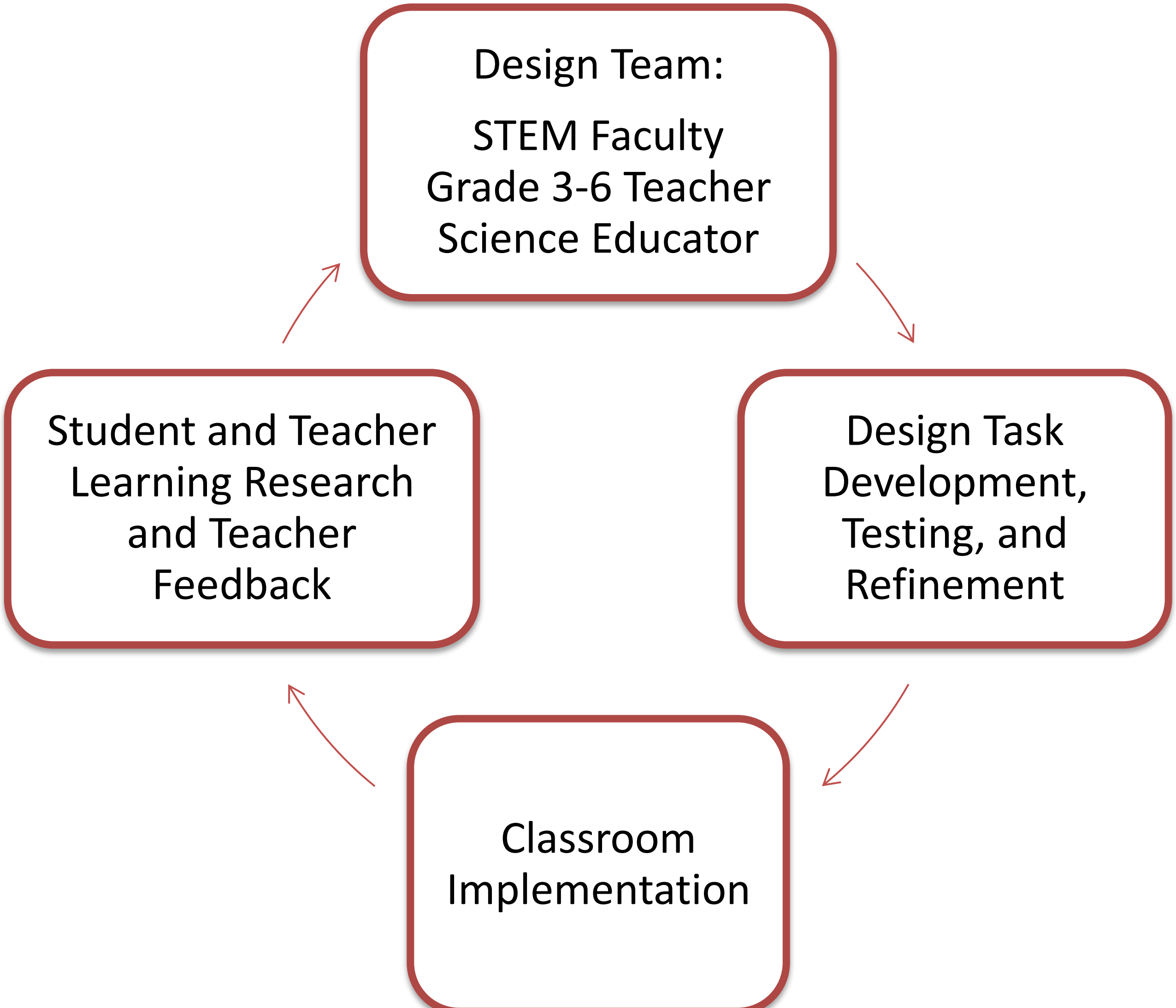

8

SLED Components

1. Faculty Design Teams and Task Development
2. Inservice Teacher Professional Development
3. Preservice Teacher Preparation
4. SLED Research related to Student and Teacher Learning

Adaptation/Development of Design-Based Curricular Materials

SLED Activity Creation Cycle



Essential Features of Design Briefs

1. Is client-driven and goal-oriented
2. Provides an authentic context
3. Includes constraints
4. Use of materials, tools, and equipment that are familiar to students
5. Yields a product that is either an artifact (prototype) or process
6. Yields multiple solutions
7. Requires team work

Examples of SLED Design Tasks

Task	Grade	Goal	Science concepts
Designing a Prosthetic Leg	5	Create a prototype of a prosthetic leg to kick a soccer ball	Mass Volume Density Forces
Creating Compost Column	5	Identify a process for making a better compost	Abiotic and biotic factors Decomposer
Roller Coaster	6	Design a prototype of a roller coaster that results in the greatest total loop diameter at the lowest cost.	Potential & kinetic energy Transformation of energy
Solar Panel Tracker	6	Develop a solar panel system that can be easily moved to track the sun, so that the panel can collect as much solar energy as possible	Direct and indirect rays Four seasons

Example of a SLED Design Task Prosthetic Limb

Boiler BioTech, a company in Warsaw, Indiana, needs assistance in designing a prosthetic leg for a young child so he/she can kick a soccer ball. Your team is responsible for designing and testing a prototype of a prosthetic leg that mimics the same movement of a hinge joint.

See sledhub.org for more examples.


You'll always miss 100% of the shots you don't take.
zaac
JaKie
Brent

In-Service Teacher Professional Development

In-Service Teacher Professional Development

- Teacher professional development is anchored by a two-week summer institute designed to introduce teachers to engineering design as a way to teach science.
- Teachers work with design teams and test design tasks, visit a community partner to engineering in action, develop skills through mini-workshops, map curriculum, and develop personal lesson implementation plans.

In-Service Teacher Professional Development

- Follow-up activities during the school year include progress reports and reflection sessions.
- Online activities on content and pedagogy are available via the project's electronic hub (sledhub.org).

Pre-Service Teacher Preparation

Pre-Service Teacher Component

- Pre-service teachers apply to participate in the SLED summer institute.
- They then participate in a special section of an elementary science methods course focused on engineering design.
- Pre-service teachers are paired with SLED in-service teachers to co-develop, implement, and assess their implementations of SLED task during an 8 week field experience


Arlington
Woods


salts
Design a fair test investigation to determine which salt makes a hot pack hot and which salt makes a cold pack cold
Get teacher approval before conducting your investigation

SLED Research

SLED Research

Partnership Development

- Support implementation
- Promote sustainability
- Impact on all partners, including STEM faculty

Teacher Learning

- Implementation
- Effectiveness
- Challenges

Student Learning

- Children's conceptualizations
- New science content knowledge
- Transfer of learning

Measures of Effective STEM Teaching

- Interviews (individual and focus group)
- Classroom observations
  - Developed the *Engineering Design-based Classroom Observational Rubric*
- Implementation Plans
  - Adapted version of the Penn Science Teacher Institute's Science Lesson Plan analysis Instrument (SLPAI) (Jacobs, Martin, & Otieno, 2008).
- Teacher reflections
- Surveys
- Supporting documents (i.e., teacher implementation plans, teacher-created resources, and student work)

Evidence of teachers' plans for implementation

Year	# of plans (14 teams)	# of tasks	# of schools
2011-2012	29	10	6
2012-2013	56	16	7

Quality of implementation plans 2011-2012

Implementation plans (n=29)

Distribution of plans	Mean score
Grade 5	64.3
Grade 6	67.5
All plans	66.0

Maximum score = 80

Teachers' instructional attempts at integrating engineering design-based pedagogies

Dimensions of Engineering Design-based Teaching Observational Protocol

Dimension	First Implementation Mean Score	Second Implementation Mean Score
Lesson Design and Implementation	2.42	2.57
Content	1.64	1.77
Portrayal and Use of SLED-endorsed engineering practices	2.51	2.60
Overall Score	2.19	2.41

Portrayal and Use of SLED-endorsed Engineering Practices	Mean	
Teacher facilitated the identification of the problem	4.00	4.00
Students and teacher used a variety of materials	3.20	3.15
Students actively engaged in questioning and their comments determined the focus and direction of design	2.10	2.34
Students actively engaged in planning (individually and in teams)	3.80	4.00
Students actively engaged in the construction of their designs	3.40	3.67
Students tested their designs	1.76	1.56
Students generated a feasible solution that aligns with the client's needs, criteria, and constraints	1.96	1.87
Students analyzed data collected in the testing of their designs	1.24	1.20
Students communicated the results of their designs and performance of their designs	2.44	2.40
Students engaged in re-design	1.15	1.76

Measures of Effective STEM Learning

- Think-Aloud protocols
- Knowledge tests
- Open-response tasks
- Indiana Statewide Testing for Education Progress [ISTEP]

Evidence of student learning through design: Prosthetic Leg Example

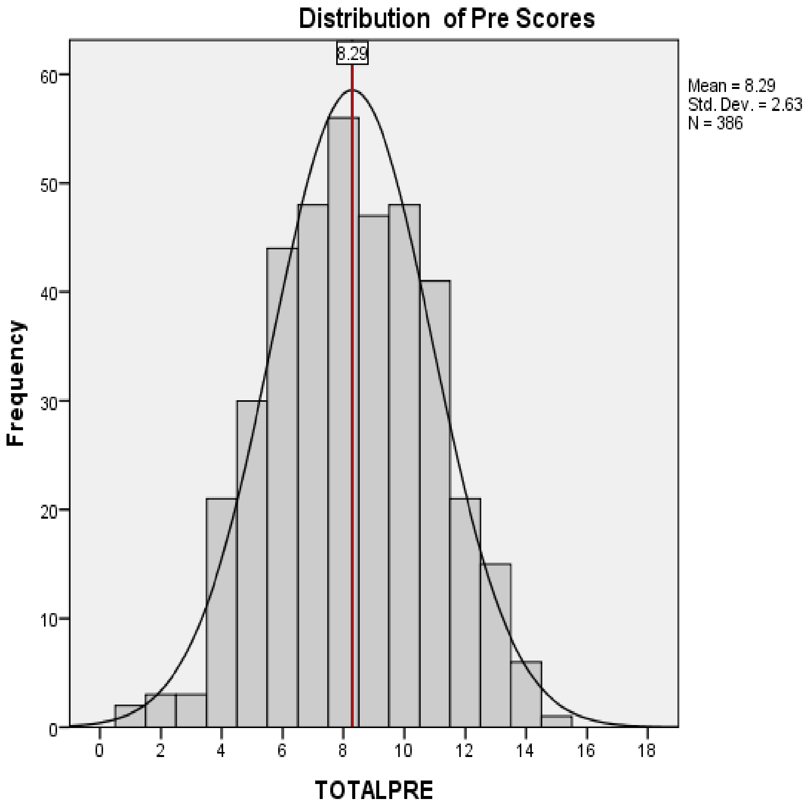
- Overall (Total = 18 points)
  - Implemented in 4 schools by 14 teachers (matched cases, n = 386)

	Total Score (Cohort 1)		
	Pre- Test	Post-Test	Gain Score
Mean	8.29	11.26	2.97^{b}
St. dev.	2.63	2.95	2.78

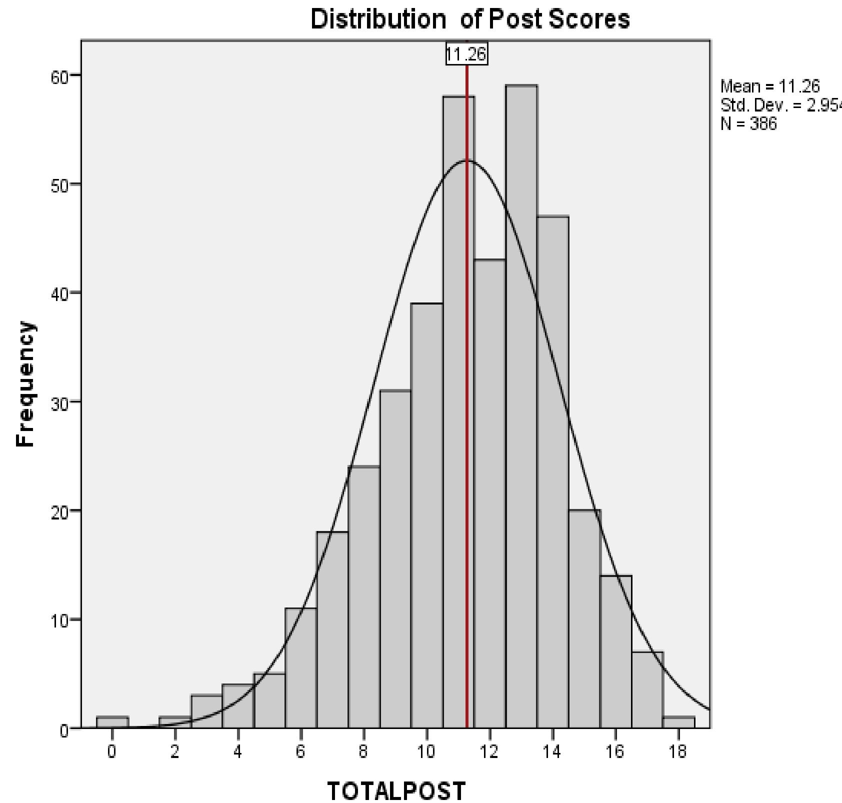
^{b} $p < 0.05$

Prosthetic Leg (Cohort 1)

Pre-test distribution
Cohort 1



Post-test distribution
Cohort1



Prosthetic Leg (Cohort 2)

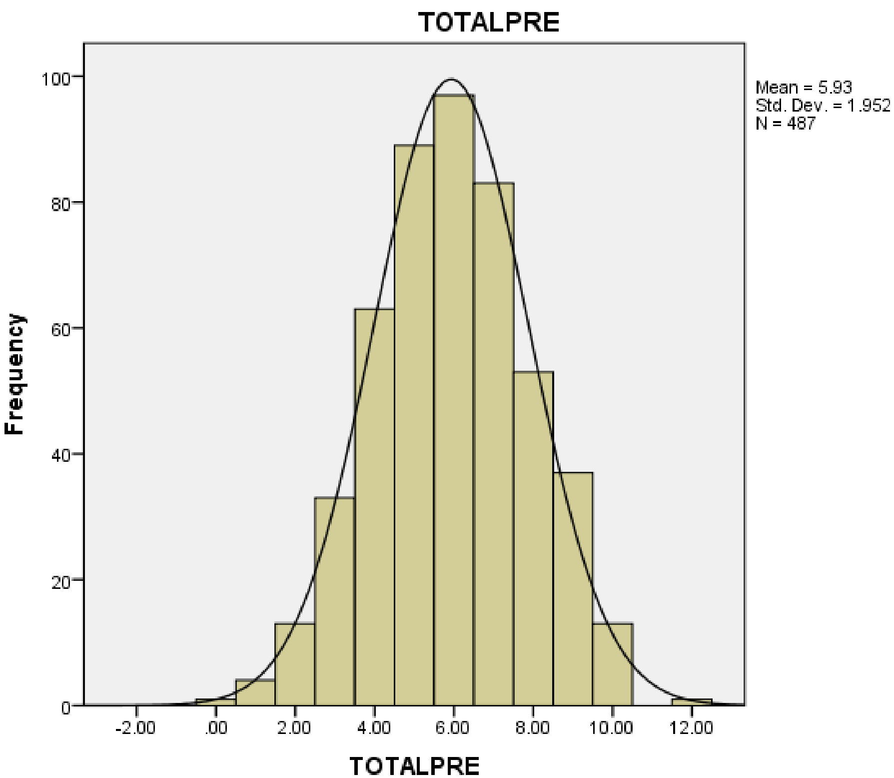
- Overall (Total = 12 points)
  - Implemented in 5 schools by 14 teachers (matched cases, n = 487)

	Total Score (Cohort 2)		
	Pre- Test	Post-Test	Gain Score
Mean	5.93	8.02	2.09[a]
St. dev.	1.95	2.22	2.38

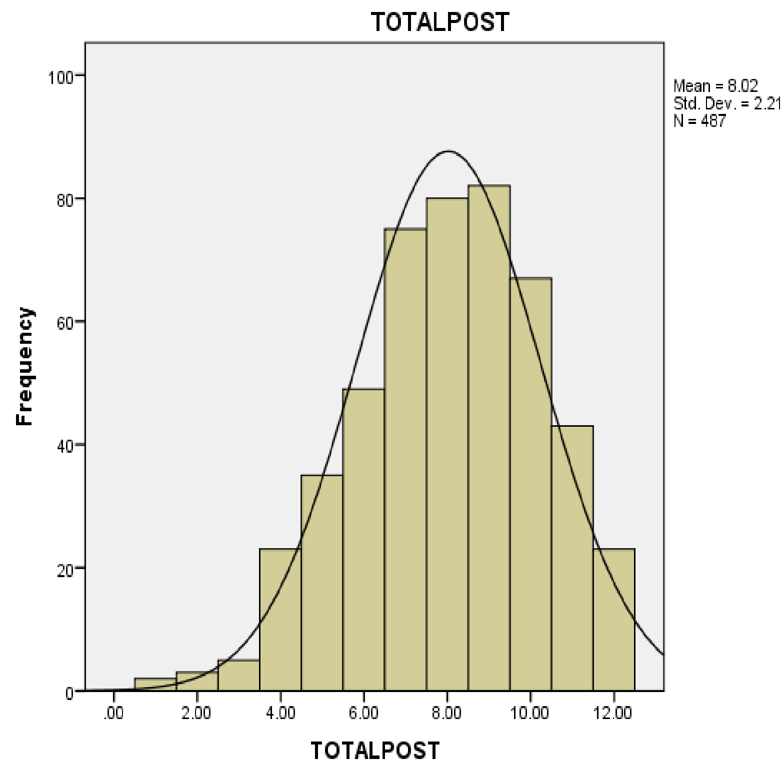
[a] $p < 0.05$

Prosthetic Leg (Cohort 2)

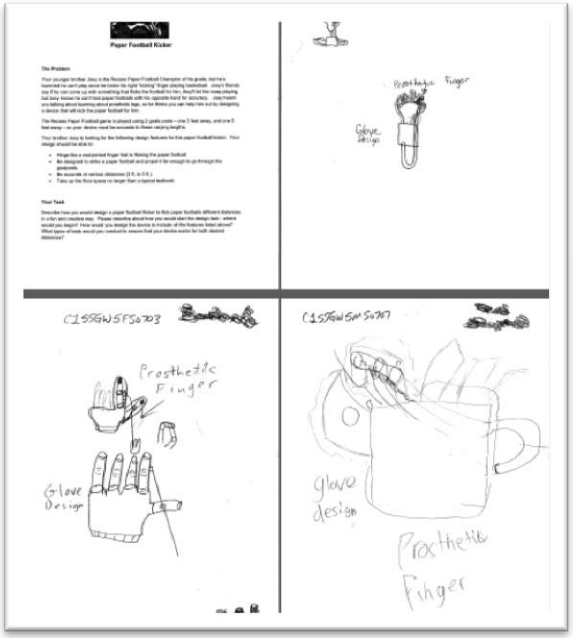
Pre-test distribution
Cohort 2



Post-test distribution
Cohort 2

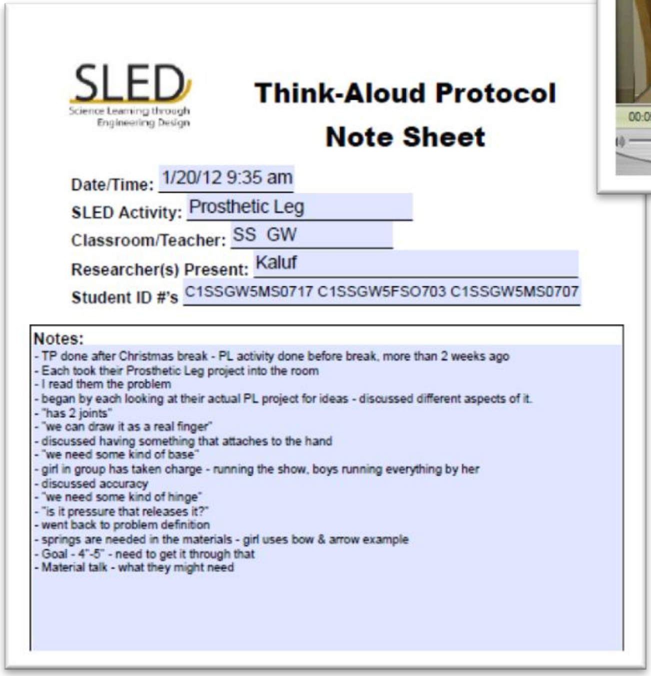


Data Sources for Think-Aloud Protocols



Student Drawings

Session Notes



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Think-Aloud Protocol Note Sheet

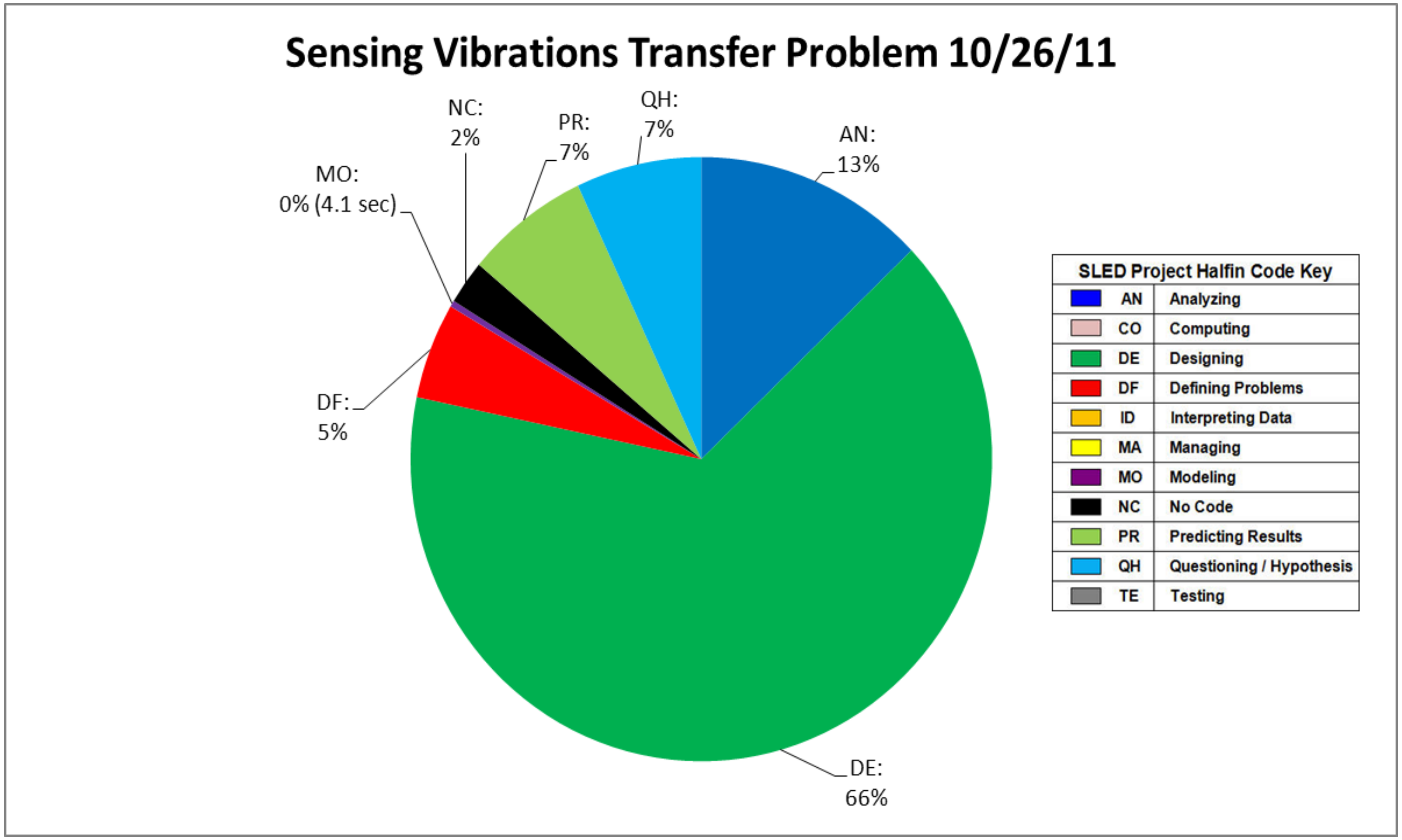
Date/Time: 1/20/12 9:35 am
SLED Activity: Prosthetic Leg
Classroom/Teacher: SS GW
Researcher(s) Present: Kaluf
Student ID #'s C1SSGW5MS0717 C1SSGW5FSO703 C1SSGW5MS0707

Notes:
- TP done after Christmas break - PL activity done before break, more than 2 weeks ago
- Each took their Prosthetic Leg project into the room
- I read them the problem
- began by each looking at their actual PL project for ideas - discussed different aspects of it.
- "has 2 joints"
- "we can draw it as a real finger"
- discussed having something that attaches to the hand
- "we need some kind of base"
- girl in group has taken charge - running the show, boys running everything by her
- discussed accuracy
- "we need some kind of hinge"
- "is it pressure that releases it?"
- went back to problem definition
- springs are needed in the materials - girl uses bow & arrow example
- Goal - 4"-5" - need to get it through that
- Material talk - what they might need

Video File

Analysis

ID	CODE	TIME
1	DE	00:14.5
2	DE	00:02.2
3	DE	00:01.4
4	DE	00:10.3
5	DE	00:01.6
6	DE	00:06.7
7	AN	00:01.2
8	DE	00:23.2
9	PR	00:03.7
10	AN	00:03.5
11	DE	00:05.8
12	DE	00:04.4
13	NC	00:06.0
14	DE	00:11.2
15	QH	00:02.3
16	DE	00:15.8
17	DE	00:22.5
18	PR	00:02.0
19	DE	00:06.0
20	DE	00:03.4
21	PR	00:01.4
22	DE	00:34.0
23	PR	00:03.2
24	PR	00:04.7
25	DE	00:11.4



For more information, contact:

- E-mail: sled@purdue.edu
- Web: http://sledhub.org