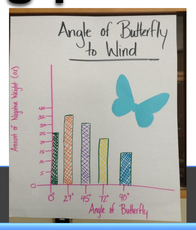
What will you do to help elementary students who struggle in the engineering process? Analysis of teachers' reflections. (Fundamental)

Zachary Minken, Augusto Macalalag, & Najah Naylor

ARCADIA UNIVERSITY SINCE 1853



Course, Problem, & Research Question

Course Description:

Our study was conducted during the 3-credit course, *Introduction to STEM Education*, taught by the second author for 15 weeks in a small liberal arts college in the mid-Atlantic region of the United States. Throughout this graduate methods course, teachers were introduced to the science and engineering practices, crosscutting concepts, and core ideas outlined in the *Framework for K-12 Science Education* [12]. Specific course objectives included: (a) developing or adapting a unit to incorporate science inquiry and EDP practices, (b) creating assessments to analyze students' conceptual understandings and difficulties in science, (c) implement and reflect on instruction, (d) utilize STEM curricula and resources, and (e) incorporate physical science concepts. The four core assignments consisted of writing a teaching statement, developing and implementing a STEM unit, writing reflections after watching video-captured instruction that focused on science or engineering lessons, and pre-and post-tests.

Problem:

Developing lessons with science and engineering practices is challenging to do particularly for elementary teachers who have limited knowledge, pedagogy, and experiences in these domains. Uncovering teachers' initial and developing ideas about components of good science and engineering instruction can provide insights on the teachers' notions about the general and specific teaching methods that are important to them.

Research Questions: To what extent, if any, do teachers' knowledge of the EDP change before and after the course? In what ways, if any, do teachers' pedagogical moves to scaffold students' learning experience change at the end of the course?

Participants, Instruments, & Methods

Participants:

- 17 In-service Elementary Teachers
- Majority (N=13) have 7 or more years of teaching experience while others have 6 or fewer years
- Majority (N=12) have a background in early childhood or elementary education

Instruments:

Identical pre- and post-tests were used to measure participants understanding of the EDP and how it can be implemented in elementary classrooms. They answered the following questions based on a scenario in which the reader is tasked with designing a coat for use on a hike up Mt. Everest (adapted from Boston Museum of Science et al., 2011):

- 25A: List and describe the steps you will take to design and create a type of coat for your team members
- 25B: You provided this design challenge for your students to solve. One group started to create the coat as soon as they receive the materials.
  - A: What steps did they skip?
  - B: What advice would you give them?
- 25C: A different group of students is having some trouble because they could not agree on the color and materials to use for the coat. What advice would you give them to resolve this issue?

Methods:

Data Collection

- Teachers completed identical pre- and post-tests at the beginning and end of the course
- Data for this study came from the four open ended questions described above

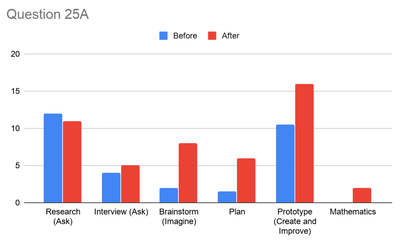
Coding and Data Analysis

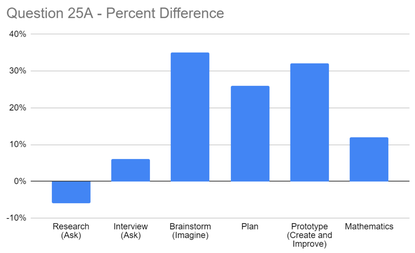
- Coding manual was developed by the first author and consisted of two types of codes:
  - EDP Content Codes: align with teachers' observed conceptions of the steps involved in the EDP
  - EDP Teaching Codes: designed to capture teachers' stated pedagogical moves and instructional strategies relating to teaching the EDP
- Two independent coders analyzed the full papers using the coding manual
- The two coders double-coded 100% of the papers with 90% agreement or better for each question
- Disagreements were discussed and negotiated
- Agreed codes were included in this report
- A quantitative analysis of a qualitative study was done (Chi, 1997)

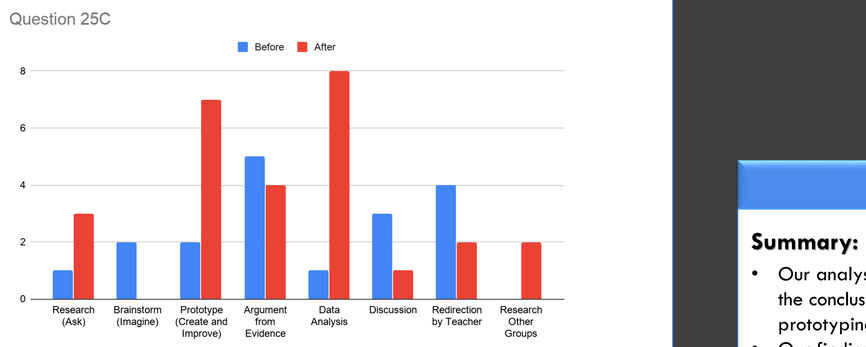
Coding Manual

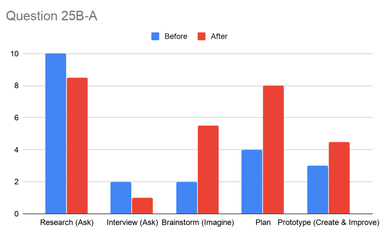
Question 25A: List and describe the steps you are going to take to design and create a type of coat for your team members	
Question 25B-A: You provided this challenge to your students to solve. One group started to create the coat as soon as they receive the materials. What steps did they skip?	
Question 25B-B: What advice would you give them?	
Question 25C: A different group of students is having some trouble because they could not agree on the color and materials to use for the coat. What advice would you give them to resolve this issue?	
EDP Content Codes	**Examples**
Research: looking things up (online or offline), reading articles or watching videos to look for information	"Research: What is the weather like in the mountains aside from cold, is it wet? Dry?" -- Stephanie
Interview: communicating with experts in order to obtain their opinion	"Call NASA for ideas for insalation [sic]" -- Micaela; "interview hikers from various parts of the world with varying degrees of experience" -- Jaheim; "survey actual hikers" -- Aiyanah
Brainstorm: coming up with a list of ideas, either individually or with a group; can be written or verbal	"Brainstorm a list of possible ideas -- anything goes" -- Dymiere; "I would think of all materials available that might lend themselves to this challenge" -- Solomon
Plan: mention of developing/outlining steps or a specific process for solving a problem	"discuss plan [and] what features the coat should have" -- Jaylin; "plan how to do it by using prior knowledge and experience" -- Kahree
Prototype: going through an iterative process of design/redesign, creating models, revising initial ideas, and/or a process of trial and error	"Revise prototype based on data findings and communicate for feedback. Repeat until data communicates effectiveness" -- Xiomara; "Based on these tests any problems would be adressed [sic], the prototype would be redesigned and re-tested." -- Manuela
Mathematics: mention of any formulae or necessary/potential calculations or creation of tables/charts/graphs	"Gather mathematical data of how the models succeeded (or failed) in meeting the criteria" -- Francis
EDP Teaching Codes	**Examples**
Slow Down: as a direct quote or idea	"stop and think about the design process" -- Dymiere; "slow down -- get to know who you are designing for" -- Jameel
Analogies: use of analogies as an explanatory teaching tool	"Think about insulation. Why do many people in a room keep it warmer? Why does a thermos keep liquid cool or warm?" -- Daneyah
Argument from Evidence: mention of persuading others based on scientific observations or other evidence; includes creation of pros/cons list	"use the available data to explain/defend the materials they would like to use" -- Xiomara; "I would invite the students to come up with data driven arguments to defend their ideas." -- Eva
Data Analysis: mention of analyzing various data in order to reach a conclusion	"run some tests to collect data on the attributes they are debating" -- Aiyanah; "they should make a decision based on the evidence. They need to use the information they have to make an informed decision" -- Manuela
Discussion: talking with others about ideas without explicit mention of specifically involving evidence	"Discuss what the most important features should be" -- Sitsofe
Redirection by Teacher: treating ideological conflict between students as a misbehavior requiring teacher intervention that does not encourage debate or discourse, but instead seeks to resolve the conflict as quickly as possible by ignoring the root of the conflict; can include choosing approach at random	"This is not relevant to the design" -- Kevin; "I would tell them to each put their ideas on a piece of paper and place in a hat. Then do a random drawing of the ideas and begin" -- Solomon
Research Other Groups: mention of observing/interacting with other groups to uncover other solutions or examine/explore other ideas	"An additional option would be for them to gather information from other groups to see how that info might affect the outcome" -- Stephanie

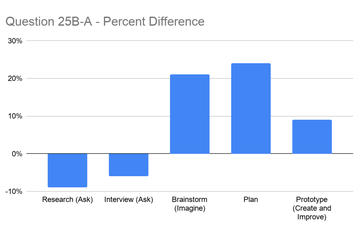
Findings

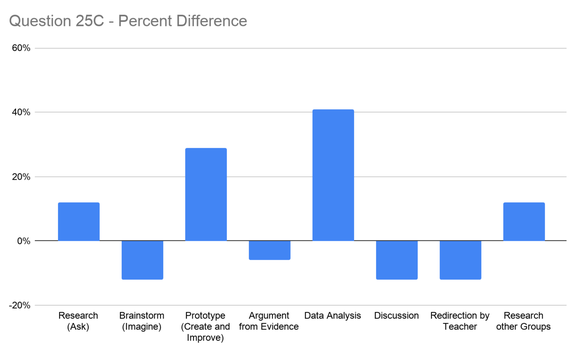


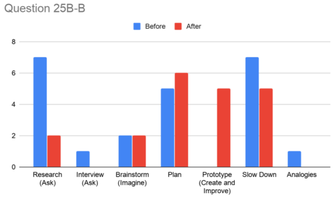


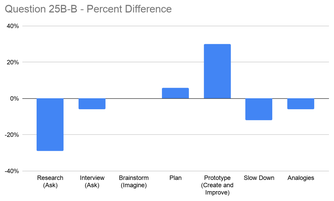












Conclusions and Limitations

Summary:

- Our analysis of data suggests that participants had a deeper understanding of EDP at the conclusion of the course, with particular emphasis on brainstorming, planning, and prototyping as steps of the EDP
- Our findings suggest that teachers recognize the need for explicitly teaching planning and prototyping skills to students with regard to teachers' instructional strategies with regard to teaching EDP.
- Teachers' focus had shifted to data analysis as a means for resolving disagreements among students engaged in the EDP. This suggests sophistication of their pedagogical knowledge of EDP that points to revision of prototypes based on evidence.

Limitations:

- Written tests are only one of many ways of looking at teachers' knowledge and pedagogical moves, and may not be the most accurate reflection of what teachers' instruction would look like in the classrooms.
- Domain-specific knowledge likely had an effect on the teachers' abilities to design EDP lessons, but was not described or accounted for in this study.
- We are unable to describe how our teachers implemented their lessons in the classroom because we did not collect data during classroom implementation.