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SCAFFOLDING EVIDENCE-BASED REASONING IN A TECHNOLOGY SUPPORTED ENGINEERING DESIGN ACTIVITY

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Engineering Design (ED) challenges are increasingly used as a context to learn science. Research shows that there is a need for strategies that facilitate learners to identify, apply, and reflect on ways scientific principles can inform creation and evaluation of ED solutions. We investigate the use of contrasting cases and argumentation scaffolds to facilitate use of evidence-based reasoning in a CAD supported ED tasks. Elementary education majors in a physics course analyzed solutions to an ED problem in two conditions: 1) identify similarities and differences, 2) evaluate and produce an argument for a "good" design solution. We found that the argumentation condition used scientific evidence-based reasoning significantly more frequently in their responses than the control. Results indicate that the contrasting cases with argumentation scaffolds shows promise in facilitating students' use of evidence-based reasoning in their ED tasks.

Keywords: evidence-based approaches, integrated learning, problem solving

INTRODUCTION

There have been numerous calls for advancing STEM education to address global challenges (Kelley & Knowles, 2016). Recent, science education reform documents in the U.S. have recommended the integration of real-world engineering design (ED) challenges to increase student interest and learning of in science, expand the 21st century STEM-capable workforce, and increase STEM literacy for all students (NGSS Lead States, 2013). In this new vision ED expands the range of inquiry-based practices to enhance the teaching of science. Most elementary teachers in the U.S. are acutely underprepared to teach science, let alone integrate ED with it (e.g. Cunningham & Carlsen, 2014). Furthermore, learners typically do not attend to underlying science principles and phenomena while solving ED challenges (Baumgartner & Reiser, 1998). They rely on trial and error and not science evidence-based reasoning to justify design decisions (Kolodner et al., 2003). This is akin to novice-like, surface feature focused strategies that learners often tend to use while solving or categorizing problems (Chi, Feltovich, & Glaser, 1981).

Analyzing contrasting cases that have embedded similarities and differences highlighting science principles can facilitate learners to search for ways in which these principles are applied (Sidney, Hattikudur & Alibali, 2015), but learners need prompts to do this productively (e.g. Roelle & Berthold, 2015). The process of constructing solutions and explanations includes argumentation to support claims with evidence and reasoning (Mathis, Siverling, Glancy, & Moore, 2017). Argumentation is a critical science and engineering practice, but learners need scaffolds to compose arguments to support their problem-solving steps and rationale behind their action (Christodoulou & Osborne, 2014). In this study we use argumentation prompts (Author, 2017) to facilitate students to support their responses to a contrasting case task. We adopt the claim, evidence, reasoning (CER) perspective (McNeill, Lizotte, Krajcik, & Marx, 2006) of argumentation. In this perspective, the quality of an argument focuses on: clarity of claim(s), sufficiency of evidence, and relationship between them (Chen, Hand, & McDowell, 2013). Participants contrasted two solutions to a design challenge. One condition received prompts to identify similarities and differences. The other condition received prompts to produce arguments to support their solution. Our research question was: *To what extent do students in each condition use evidence-based reasoning to support their design solution?*

RESEARCH METHODS

Fifty one participants enrolled in a physics course for elementary education majors at a large U.S. Midwestern land grant university engaged in a challenge to design an affordable, energy zero home using a CAD software, *Energy3D* (http://energy.concord.org/energy3d/). The software allows students to change design parameters such house size, shape, materials, solar panels and others. To facilitate integration of science in ED, we modified an ED cycle (Atman, et al., 2007; Capobianco, Nyquist, & Tyrie, 2013) by taking a 'detour' into inquiry-based adaptation of a 3E learning cycle (Karplus & Butts, 1977). After one iteration through the ED cycle, participants transitioned into the explore phase followed by the explain phase, and back to the ED cycle coinciding with the elaborate phase of the learning cycle (Figure 1).

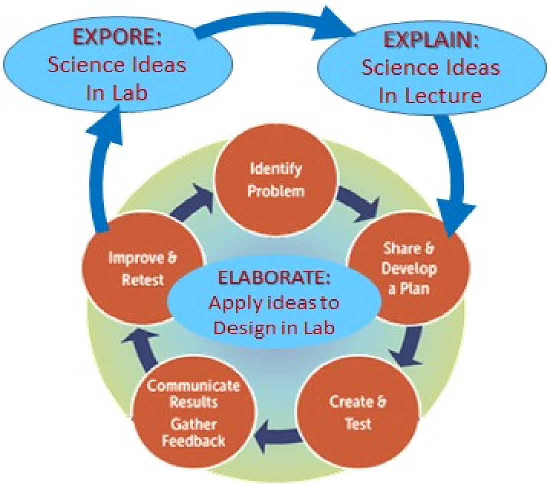

Figure 1. Engineering Design Cycle (Capobianco, et al., 2013) integrated with 3E learning cycle (Karplus & Butts, 1977).

In the Week 1 of the unit, participants were given an ED challenge to design a zero energy home costing less than $150K, at least 100 square meters in area, and 6 meters in height, with windows on each side. They started with sub-optimal design and used the *Energy3D* program to refine this design based on prior knowledge. In Week 2, they completed inquiry-based activities exploring and explaining the phenomenon of radiation, returning in Week3 to use *Energy3D* to further refine their home design based on what they had learned about radiation. In Week 3, they completed inquiry-based activities exploring and explaining the phenomena of *conduction* and *convection*, and in Week 4 they again used *Energy3D* to redesign the house from scratch and critique contrasting designs produced by hypothetical students.

Students were assigned to two conditions, both of which completed the four-week sequence above. with the control condition receiving prompts to provide an explanation and the argumentation condition receiving prompts to provide good scientific arguments based on Nussbaum and Schraw (2007). Data were collected in the end-of-unit quiz that was completed by students. Students were presented a contrasting case transfer task (Table 1) to design a solar cooker.

<table>
<tr><td colspan="2">You are taking a group of elementary children on a field trip through the woods on a cool, sunny fall day. Around noon you decide to take advantage of the sun to heat up some soup you have brought with you. You have the following materials: tin cans, aluminum foil, black trash bag, transparent zip lock bags, Styrofoam cups. Two students come up with two different designs for how to use the materials to build a 'solar cooker' to heat the soup.</td></tr>
<tr><td><u>Jose</u>: I will put the soup in the Styrofoam cup because this will not allow heat to escape. I will take the aluminum foil and wrap the cup on the outside because it will prevent the cold from outside to come in and cover the top with a cut out piece of black trash bag and cover the top of the Styrofoam cup so that it can absorb the sun's heat.</td><td><u>Jamila</u>: I would prefer to use the tin can, because the tin allows the heat to come in easily. I will cut out a piece of the black trash bag material and wrap it on the outside because black absorbs heat from the sub. I will not cover it with anything, because it you cover it, you block out the heat from the sun. After it has heated up some, then I will cover the top with foil.</td></tr>
<tr><td colspan="2">Which explanation (or combination thereof) best provides a justification to design a 'solar cooker'? Or, do you have a different explanation. Explain, elaborate, and justify your preferred explanation.</td></tr>
</table>

Table 1. Contrasting Design Tasks

ANALYSIS AND RESULTS

Students' responses were coded using the three-component framework (McNeill, et al., 2006) : (i) *Claim*: a statement describing what a design feature will accomplish (ii) *Evidence*: A science concept that supports the claim (iii) *Reasoning*: explains *why* the science concept or idea supports the claim. An example of the coding scheme being applied to a response fragment is shown in Table 2. Two-independent raters coded all responses and discussed codes to reach 100% agreement. A single factor ANOVA showed that the argument condition had significantly more number of claims (Mean=5.90, SD=2.34) supported by scientific evidence and reasoning ($F(1, 49) = 20.71$, $p = .000$) than the control condition (Mean=2.87, SD=1.87).

Response Fragment	*Claim*	*Evidence*	*Reasoning*
"The black trash bag has low albedo, so more heat will be absorbed rather than reflected. This will assist in heating."	The black trash bag… will assist in heating	The black trash bag has low *albedo*.	so more heat will be absorbed rather than reflected

Table 2. Example of the coding scheme applied to a response fragment

CONCLUSIONS

We implemented the use of contrasting cases and argumentation scaffolds in a physics course for elementary education majors to address the problem with the use of design-based instruction to facilitate the learning of science. We found that the argumentation condition provided scientifically appropriate evidence and reasoning to support their design claims much more frequently than the control group that did not receive the prompts or the guidelines for good scientific argumentation. The results of this study seem to suggest that the use of contrasting designs and argumentation scaffolds used here may be facilitate learners' use of evidence-based reasoning in engineering design challenges and must be explored further.

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