Investigating the Use of Anchoring for Promoting Design Thinking

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Abstract: There has been an increased emphasis on integrating design thinking in every aspect of student learning at an early stage. However, teachers still lack the resources and scaffolds to facilitate such integration. In this paper, I present a way for scaffolding design thinking in middle school classrooms by using incomplete models as anchors. Findings show that the use of an incomplete seed model as an anchor evoked different responses from the student designers – some extending it immediately, some returning back to it after exploring other design options, and some likely referring to it implicitly. The incomplete seed model provided an example to the students for practicing design thinking and make tradeoffs. The incompleteness also allowed students to pursue different design trajectories.

Introduction

We are faced with a future where engineers have to increasingly make very complex design decisions, starting from determining how to build efficient autonomous vehicles, to designing secure artificial intelligence driven personal assistants and even building interplanetary settlements. These endeavors will require design thinking at every stage and it is best to start training as early as possible. In order to prepare students for this future, policy changes to the middle and high school standards require US school curricula to integrate design thinking in every aspect of student learning (NAE, 2009). However, this implementation has been slow to come primarily due to lack of age-appropriate resources and scaffolds for young students that might help them practice design thinking (Moore et al., 2014). In this paper, I address this gap and present a way for scaffolding design thinking in middle school classrooms by using incomplete models as anchors.

Framework

Models are simplified representations of complex systems that are frequently used as a thinking tool for understanding the system by manipulating various model parameters (Harrison & Treagust, 2000). Models help make reasoning and ideas inspectable amongst peers as well as evaluators (Lehrer & Schauble, 2000). In classrooms, models serve as tools for overcoming inert knowledge (Renkl, Mandl & Gruber, 1996) by anchoring instructions and discussions to a concrete representation of the system (CTGV, 1990). Anchoring using such models situates new knowledge "in the context of immediate application to a problem solution and not in an abstract, decontextualized way" (Renkl, Mandl & Gruber, 1996, p. 119). Models, in particular the incomplete ones that allow the user to fill in the gaps, have been found to be helpful during problem-solving tasks by encouraging self-explanations (Renkl & Atkinson, 2000). Thus, in this study I use incomplete models to drive students' problem-solving process using design thinking while they are working on a design challenge. Design thinking as the systematic iterative process of determining the goal or scope of a problem, generating ideas for optimizing the solution, evaluating the ideas by making tradeoffs and checking their fit in the solution space, and implementing the ideas to achieve the intended goal (Sheppard, 2003).

Method

This case study was conducted in an urban school in the Midwest US and spanned across 10 lessons, each 45-minute long. 12 students – grouped into 4 teams or "plumbing companies" – from the 6th grade worked on a design challenge using an incomplete model as the seed model. Every group was given the incomplete model that acted as an initiator for design ideas. Students had to optimize this seed model within the given constraints ($3000 budget and min 10 psi at each of the three taps A, B and C). Data sources included student conversations and models created by them. The incomplete model had a cost of $1203 and connected the source supply only to tap B. Three types of pipes were provided for completing the model, each having a certain cost and resulting in a specific pressure drop – 1-inch ($45, 1 psi drop), ¾-inch ($33, 4 psi drop) and ½-inch ($28, 12 psi drop).

Findings and discussion

Three ways of using the incomplete model emerged during the design process- delayed anchoring, immediate anchoring, and implicit anchoring. In the first instance, students demonstrated *delayed anchoring*. In the first iteration, after analyzing the seed model, Team B took it apart and reflected on the types of pipes that they had used; mostly 1-inch diameter pipes. S2 mentioned that they were trying to reduce the cost while satisfying the pressure constraint (10 psi). After this, the team revised their model by using different combinations of pipe diameters. They also moved the placement of pipes to reduce the cost of the model and ensure adequate pressure at the taps. The team also used the seed model to reflect on their prior design decisions and brainstormed alternative paths that may reduce the cost while meeting the pressure requirement. The team finally settled on a design similar to the seed model's design since it had the least pipe bends and thus was their cheapest model.

In the second instance, students demonstrated *immediate anchoring*. Team C began their design session by analyzing the seed model - *"Just connect it using more pipes… but we have to get it cheap, under budget"*. The team then modified the model by simply adding more pipes to the seed model's design thereby extending it. They made tradeoff decisions, determining what diameter of pipes to use for extending the seed model and also figuring out whether they needed to replace any pipes in the seed model. They kept the pressure at tap B same since it satisfied the pressure constraint and went on to make sure that their cost was below the budget *("this premade one (seed model) is exactly 10. So, our psi is good. We just have to make sure our money is good"*). S9 used the given pressure of 10 psi at tap B to justify why they did not need to replace the ¾-inch diameter pipes of the seed model. However, he indicated that the team needed to worry about the cost, moving the team towards making tradeoffs between cost and pressure. The final model looked very similar to the seed model's design.

In the third instance, students demonstrated *implicit anchoring*. After analyzing the seed model during the first iteration, Team A concluded that the model could be improved for the "greater good" but at a higher price (more than the incomplete model's cost). The team then took apart the model and started rebuilding it. They discussed various ideas, gesturing where the pipes should go and, in the end, opted for a design that was very similar to the seed model. However, the team did not refer to the seed model explicitly in this case. S3 suggested using ¾-inch diameter pipes but realized immediately that it would cause a huge drop in pressure, thus using 1-inch diameter pipes instead of ¾-inch diameter pipes. S13 then cautioned S3 that using only 1-inch pipes would increase their cost, highlighting the tradeoff of using 1-inch diameter pipes. In response, S3 used ½-inch diameter pipe near the taps to keep the cost down. The final model looked very similar to the seed model's design.

The use of incomplete seed model as an anchor evoked different types of students' responses – some extending it immediately, some returning back to it after exploring other design options, and some likely referring to it implicitly. The seed model appears to have provided an example helping students engage in the design thinking process and make tradeoffs. Students were able to immediately apply their knowledge about relationship between system variables to improve the seed model's design, potentially avoiding the new knowledge from becoming "inert." Additionally, the incompleteness of the seed model seems to have offered different design trajectories to the teams who ultimately gravitated towards optimal designs. Thus, anchoring using such incomplete models provide an age-appropriate effective scaffold for introducing design thinking in middle school. Further research is needed to determine the generalizability of these findings as well as evaluate the far transfer effect of such scaffolds. Also, future work will explore software-based representation of incomplete models to further understand the effect of form factor of the models on scaffolding design thinking.

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