Supporting Engineering Students' Estimation Skill Using a Collaborative Digital Learning Environment

Aditi Kothiyal, Indian Institute of Technology Bombay, aditi.kothiyal@iitb.ac.in

Goals of the research

Professional engineers are routinely called upon to make estimates during the course of their work (Linder, 1999). However the current engineering curricula do not include instruction on estimation (Linder, 1999). The goal of my project is to design and evaluate a collaborative digital learning environment to improve students' estimation skill. The design of the learning environment will be based on two inputs, namely, the estimation practices of experts and students' natural approach towards ill-structured engineering problems (like estimation).

Background of the project

Consider this problem: "ABC Company has designed a toy laptop for kids which helps them spell and read and is touch sensitive. Estimate how long the laptop will run on 2 AA batteries." Professional engineers must regularly make estimates such as these wherein an unknown parameter must be determined. Often unclear to non-experts is, where to begin and what method to use to obtain a good estimate. Such estimation is used, a) to do sanity checks of results b) when there is uncertainty in the data or conceptual models c) to establish the feasibility of a design and d) to eliminate candidate design solutions (Dunn-Rankin, 2001). Researchers (Linder, 1999) found that engineering undergraduates provided poor estimates for even simple engineering quantities such as force and energy. Despite this known deficiency, there do not exist systematic teaching-learning tools or strategies for engineering estimation.

Estimation problems arise in other sciences as well. For example, researchers (Ogilvie, 2009) found that that learning to solve estimation problems leads to expert-like problem solving behaviors in Physics. Thus estimation is an important skill and should be explicitly taught to students in the STEM disciplines.

Research suggests that engineering problems are solved collaboratively and using digital technology (Johri & Olds, 2011). Engineers extensively use representations and digital technology facilitates the creation and exchange of representations at a large scale (Johri & Olds, 2011). Therefore in order to provide an authentic learning environment (LE) for engineering estimation, I propose a collaborative digital LE as part of my doctoral research.

Methodology

I am using design-based research (Cobb et al, 2003) to design and evaluate the collaborative digital LE. Studies of expert estimation practices and students' natural ill-structured problem solving behaviors will inform the choice of interactions and tasks (see Figure 1 below) in the LE.

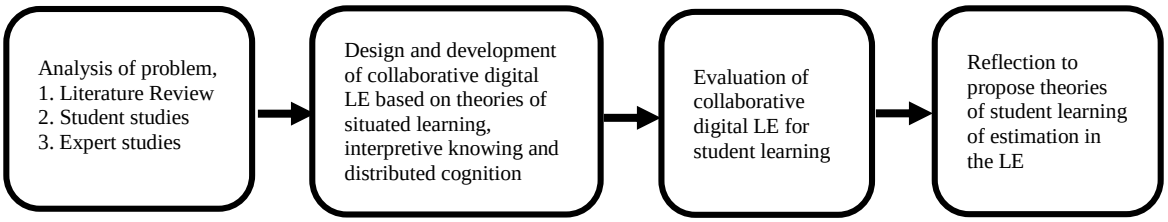

Figure 1. Stages of design based research

Understanding students' ill-structured problem solving practices

I performed a pilot classroom study with two groups of engineering students. One group got ill-structured problem solving instruction using a strategy based on productive failure (Kapur, 2008) while the other group learned with question prompts and peer interaction (Ge, 2003). After three interventions, I interviewed students to identify how they approach engineering problems, what heuristics they use and how they apply knowledge. The interviews were analyzed using content analysis and I identified several categories of student behaviors and heuristics.

We found that students in the productive failure group show a wider variety of behaviors and heuristics to construct the problem space, generate and defend solutions and evaluate and revise them. Further, these students reflect more on the role of various factors in their problem solving process. Importantly, we found that students

are not aware of the importance of their own problem solving behaviors; hence we need to include features in the LE to improve student awareness and ensure that students explicitly practice them.

Understanding expert estimation practices

While there is research on students' practices of engineering estimation (Linder, 1999), there are no studies of how experts perform estimation. Therefore, I am studying expert engineers from different engineering disciplines as they solve estimation problems from inside and outside of their parent disciplines. This study will produce rich case studies of how experts solve estimation problems when they have domain knowledge and without it. These insights will be used to design the interactions in the LE such that that it supports the attainment of expertise. Moreover this analysis will identify and define the sub-skills included in the skill of engineering estimation. Then the tasks in the LE can be constructed to support the development of all these sub-skills.

Design a collaborative digital learning environment

The design of the LE will be based on the theories of situated learning (Johri & Olds, 2011), interpretive knowing (Bransford & Schwartz, 1999) and distributed cognition (Hollan et al, 2000). The LE will include authentic tasks so that learning is situated and tasks for the development of all sub-skills. The interactions will be based on expert actions and include the affordance to create problem representations. I will focus on student learning and develop a theoretical account of how engineering students develop estimation skill using the LE. I hope to argue that the opportunity to practice the sub-skills and create problem representations in the LE will promote integration of knowledge and skills required for solving estimation problems.

Issues to be discussed

The primary issue is to identify the skills and behaviors to be extracted during the analysis of the expert studies data. A preliminary list includes the domain dependent and independent parts of the experts' estimation strategies, heuristics used, actions that have productive consequences in estimation and the most useful steps in estimation. Also, how do we identify when an expert is using "intuition" or a "cognitive trigger" which causes everything to "come together", since experts often do not articulate this in their solutions.

The LE should enable students to do experts' productive actions. How should these actions translate to interactions which the students are impelled to do in the digital LE? How can we include experts' "intuition" in the LE? Researchers (Wu et al, 2011) designed a tangible interactive tabletop LE, based on studies of expert modeling practice, to support mathematical modeling. I would like to discuss how to translate insights from my expert studies on estimation to interactions on the LE that will develop estimation skill.

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