The Design Compass: A Computer Tool for Scaffolding Students' Metacognition and Discussions about their Engineering Design Process

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Abstract

This paper reports on the *Design Compass,* a classroom tool for helping students record and reflect on their design process as they work on and complete a design challenge. The *Design Compass* software provides an interface where students can identify and record the various design steps they used while performing them, and add digital notes and pictures to document their work. In the *Design Log* view, students can review steps taken, and print the record of work done, which can be shared and discussed with their instructor or classmates. The paper describes the concepts underlying the creation of the *Design Compass*, its features as a metacognitive tool and how it works, and provides scenarios of its use as a teaching and assessment tool with eighth-grade technology education students, and in teacher professional development workshops.

The Design Compass Concept

The *Design Compass* [DC] is an educational tool that students can use to identify and record the steps in the engineering design process that they use while designing. It was developed as part of the work of a NSF-funded IEECI project, "Using RoboBooks To Build Scalable K12/Engineering Partnerships" (NSF 08-35949, 08-36008), a collaborative effort between Tufts University and City College of New York. The *Design Compass* supports students in representing and documenting their design process, and enables them to share a log of their work with others (teachers, observers and peers). Traditionally, as students work through a design challenge, the teacher provides some scaffolding regarding what design step the students should do, perhaps advising them, for example, to attempt some timely research, or to brainstorm for new approaches if the team has gotten fixated on a particular approach. Students are often asked to create a post-hoc portfolio of their design project work; however, they are rarely given the tools to collect portfolio data of their work in real time. Flashes of inspirations and insights that frequently occur during designing are often forgotten by the time a student documents the session's work. The Design Compass provides an overview of students' work that is based on aggregated, quantitative data associated with the design steps and includes digital notes and images of sketches and prototypes useful in summative portfolio reporting.

Features and Theory Behind the Design Compass

The current *Design Compass* prototype is an interpreted software program that is run using the LabView™-based ROBOLAB™ programming environment. The user interface has two pages. The Compass page (see Figure 1) displays a standard engineering design process model (Massachusetts DOE, 2006), means for entering short text-based descriptions and digital snapshots of sketches or prototypes to be entered by users, and clocks to note time spent on each design step. The Log page (see Figure 2) provides a spreadsheet-styled chronological list of steps taken, and is the place where users can view, edit and append the logged information. By clicking on another button in the *Log*, students can view aggregated data in histogram form on steps they have taken during a single design session or an entire design project.

The *Compass*' clickable picture of the design cycle scaffolds students' recall of the design process and metacognitive thinking about their work, while generating an reviewable record or *Log* of recent or distant past iterations of design work. Metacognition involves the monitoring of oneself and others regarding tasks that are

done and declarative and procedural knowledge used (Flavell, 1979), and is at work when designers "stand outside themselves and look in at their own designing" (Kimbell & Perry, 2001). Metacognitive thinking is associated with the production of higher quality design products (Adams & Atman, 2000). Students tracking and then reflecting on how they explored and solved a design task can in particular influence two dimensions of metacognition, *knowledge of cognition* and *regulation of cognition* (Schraw, 1998). Students can gain *knowledge of* their design process (or cognition) by recording how they are going about solving the design challenge, which may support their understanding when and why they do what they do. Mapping their personal design process onto some standard engineering design process can deepen students' understanding of those design engineering design steps.

The DC log page displays a chronological listing of tasks done with day, design step, task time, total time, notes, images, and a histogram showing the total time spent on each design step. Students are able to identify how they moved from step to step, and the kind of work they did associated with each step. The *Log* page includes a tab for displaying a histogram of the time the students spent on each step of the design process. This aggregated view of the students' design work may surprise students and teachers alike with how much or little time they may have spent on the various steps, and is designed to alert students to patterns in their design process that might need to be adjusted.

Design Compass in the Classroom & Teacher Workshop

The *Compass* is designed to impact not only students' thinking but classroom practice as well. In lab-based design classes, teachers periodically visit design teams, and ask for an accounting of recent design work. Such conversations provide instructors with formative feedback that can lead them to alter instruction or suggest different design steps a team could take. The problem with such conversations is that the data teams deliver to their instructors is based on recalled events – the memory of which is subject to distortions over time. Errors also arise from students not properly identifying the steps they had been using in the first place.

The DC Log and its histograms provide student-generated data that instructor and students can review during a design meeting -- an improvement over relying upon what students remember after the fact. Teacher feedback can improve, given a more accurate accounting of past work. There is also a chance to improve students' *regulation of* and *reflection on* the design process. With access to more accurate accounts of how long they spent doing certain design steps, or how many times they redesigned their prototypes, students can make plausible inferences about what worked well regarding *how* they completed the design, how they might allocate their time better in the future, and be more strategic in selecting design step to employ; e.g., spend more time clarifying or framing the problem before researching possible solutions.

The Design Compass provides opportunities for training and assessing students in identifying design steps, when the DC is used in conjunction with digital videos of other teams doing design work. In one eighth-grade technology education class in Baldwin, NY, students were introduced to the *Compass* after they watched an ABC "Nightline" program entitled "The Deep Dive" about the IDEO product design firm. Students first watched the 21-minute sequence without interruption, had a teacher-led discussion of the company's approach to design, and then used the *Compass* to identify steps members of the IDEO design team used. Students then watched videos of teams of middle-school students solving a design challenge they themselves had just faced, and used the DC to identify strategies teams employed on the videos. Finally, students used the *Compass* to document their own work in designing a robotic shopping cart, a task from the Robocart curriculum.

The DC has potential as a tool for teacher professional development. In a RoboCart Workshop held at Tufts University in August 2009, Boston Public School teachers used the DC while they designed a LEGO robot. Over the course of the workshop, teachers working in teams of two took turns serving the role of DC recorder, who is responsible for recording design steps and documenting the team's work. At the end of the exercise, the teachers noted that the DC would be a great tool for them to scaffold their students dong the design process because it enable them to monitor students' progress, in what they called a "chaotic LEGO environment", in a more fine-grained manner. A few teachers attending in August 2009 the Robocart Summer Workshop held at Copiague, NY, commented that middle-school students might be find using the DC overly challenging. An area of future research should involve testing the use and efficacy of DC by older users, including high school and college students as they do engineering design activities.

References

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