Design Compass: Facilitating metacognition in construction activities in K-16 classrooms

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Abstract

Design Compass is an educational tool designed to facilitate learners' metacognitive thinking during construction activities. Learners record their progress through the engineering design process by selecting the appropriate step in the Design Compass, which tracks the amount of time spent on each step and presents this data to the learner in the form of a histogram. A study was conducted to evaluate the usability of the Design Compass. Participants recorded their process in the Design Compass while working on a construction activity. Results suggest that the Compass is easy to pick up and use and leads to more reflective thinking, but does not capture multitasking by individuals or groups. Further revisions to the Design Compass are discussed.

Keywords

Engineering, metacognition, constructionism

Introduction: Constructionism

Constructionism can be thought of as "learning-by-making" (Papert, 1980). Through the physical creation of artifacts, learners engage with science content in a meaningful and authentic way. Infusing hands-on construction activities into engineering curriculum can increase learning and retention (Ortiz, 2010). The process of manipulating materials in an effort to create artifacts provides opportunities for engaging and motivating learners (Kolodner & Nagel, 1999).

In a typical construction activity, learners have limited opportunities to reflect on their process. When learners are asked to describe what they did at the completion of the activity, they often struggle with accurately recalling what they did during the activity (Crismond & Atman, in press). Some curriculum designers combat this by scaffolding the design process for students (e.g., Learning By Design, Engineering is Elementary); however, the majority of these efforts dictate the process to the students rather than allow them to identify, on their own, how they engage in the process. This bucks the constructionist philosophy that aims to have students engage in personally meaningful exercises rather than rote, pre-determined processes.

There is a missed opportunity here to infuse metacognition into constructionist activities. Metacognition is the monitoring of one's own thinking (Flavell, 1979). Influsing metacognitive opportunities into the design process allows students to reflect, debug and systematize their processes, and is associated with the production of higher-quality products (Adams & Atman, 2000).

The Design Compass as a Constructionist Tool

Design Compass is an educational tool that allows users to track their progress through the engineering design process while working on a construction activity (Crismond, Hynes, & Danahy, 2010).

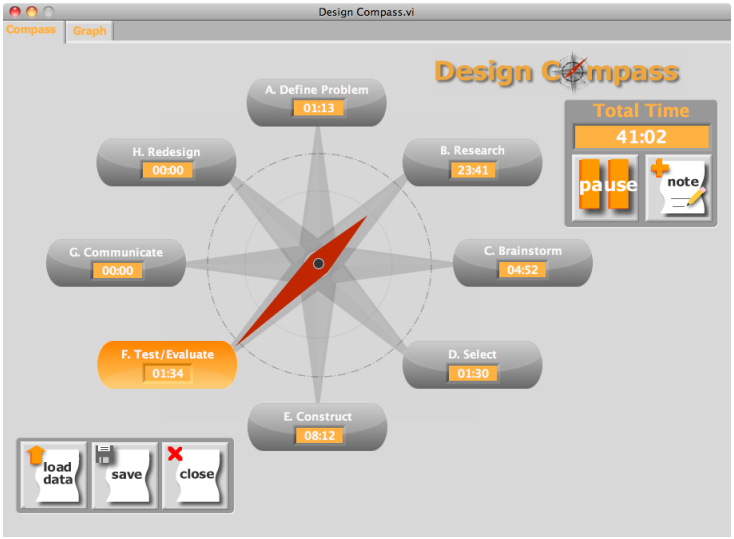

Figure 1. Compass (Main View) of the Design Compass

The main screen, shown in Figure 1, contains a timer that keeps track of the total time, as well as the steps of the engineering design process (i.e. define problem, brainstorm, research, etc.) (Massachusetts DOE, 2006). When a step is selected, the red arrow of the compass points to that selected step, and a timer associated with that step begins to keep time. Users are also able record notes and upload images.

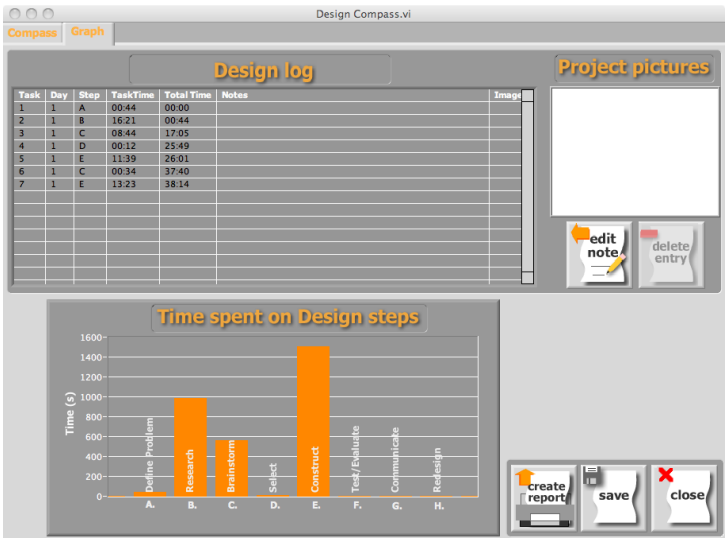

Figure 2. Data View of the Design Compass

The graph view displays a table with cumulative data about the order of the steps and the time spent in each in step. Data from the table is summarized in a histogram, which allows users to compare the amount of time spent on each of the steps.

While learners work through an activity, they are challenged to think actively about what step of the design process they are on in order to report this in the Compass, as well as presented with opportunities to capture their process in notes and images. After completing the activity, learners are able to reflect using quantitative data.

Method

A study of the Design Compass was conducted with five undergraduate students from various engineering disciplines. The participants used the Design Compass while completing a constructionist activity in which they needed to build a prototype of a one-handed jar opener using LEGO bricks (Lemons, Carberry, Swan, Jarvin, & Rogers, 2010). Participants had seventy-five minutes to brainstorm, research, and construct a working model. To compare the use of Design Compass in a group with the use of an individual, three of the participants were placed in a group and instructed to work together on a single model, while the other two participants worked individually on separate models.

Participants were asked to record their steps on the Design Compass as they progressed through the activity. Data in the form of video, screen capture, and Design Compass log files were collected for each of the three groups. Participants were also asked to fill out pre- and post-activity questionnaires.

Results

Results suggest that the Design Compass is well suited for facilitating constructionist activities. A majority of participants reported that the Design Compass is easy to pick up and use, and all five reported that they reflected on their process more than they usually do during a design activity.

In an attempt to assess how closely participants' reporting of steps matched with what they were actually doing, video footage was compared with the Design Compass log files. The footage showed that most of the work during the 'Construction' and 'Test' steps was actually individuals multitasking (such as testing the durability of a material while constructing) or rapidly switching between steps. In the case of the three-person group, individuals within the group were working simultaneously on different steps (see Figure 3).

Figure 3. Group Members Working on Different Steps Simultaneously

The individual on the left is examining and testing out materials, while the individual in the middle is testing the device and the individual on the right is constructing it.

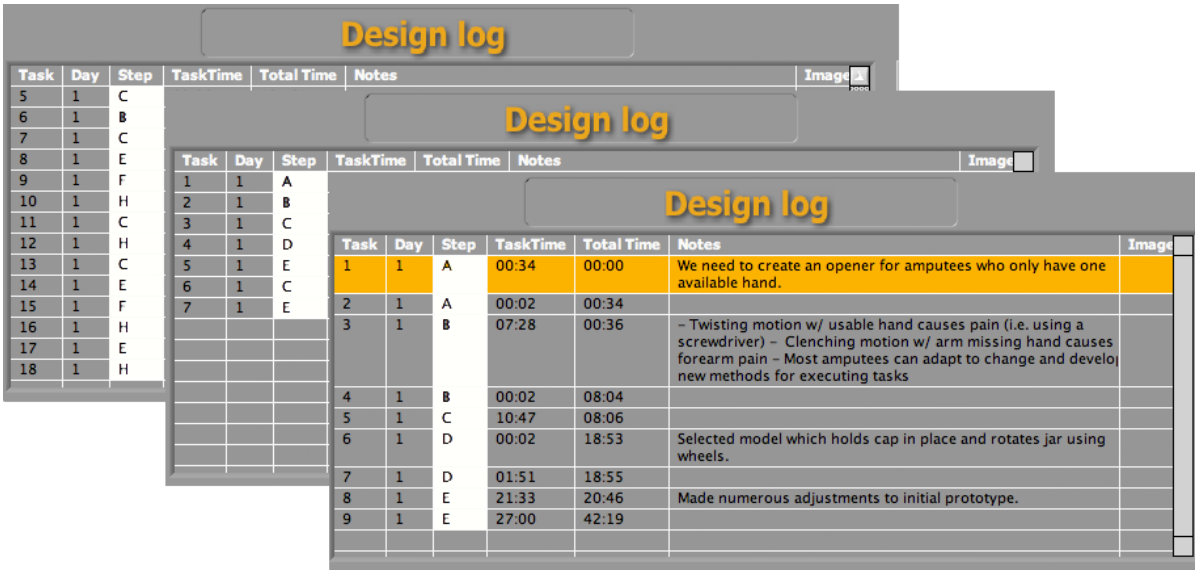

Figure 4. Comparing Log Files Across Groups

A comparison of the three groups to each other reveals that the three-person group worked more iteratively than did the two one-person groups (see Figure 4). Evaluating the order of steps taken by each of the groups shows that the three-person group (far left) completed several iterations throughout the activity, while the two one-person groups (middle, right) worked in a more linear fashion, completing at most two iterations. *Note: A: Define Problem; B: Research; C: Brainstorm; D: Select; E: Construct; F: Test/Evaluate; G: Communicate; H: Redesign*

Discussion

Results from this study suggest that Design Compass can facilitate classroom interactions during engineering design activities through the recording and viewing of quantitative data about steps of the design process. Instructors can use the data to assess students' progress through the design process and determine how to best assist students with future activities. Following the completion of an activity, instructors can facilitate discussion about variance in data between groups.

The Future of Design Compass

The results discussed above are informing the interface and functionality of the next version of the Design Compass currently in development. While including most of the same features and capabilities, the second version will also have the following affordances:

1. Individual and Group Multitasking: Users will be able to select multiple steps to work on at once and designate which group member is working on which step if group members are working simultaneously on different steps.
2. Resources: Instructors will be able to integrate digital resources into the interface, such as images, videos, and text.
3. Customization: Instructors will be able to customize the steps of the design process to align with local standards.

The revised Design Compass interface will be more intuitive for use; an early mock-up is included (see Figure 5).

Figure 5. Early Mock-up of Next Version of Design Compass

This design is intended to be easy for users to pick up and use. Users drag steps into the dashboard arch to begin tracking and adjust the percentages to designate the percent of their time they are currently working on each of the steps. The watch in the top right keeps track of the total time. By clicking on the pencil, users will be able to enter text or draw sketches in the workspace. Behind the workspace are pages for resources uploaded by the instructor and data visualizations of the user's step data. Users can click on the camera to take pictures.

Subsequent versions may include additional features, such as optimization for mobile and touch-screen devices such as the iPad, the ability to compare data across projects, and a physical device

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