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Knowledge Representation in Engineering Design: An Initial Investigation

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Introduction

Engineering design is a domain in which a number of complex problem solving activities occur. As in all such tasks, cognitive processes operate upon the internal representations of the task as well as upon other relevant knowledge. These representations can change over the course of experience in order to enable a person to better respond to the problems and challenges of a domain. The time course of these representation changes is a reflection of the structure and content of a domain as well as the cognitive learning mechanisms responsible for the changes.

The goal of the work presented here is to identify some of the characteristic differences that distinguish experts and novices in this domain. While these studies only include freshman and senior engineering students, there are a number of interesting findings, and there are plans to extend this work to professional engineers. The first study utilizes a recall paradigm that has been employed by a number of researchers looking at expert/novice differences (e.g., Chase & Simon, 1973). The second study uses Latent Semantic Analysis (Deerwester, Dumais, Furnas, & Landauer, 1990) as a methodological tool to aid in exploring and analyzing the content of students' representations.

Experiment 1: Recall Paradigm

In this study, a recall paradigm was utilized that extends an approach used by others to study chunking differences in expert/novice behavior (Chase & Simon, 1973). In the original methodology both recall and perception tasks were used and chunks were identified based on inter-response times (IRTs) that were common to both tasks. In our experiment, only a recall task was conducted, and analysis of IRTs was only one of many measures used to look at representation differences. In addition to IRTs, we looked at solution times, errors, patterns of recall, and alternate methods of identifying chunks.

Freshmen make more errors than seniors, and the analyses indicate that this is mostly due to increased errors in remembering connections. There is also some indication that freshmen may make more connection errors as problem difficulty increases, but this interaction failed to reach significance probably due to lack of power. Seniors tend to rely more on recall methods that utilize the natural flow of power from one component to the next than do freshmen. Results from the chunking data indicate that most students

agree on what should be included in a chunk, and the amount of agreement among students increases with experience as do the sizes of the chunks. In general it appears that freshmen differ from seniors on their understanding and ability to remember information about the connections and interactions between components.

Experiment II: Latent Semantic Analysis

In this study, students were asked to write brief descriptions of devices that were presented in diagrams. These descriptions were then used to create a multidimensional semantic space using LSA. One assumption underlying this study is that the information students choose to include in a brief description is what they find important about the device, and that this importance is also related to their mental representation of the device.

The results from this study agree with those of the first study in that seniors are shown to incorporate more function and connectivity information into their representations. Senior and freshman descriptions do not differ on their similarity to prototypical descriptions, which were produced by averaging document vectors. However, they do differ on the amount of functional content they include in their descriptions. Using such multidimensional semantic spaces may be one way of examining differences in mental representations. Results from both studies provide insight into the representations employed in engineering design, and understanding these representations is essential for producing a fine-grained model of the cognitive processes underlying design.

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