"VISUAL SELVES": CONSTRUCTION SCIENCE STUDENTS' PERCEPTIONS ABOUT THEIR ABILITIES TO REPRESENT SPATIAL RELATED PROBLEMS INTERNALLY AND EXTERNALLY

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ABSTRACT

This proposal reports the findings from interviews with construction science students about their visualization of problems in a two-dimensional and a three-dimensional task. The specific research questions focused on the individual characteristics that students identify as influencing their spatial ability to generate internal and external representations. Thematic analysis was used to analyze interview data. The findings showed that the existing instructional model about generating representations internally and externally may need revisions to its sequence and more focus on integrating students' prior knowledge and experience.

KEYWORDS

Spatial abilities, visualization, internal representations, external representations

1. INTRODUCTION

Spatial thinking is an important skill set for various careers, such as medicine, chemistry, engineering, mathematics, geography, and architecture (National Research Council [NRC], 2006; Orion, Ben-Chaim, and Kali, 1997). Engineers and architects think spatially when designing a new building or roadway. Scientists think spatially when looking at complex molecular structures. Therefore, spatial thinking should be included in instruction to develop students' domain expertise. The National Research Council (2006) defines spatial thinking as a combination of 1) spatial abilities, 2) spatial skills, and 3) spatial reasoning holistically applied to complete a task or solve a problem. According to the Merriam-Webster Dictionary (2012), ability is defined as a natural aptitude or acquired proficiency and skills are defined as a developed ability. Spatial reasoning involves the application of spatial ability and skills to go beyond what an individual perceives in space to reason about an object. To accomplish spatial reasoning an individual must manipulate an object by adding to, and transforming, the information input from one's perception about the object to make decisions and solve problems (Tversky, 2005).

Important to spatial thinking is the ability to generate internal and external representations to assist with remembering, understanding, reasoning, and communication about the properties of and relations between objects represented in space (NRC, 2006). Internal representations are cognitive whereas external representations are graphic, linguistic, or physical. External representation refers to sketches and physical models, while internal representation refers to mental images and models. Previous research indicates that external representation leads to significantly more successful problem handling, efficient problem-solving, and higher quality solutions (Rőmer, Leinert, & Sachse, 2000). The ability to generate internal representations is also important for spatial thinking (NRC, 2006). Individuals generate internal representations through a combination of visual images and mental models based on the description, graphic, or picture provided about the subject (Schnotz, 2005).

2. PURPOSES

Past research on spatial reasoning did not address ill-structured problem solving in the context of a science, technology, engineering, and mathematics (STEM) discipline (Carroll, Thomas, Malhorta, 1980). Ill-structured problems are those with vague goals and multiple solutions, or solution paths, and solving this kind of problem requires problem representation, justification skills, monitoring, and evaluation (Ge & Land, 2003). The goal of this research was to investigate students' spatial representation ability in different dimensions. Specifically, the purpose of the study was to 1) investigate the approaches taken by students when solving a spatial problem-solving task in two-dimensional (2D) context versus a three-dimensional (3D) context; and 2) to understand how internal and external representations interact with students' approaches to the spatial tasks. The current study sought to answer the following research questions:

1. Which individual characteristics and views about visualization do undergraduate students identify as influencing their ability to generate internal and external representations?
2. How do individual experiences and prior knowledge influence an undergraduate student's ability to visually represent problems internally and externally for spatial problem solving?
3. How do undergraduate students approach a spatial-related task when it is presented in a two-dimensional view compared to the same task presented in a three-dimensional view?
4. How do novice undergraduate students visualize a spatial task presented in a two-dimensional view compared to a spatial task presented in a three-dimensional view?
    - How do students represent each spatial-related task internally?
    - How do students represent each spatial-related task externally?

The findings from this research would serve to inform the instruction involving spatial reasoning to determine if the current instructional strategies about spatial representations are appropriate or sufficient.

3. METHOD

3.1 Participants and Sampling

An exploratory study was conducted with 43 undergraduate students (37 male; 6 female) enrolled in a Commercial Construction Capstone course in a College of Architecture at a mid-western United States university in two consecutive academic years. The written tasks in this study were completed as course activities by all the students. However, only thirty (29 male; 1 female) volunteered to participate in a follow-up interview. At the time of this paper 11 semi-structured interviews had been completed with 10 male students and 1 female student. Recruitment of students, signed consent to participate in the study, and administration of tasks was performed by the co-principal investigator for the study. The course instructor, who also administered the task, was the study's principal investigator and conducted all the interviews. Pseudonyms were assigned to each interview participant for privacy purposes.

3.2 Data Collection

This research was designed as a qualitative study. Two spatial-related problem-solving tasks (2D and 3D) were collected. In Task 1 participants were asked to identify the errors present in the building system using the 2D views provided. Errors were defined as anything that would impede or prohibit the physical construction of the building element. The participants were asked to first identify all the errors in the drawings by placing a number on the element in which the error occurs, then transfer each number to the Errors Table and include an explanation of the error to justify their identification of the element as an error. The participants were also given the option to generate a 3D representation from the 2D views on the blank sheet of paper provided with the study materials. Task 1 took twenty minutes. Seven calendar days after Task 1, Task 2 was administered, with the duration and instructions identical to Task 1. The only difference between the two tasks was the drawings provided for Task 2 were 3D views of the building instead of 2D views.

Interview durations ranged from 25 to 45 minutes. Each semi-structured interview consisted of 17 questions, such as *"What means of visualization did you use while working on the 2D error identification task?"* and "*Describe any additional ability, knowledge, techniques, or experience that you think contributes to your use of visualization."*

3.3 Data Analysis

The researchers followed the guidelines and procedures recommended by Shank (2002) to making sense of the interview data. The procedures for searching were 1) basic themes or patterns in the data, 2) plausible explanations through comparison and contrast, and 3) variables or factors for connections. Interview transcripts were analyzed and the data reduced through four steps until five themes emerged from the data:

1. Visual Selves -Individual beliefs and perceptions about visualizing.
2. Approach to Task – Students describe of their approach to completing the task.
3. Influences on Visualizing Capabilities – Students describe influencing factors on their individual capabilities to visualize.
4. Limitations/Difficulties to Visualizing – Students describe perceived limitations and difficulties to visualizing.
5. Benefits of Visualizing – Students describe their perceived benefits to visualizing.

4. FINDINGS

Due to the space limitation, only three representative interviews are reported in this paper; in addition, this paper only focuses on the theme "Visual Selves -Individual beliefs and attitudes about visualizing".

Based on the participants' responses the most positive influences on students' ability to generate representations are ability, prior knowledge, and related work experience. However, participants identified individual characteristics as having the most influence on their creation of internal representations. Each of the participants discussed visualization in some detail and it emerged as a recurring theme throughout the data. It was commonly agreed that one must be able to create an internal representation before creating an external representation.

Gerald and Donnie each expressed their belief that you have to have an internal representation, or mental image, of what you are going to sketch before you start drawing. Donnie who said:

> "I think once I got going with an external representation I would be better. Once I started visualizing in my head it would make me understand everything else a little bit better before I started creating that external representation. By the time I got through understanding the image in my head then creating a sketch would be good."

Interestingly, the students apparently believe that the ability to create internal representations is a natural ability rather than something that can be taught. For example, Gerald, a senior in the Construction Science undergraduate program, and a student who has had prior instruction about visualization since elementary school described his view on visualization as ability:

> "I think I was born with it. I think it is something that could be developed, but I'm not sure if it can be taught. I don't think everyone has that ability."

Donnie explained how he might be able to visualize something, but for some reason is unable to translate that to an external representation. Donnie's struggles with generating a sketch may be influenced in part by his limited field experience as he expressed his frustration in previous courses when professors required external representations from the students. Gerald not only believed that internal representation comes before external representation; he also believed that the ability to visualize can be developed.

Findings about Research Question 2 indicate that related work experience influences students' representations. Students believe that real-world experience has an impact on their ability to create a mental image of how the system should look. Mel was an undergraduate student with two years of job site experience who uses hand drawn sketches on a regular basis as a communication tool with the site workers he supervises. He described how his related work experience has influenced his representations:

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"I just draw on experience. I was always someone who understood how systems and things went together. Ever since I was a little kid…you know when I would see something work out or how something goes together I would expand on that and understand how other things might go with it.."

The level of prior knowledge in a subject matter area seems to intervene with real-world experience influencing the creation of a visual representation. Participants reported that their prior knowledge from course work also helps them visualize a problem solution and serves as a complementing factor with their work experience. For example, Donnie recalled concepts learned from structural systems' courses as contributing to his ability to visually recall correct examples of a system for the purpose of identifying errors with the task system, "My process for completing the task was based on knowing how it should work and where there would be a failure in the system due to the error."

The findings that prior knowledge and related work experience influence the ability to visualize appear to be consistent with situated cognition theory and the concept that knowledge is situated in the activity, context, and culture in which it is developed and used (Brown, Collins, & Duguid, 1989). Perhaps these findings mean a true relationship exists between subject matter knowledge and a situated experience.

5. DISCUSSION AND IMPLICATIONS

The results of the study indicate that the current model for instruction about the creation and use of representations should be revised. The current sequence of instruction, which consists of 1) instruction about tools and techniques to create an external representation (e.g., a sketch or computer generated drawing), 2) instruction about domain specific concepts, principles, and procedures, 3) individual real-world experience, and 4) instruction about internal representations, does not work well according to the findings. Tools and skills to use the tools do not influence participants' external representation whereas internal representation does. Therefore, the instruction should be focused more on developing students' internal representation, which would facilitate their external representation. In addition, it appears that students need to have experience applying their domain knowledge in a real-world setting prior to creating a representation. Consequently scaffolding tools need to be developed to support students' ability to see a spatial-related problem and develop an internal representation without having to wait for real-world experience. Further research is needed to explore the relationships between internal and external representations, along with the relationship among each type of representation, self-efficacy, prior knowledge, and prior real-world experience.

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