Knowledge Transfer: Does More Experience Yield Improved Design Quality?

DeLean Tolbert, Reis Lehman, Guannan Liu, Benjamin Sadler, Dr. Monica Cardella
School of Engineering Education
Purdue University
West Lafayette, IN
dtolber@purdue.edu

***Abstract*—Engineers must be able to transfer knowledge from previous experiences in order to solve complex engineering tasks. Transfer of knowledge is described as "the learning process involved when a person learns to use previously acquired knowledge, skills, competence, or expertise in a new situation" Therefore, we sought to explore how previous engineering, design, and mathematics experiences impact the quality of a design solution. In this study, 23 first-year engineering students, with diverse mathematics and design experiences, participated in research study. In this study, each student completed a pre-study survey, designed a playground for a fictitious neighborhood while thinking aloud, and completed an interview immediately after completing the playground task. They were asked to reflect on previous mathematics and design experiences and asked to make comparisons between those experiences and the design study they had just completed. The design session and the interview were recorded and the design artifacts were collected. Using Hailikari's model, the research team investigated the how knowledge transfer may impact design solution quality. The findings of the research have implications for approaches educators can use to help students apply knowledge from previous experiences and design high quality solutions.**

Keywords—Mathematics; Design; Engineering; First-Year Engineering

I. Introduction

The engineering profession is dependent upon multidisciplinary teams working together to solve diverse problems. When solving these problems, each member of the team draws from their respective knowledge and expertise. This expertise can be developed from knowledge building experiences and learning environments such as the engineering classroom, engineering organization participation and volunteer activities, along with many others. These diverse experiences help to develop a knowledge base that the engineer can transfer to other experiences. This knowledge transfer can be defined as "the learning process involved when a person learns to use previously acquired knowledge, skills, competence, or expertise in a new situation [1]." Prior to workplace experience, students in engineering disciplines must engage in the same practice of knowledge transfer. As they are not yet experts, these students are still in the process of learning the practice of identifying relevant skills and applying them to different contexts.

Engineering students have opportunities to practice the process of knowledge transfer throughout their engineering education. These opportunities might be straightforward and similar to previous contexts or more challenging because the new context is complex and more foreign [2]. Transfer of knowledge at critical academic and professional junctures can be difficult. This difficulty may be due to "differences in context, culture and modes of learning. [1]" Researchers have investigated students' and professionals' ability to transfer knowledge from one setting to another. One's ability to transfer knowledge or skills may rest in the value placed on practical or educational knowledge. Furthermore, their ability to transfer knowledge properly can impact quality of work.

The portion of work presented in this paper is a component of a larger study which investigates the interplay between mathematical and design thinking, and engineering tasks. Additional motivation for this work is to test an analytical framework that could help explore the influence of participants' previous mathematics and design experiences while also integrating the rich data (i.e. video, audio, interview, pre-survey, final design, think aloud) that is available to us.

II. Research Questions

In this qualitative investigation, we anticipate that higher quality solutions will come from students who demonstrate more evidence of engaging in the process of knowledge transfer. We also anticipate that students will transfer knowledge from diverse experiences to solve engineering problems. Therefore, the following research question and the associated sub-questions guide our inquiry: What experiences did students draw from as they completed the engineering design task? a) What experiences did students talk about in the interview? b) What was each students' quality score for the engineering design task?

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III. METHODS

This exploratory qualitative investigation employs a think aloud protocol as a study design and means of data collection. Each participant completes a pre-study survey, designed a playground for a fictitious neighborhood while thinking aloud, and completed an interview immediately after completing the 3-hour engineering design task. The interview protocol elicits student reflections on previous mathematics and design experiences, and on the comparisons between those experiences and the design study they had just completed. The design session and the interview were recorded, and the design artifacts were collected at the end of the session.

The interview responses were coded for the type of previous mathematics and design experiences that each student discussed. A descriptive experience list (i.e. activity and any additional information provided by the student) was generated for each participant. Using the engineering design task scoring rubric developed in previous iterations of the playground design task method[3], the research team scored each student's final design. Team members were trained to score similarly, which was achieved through three iterations of interrater reliability (IRR) until the team reached Cronbach's alpha, 0.79. In the first round of IRR, three members of the team used the scoring rubric to score one design following training led by the graduate student on the team. After individual coding, the team discussed all conflicts and made decisions about how to score various aspects of the designs. During the next round of iteration, another team member was added, a different design was scored and conflicts were discussed. IRR for this iteration reached Cronbach's alpha 0.79.

With respect to exploring connections between the previous experiences and the playground design scores, the Hailikari Model of Prior Knowledge (see figure 1) was used as a framework for analysis [5-6]. This model identifies types of prior knowledge (declarative and procedural) along with indicators of use of prior knowledge. These indicators provide evidence for ways educators and researcher can observe how prior knowledge is advanced and utilized. For example, in an individual has "Knowledge of facts" than she might exhibit behaviors such as recognizing and recalling. This is evidence of knowing but (according to the model) factual knowledge is not evidence of understanding or application. Hailikari's [5-6] model provided a framework for analysis and the components of knowledge were operationalized.

Declarative knowledge includes two hierarchical levels, with the lower being knowledge of facts and the higher being knowledge of meaning (coded as components of knowledge A and B, respectively).

Procedural (applied) knowledge is more advanced than declarative knowledge and it also includes two hierarchical levels, the first being integration of knowledge and the latter application of knowledge (coded as components of knowledge C and D, respectively).

The model of prior knowledge framework was used to complete a table, which linked specific experiences, the component of knowledge from Hailikari's model and the evidence from the final design, for each student. The table allowed the research team to match the experiences to aspects of the final design, to review the experiences, and to comment on the design. Table 1 includes an example excerpt from the analysis of April, a first-year engineering participant.

IV. RESULTS

The results of the study demonstrate that although the students had a great diversity of mathematics and design experiences their application of knowledge from previous experiences does not yield higher quality playground designs but may yield more creative and more interesting designs. The students had a great diversity of design and mathematics experiences which they applied in differing ways. The research team initially observed that students who had more design or mathematics experience spent more time on fewer, more specific design components. Students with less mathematics experiences were observed to develop a greater diversity of more interesting design components.

A. *Diversity of Experiences*

As a group, the students had a diverse set of experiences. The students participated in this study at diverse points in their first semester of engineering, so the previous mathematics and design experiences the students shared included pre-college experiences and experiences from their first term in college. Many of the students shared prior experience playing on a playground. Other than that activity, the experiences could be categorized as high school in-school experiences, high school extracurricular experiences and first-semester engineering course experiences.

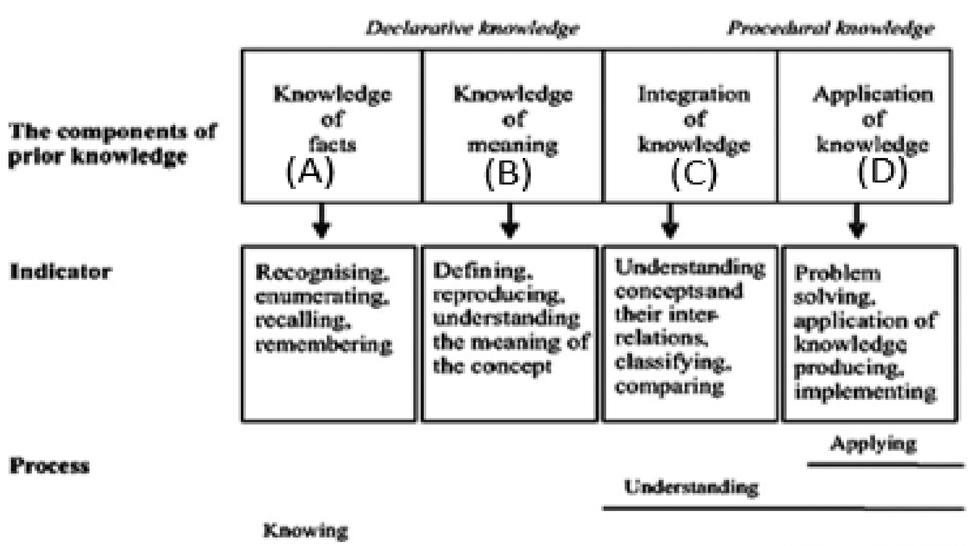

Fig. 1: Model of Prior Knowledge

Table. 1: Model of Prior knowledge framework (Excerpt from April's Table)

Activity from the interview	Evidence from final design	Halikari's Prior Knowledge model
Design Process Experience	The design process is weakly represented in this report. The subject asked the moderator for the neighborhood/children survey info which demonstrates research. Brainstorming was limited to a short 6 item list. A few of the ideas are developed before the final drawings are communicated. Their design process was not iterative.	D

High school in-class experiences included: science, engineering, mathematics, and art classes; engineering connections made within non-STEM classes, outdoors activities (i.e. visiting parks). Design competitions, college hosted summer engineering programs, jobs and hobby making were shared as high school extracurricular activities. Although students had just begun college, they were able to discuss their first semester engineering courses and the mathematics and design knowledge they were learning in those courses.

B. *Quality Scores*

Students with lower quality scores typically applied more knowledge from previous experiences. Students' scores had variable denominators. The students were scored equivalently on the first 45 items of the rubric, but the later portion of the scoring instrument was relative to the materials and design components each student used in their respective final design; therefore, the scoring instrument included up to 123 items. In order to compare final scores, the design quality comparisons we made by percentage (i.e. total score/total potential points) earned by students. The average score earned by students on this task was 41.8%, with the lowest and highest score of 29.3% and 60% respectively. It was interesting that the student with the lowest score, 29.3%, had the greatest number (N=6) of relevant experiences. On the other hand, a different student earned the highest quality score of 63% and she had no relevant design and engineering prior knowledge.

C. *Did the evidence of knowledge transfer positively impact design quality?*

Students in this study appeared to demonstrate an ability to transfer knowledge across contexts; however, the impact of knowledge transfer does not always yield higher scores on the playground design. Fig. 2 is a histogram representation of the four groups that the students fell within. The eight students in the lowest scoring group had the highest number of mathematics and design activities, which they applied to the problem. For example, participant April had the lowest score, 29.3% but had the greatest number of experiences. All six of her experiences fell within the group D (Application of prior knowledge) in Hailikari's model of prior knowledge, but she did not seem to apply that knowledge in ways that would positively impact her design score. See Table 1 for an excerpt of one researchers notes on April's previous experience and her final design.

On the other hand, Sabrina's design earned 43.2%. She shared very few experiences and doubted the value of her limited knowledge, yet her score was slightly above average. Another researcher noted that although Sabrina stated she had no mathematics experiences, her work demonstrated that she applied mathematics knowledge in beneficial ways. She had very clear dimensions and strategies for calculating the dimensions on her design.

V. Discussion

In this qualitative investigation we sought to explore how previous engineering, design, and mathematics experiences impact the quality of a design solution. The research team anticipated that higher quality solutions would come from students who demonstrate more evidence of engaging in the process of knowledge transfer. We also anticipated that students will transfer knowledge from diverse experiences to solve engineering problems. We found that students had many different mathematics and design experiences to draw from. But that students with the most experiences often earned lower scores on their final design.

We also anticipated that students will transfer knowledge from diverse experiences to solve engineering problems. The students demonstrated that they could apply knowledge across contexts; however, the application alone did not yield higher. Hailikari's model suggests that students who apply knowledge from previous experiences might earn higher scores because they better command of the knowledge itself. According to this model, the students would not solely, recall the experiential knowledge but they are able to apply it.

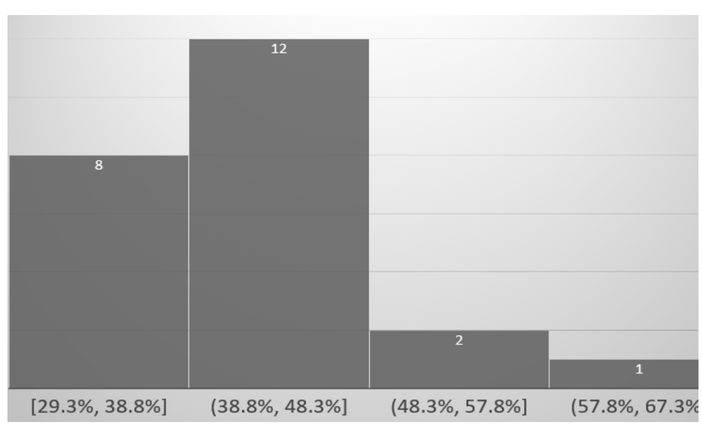

Fig. 2 Histogram of Scores

Students who applied specific knowledge from design and mathematics experiences to this design task often demonstrated restricted design making processes and slower decision making. They had fewer but more detailed equipment that carefully met the constraints. Conversely, a student with less specific mathematics and design knowledge and experiences often earned higher scores on their final solution and their designs were more creative and outside of the box. Those students' design processes were often less restrictive in nature.

Additional motivation for this work was to test Hailikari's framework for fit in future investigations of knowledge transfer and final solution quality. The data from this study do not seem to substantiate the use of the model for this work. Students who applied previously learned knowledge to this new context earned lower scores. There must be something else at play. Perhaps, students with less previously learned knowledge experienced fewer instances of fixation and made faster decisions because they lacked the knowledge and insight to dwell on design aspects. It is possible that students with previous experience earned lower scores because they fixated on aspects of the design, used their knowledge to solve those aspects but did not allow themselves time to address other aspects of the design task. Another consideration for future work, is the overall alignment between the quality scoring rubric and the Hailikari's model of prior knowledge.

VI. CONCLUSIONS

Our findings support related work which explored the design processes of novices and experts on the same playground design task. Novices, because of lack of experiences, are more open to exploring and what they know to be correct, while the experts may make more assumptions developed from their experiences. Both draw on prior knowledge, but the novice can often provide a more creative and well defined solution. The results of this study and the connection to expert/novice studies demonstrate that it is important for students, with diverse experiences and transferable knowledge, to be open to explore alternate solutions and strategies. The previous experiences are valuable but students must still explore and educators must encourage exploration as the students are developing design skills. This work will support the need to place value on learning in diverse settings and to give students tools necessary to transfer knowledge across boundaries and contexts in order to produce high quality solutions.

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