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Engineering Students' Epistemological Thinking in the Context of Senior Design Projects

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Work-in-Progress:

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Abstract

Senior Design Projects, as culminating, comprehensive design experiences for engineering undergraduates, were hypothesized to be associated with the steep growth in students' epistemological development during the last year of college. Nevertheless, few studies have specifically explored engineering students' epistemological thinking and the associated factors in the context of senior design. This work-in-progress adopted a mixed methods design, and explored engineering students' epistemological thinking in the context of senior design projects. A validated survey framed in Perry's theory was used to explore engineering students' epistemological development among the pre- and post- groups for engagement in senior design projects. Statistics showed a significant difference in their levels of epistemological development, particularly, their development of relativistic thinking. Also, twenty-one students from the survey respondents were interviewed in a one-on-one manner to explore the factors that were associated with students' epistemological development in a senior design projects context. Qualitative analyses indicated that the way in which senior design projects were organized and people factors such as mentors' roles and functions were closely related to students' epistemological development. Meanwhile, a close link between students' epistemological development level and their self-regulated learning skills was highlighted.

Introduction

In engineering education, researchers have exhibited increased interest in students' epistemological thinking in their development from novices to competent engineers [1]-[5]. Prior research suggested that students' design experiences had positive relationship with their epistemological development [6]. Also, extensive experiential learning experiences in engineering courses positively influenced students' intellectual growth [7].

Senior Design Projects (SDPs), as culminating, comprehensive design experiences for engineering undergraduate, are believed to bring about many learning outcomes among engineering students, for example, independent thinking, critical thinking, creative thinking and hands-on skills [8]-[10]. Moreover, it was hypothesized that engagement in the SDPs was closely associated with the steep growth in students' epistemological development during the last year of college [1]. Students' *epistemological thinking* refers to their reflections on "the limits of knowledge", "the certainty of knowledge", and the "criteria for knowing" [11]. Expert engineers tended to demonstrate more sophisticated manner of epistemological thinking than novices [12]. Nevertheless, few studies have specifically explored engineering students' epistemological thinking and the associated factors in the context of SDPs.

Therefore, in order to further explore the epistemological development of engineering students and its influence factors in the context of SDPs, this study proposes the following two research questions:

1. What is the epistemological development status of senior engineering students before and after SDPs?

2. What are the main factors that influence engineering students' epistemological development in the context of SDPs?

Literature review

SDPs stand as an important bridge for engineering students' transition from school to working environment. As the last learning stage before graduation, it represents a unique opportunity for engineering students to integrate what they have learned in class with the real engineering world, applying theoretical knowledge to solve actual problems.

As indicated by prior findings, SDPs were found to be useful in developing engineering students' multiple skills and abilities, such as independent thinking, critical thinking, creative thinking and hands-on skills [8]-[10]. For instance, using self-reported questionnaires among senior students， Marques (2017) pointed out that engagements in SDPs can strengthen students' soft skills like communication and public speaking [9]. Also, Xiong and Liu (2012) suggested that students who participated in SDPs got their critical thinking and engineering design thinking improved [13]. In addition, applying self-efficacy scales, Dunlap (2005) measured students' self-efficacy in a capstone environment. Pre- and post- data showed a statistically significant change in student perceptions of personal ability and preparedness for engineering profession, which suggested that SDPs—project-based activities accompanied by collaboration and reflective strategies—may help them experience skill development and build confidence [14].

Although some researches indicated that personal epistemology is related to students' advancement during problem-solving process in undergraduate engineering curriculum, direct evidences are still needed when it comes to whether and how students' epistemological development will be enhanced in the context of SDPs. Development of students' personal epistemology along Perry's positions, particularly in the last year of college, was observed by Wise et al. (2004) [1]. Other researchers offered additional evidence as to undergraduate students' development of more sophisticated epistemic beliefs from Lowerclassmen (freshmen and sophomores) to Upperclassmen (juniors and seniors) [15-16]. Researchers pointed out the possible cause which facilitated the students' epistemological development may be the engagement with SDPs and similar ill-structured project-based learning activities [1, 15-16]. Yet, direct evidences are still needed to validate the roles of SDP experiences in promoting engineering students' epistemological thinking and relevant factors within such context.

Theoretical framework

Personal epistemology can be traced back to Jean Piaget's theory of intellectual development of children. In the realm of personal epistemology, the pioneering work by William Perry delineated a scheme of young adults' epistemological development from a dualistic to a relativistic way of thinking [17]. The developmental process can be grouped into four major stages, respectively, Dualism, Multiplicity, Relativism, and Commitment. Later, researchers have expanded the models in various manners. Nevertheless, the main thread of epistemological development - from a dualistic, black-and-white manner of thinking to a contextual, constructivist way of thinking, was confirmed repeated by subsequent studies [18]-[20]. The Perry' theory and its subsequent related frameworks were widely applied among engineering students for it was suggested that expert engineers tended to possess more advanced ways of epistemological thinking than novices [12].

Methodology

Guided by the theoretical line of epistemological development, this study adopts a mixed-methods approach. Quantitatively, the revised Zhang's Cognitive Development Inventory (ZCDI) [21]-[24], an instrument designed in the context of Perry's theory, was used to measure students' epistemological development. Specifically, the revised ZCDI reflected the four stages of epistemological development. It has 45 statements in total, which can be divided into four subscales, with 20, 8, 9 and 8 items for Dualism, Multiplicity, Relativism and Commitment respectively [24]. Participants were invited to provide a response on a 5-point Likert scale, indicating the level of agreement or disagreement with each of the statement. Semi-structured one-to-one interviews were followed up among 21 respondents to explore relevant factors of students' epistemological development in the context of SDPs.

First, the latest version of revised ZCDI [24] were administered among the first cohort of seniors from M College of H University in June 2019 (Post-test, after the SDPs experiences) and the second cohort of seniors in Dec 2019 (Pre-test, before the SDPs experiences). Together, 141 of complete responses were collected from post-test group and 138 were collected from the pre-test group. The response rates were 35.2% and 34.5% respectively. A T-test was conducted. It should be noted here that we have used two consecutive cohorts in conducting the pre- and post- tests, assuming that they were similar in their epistemological thinking at the starting point before the SDPs experiences. This was designed in such a manner because of our limited access to opportunities to distribute surveys among the students.

Qualitatively, an interview protocol was designed to explore the roles of students, their peers/teammates, and advisors in the context of SDPs and relevant factors. Sample interview questions include descriptive questions such as, can you describe the processes of completing your capstone project briefly? What roles did you play in a capstone project? What method did you use in order to finish your task? As you think about your instructors, professors, advisors, what role do you think they have played? What kinds of interactions with them helped you with your capstone project?

Preliminary Findings

Quantitatively, the T-test result of the students' responses from the pre- and post-groups suggested a statistically significant difference in their levels of epistemological development, particularly, their development of relativistic thinking. For the scale of relativism, the average score and standard deviation for engineering students in the pre-test group were 3.844 ±464 (n=138). The average score and standard deviation for engineering students in the post-test group were 3.994 ± .368 (n=141); F= 1.856, p< .001. Both qualitative and quantitative data analysis work are still under way, including the process of cross-checking the qualitative data with the survey results.

In addition, our preliminary qualitative analyses indicated that, the way SDPs were organized, that is, whether they were individual or group projects, university-sponsored or university-industry co-sponsored projects, can make a difference in students' learning experiences, which were then closely related to their different demonstrations of epistemological thinking. For instance, one student reflected on his engagement in SDP,

> *I think SDPs was a more complete research experience in which we devoted a lot. This project provided a good foundation for my graduate studies, experiencing what research was like. The experiences from previous projects were not quite as complete… Moreover, we were required to report to the company (for SDPs). Therefore, the requirement for the results was more demanding. As a consequence, we set a high goal. It was a research experience.* -Boki

Moreover, people factors such as mentors' roles and functions in the SDPs process were also associated with students' epistemological development. The epistemological thinking of engineering students may be influenced by the guidance of professors, cooperation with peers, and communication with other stakeholders. Such guidance from professors usually did not take a form of specific and detailed guidance. Instead, it mainly referred to giving the overall direction of a project. Furthermore, when students realized that it was up to them to acquire knowledge by themselves, they often realized the limits of their own knowledge and way of thinking. For example, Kevin talked about the role of his mentor for the project,

> *I think my mentor was more like a light that guides my directions. In other words, she may say, you can go this way or that way, but she wouldn't tell you how to do specifically, leaving space for us to explore. We had to explore by*

ourselves first, and discussed with her later after we found out solutions…She may give us affirmation or further suggestions. Therefore, she was more like a guide for the general direction. -Kevin

In addition, we observed a close link between engineering students' epistemological development level and their self-regulated learning skills. Collecting and reading a large number of literature might help provide opportunities for students to understand the views of different scholars. Based on that, students may gradually try to analyze and integrate those views and ideas. Prior research also suggested that students who were in the advanced stage of epistemological development tended to also demonstrate active engagement in self-regulated learning [24]. In our analysis of the interview transcripts, Boki, who seemed to have demonstrated an advanced manner of epistemological thinking in the senior design experiences, described the experiences of learning by himself during the SDP,

Because it belonged to mathematics, not engineering. I was a little confused at first. So I went to the library to find some books. Quieting down and devoted to reading, I learned a lot. I think reading books with questions is very helpful…I learnt very relevant materials…After reading some sections, I discussed with the team members and the mentor. Meanwhile, I searched in the internet…So, exploring on your own can yield some additional gains...Things that passively passed from the professors may ended after your listening. Things that were not thought up by yourself may not last long, and you may not learn very well either. -Boki

Future work

Based upon the preliminary work, future work includes further analyses of qualitative data concerning the additional factors as related to engineering students' epistemological development in the context of SDPs. Also, upon the analyses of both the qualitative and quantitative results, we will seek to understand how the two parts can inform each other. For the factors that are already identified, further research will be undertaken to understand how the factors influence engineering students' epistemological development. Additionally, future research will be focusing on the advantages and disadvantages of different forms of SDPs as regards to students' epistemological development.

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