Enhancing Multiple Thinking through the Engineering Design Process

Dr. Jaby Mohammed, Petroleum Institute

Jaby Mohammed is a faculty at The Petroleum Institute, Abu Dhabi, UAE. He received his PhD in Industrial Engineering from University of Louisville (2006), masters in Industrial Engineering from University of Louisville (2003) and also a master's in business administration from Indira Gandhi National Open University (2001). His research interests include advanced manufacturing, design methodologies, six sigma, lean manufacturing, and engineering education. He previously taught at Indiana Purdue Fort Wayne, IN and at Morehead State University, KY. He is a member of IIE, SME, ASQ, ASEE, and Informs.

Ms. Mary Ragnhild Hilja Hatakka, Petroleum Institute

Dr Mary Hatakka has over 20 years of experience teaching academic literacy skills, English for Specific Purposes to engineering students and study skills in general. She has recently completed her doctorate at the university of Exeter, UK, and is currently working on improving first year students' transition from school to university. Her current research interests are academic literacy skills,engineering habits of mind and developing workplace skills for engineering students.

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Abstract

The impact of the quality of engineering students' education on the industry of a country cannot be underestimated. While there are numerous studies on the types of qualities that graduate engineers should have, the extent to which undergraduate engineering students choose to acquire these qualities or skills depends greatly on the type of epistemic beliefs that they have. The purpose of the current study was to investigate the epistemic beliefs of first year engineering students. It is the first part of a study aiming to establish both the general epistemic beliefs [1] of engineering students, as well as if and how these beliefs relate to students' Engineering Habits of Mind [2]. The primary instrument used in this first phase of the study was Schraw, Dunkle, and Bendixen's (2002) Epistemic Belief Inventory (EBI) [3]. The instrument is in the form of a questionnaire and it was administered to 39 female students in their freshman and sophomore years in an engineering college in the Arabian Gulf. The results showed that there was very little variation between the two levels of students, indicating that the issue of developing students' epistemic beliefs needs to be addressed more thoroughly. This could be done possibly in the introductory engineering courses or as curriculum infused in other Science, Technology, Engineering and Mathematics (STEM) courses.

Keywords—epitemic beliefs; inventory; engineering students; female; Arabian Gulf

Introduction

Several studies have been done on the kinds of qualifications, knowledge and skills that the 21st century engineer should have. To illustrate an example of such skills reflecting the needs of industry, Rajala [4] defines the areas of competence necessary for a global engineering professional as global competence, technical competence and professional competence. However, she points out that the attributes which are associated with each of these competences present a challenge for engineering educators regarding both the context in which they should be introduced, as well as "determining what can be accomplished within the constraints of a university education" [4]. From an educational stance, the Accreditation Board for Engineering and Technology (ABET) [5], states engineering students' minimum learning outcomes (a) through (k) as shown in Table 1:

Table 1: ABET learning outcomes

a) an ability to apply knowledge of mathematics, science and engineering
b) an ability to design and conduct experiments, as well as to analyze and interpret data
c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d) an ability to function on multidisciplinary teams
e) an ability to identify, formulate, and solve engineering problems
f) an understanding of professional and ethical responsibility
g) an ability to communicate effectively

> h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
> i) a recognition of the need for, and an ability to engage in life-long learning
> j) a knowledge of contemporary issues
> k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The lists of competences, attributes and learning outcomes are based on much research and have been modified over time to ensure that engineering education develops along with industrial needs and college learning outcomes are adjusted accordingly. Feedback is also frequently sought from industries [4], which have become more and more multinational, another aspect that affects the nature of learning outcomes in engineering education.

However, the extent to which undergraduate engineering students choose to acquire the desired qualities or skills depends greatly on the types of epistemic beliefs that they have. Epistemology is the philosophic study of where one believes knowledge comes from and what it is like [6]. Epistemic beliefs can be related to research, personal knowledge or professional knowledge among other things. As far as college education is concerned, the person who is recognized as the pioneer in developing the first framework of the kinds of knowledge that undergraduate students have is William Perry [1]. According to Perry [7], undergraduate students can go through four hierarchical levels of knowledge development as follows; the first stage is dualism (knowledge is either right or wrong as determined by a figure of authority); stage two is multiplicity (knowledge is about differing opinions); stage three is called relativism (knowledge is dependent on context) and stage four, which Perry called 'commitment' whereby knowledge is the ability to make decision based on informed opinions. In studies done on undergraduate engineering students using Perry's model in the USA in the 1980s, 1990s and at the start of the 21st century, "most engineering undergraduates complete college in the lower classifications of either dualism or multiplicity" [1]. According to [8], Perry's model is the most common model used to measure an understanding of where knowledge comes from in engineering education. However, Schommer was the first to come up with a quantitative way to measure epistemological beliefs [1] and the Epistemic Belief Inventory (EBI) [3] used in the current study is based on Schommer's model.

Background

Context of the Current Study

Students in the Arabian Gulf region opt to study engineering majors for a variety of reasons, including parental pressure. A job in any field of engineering, but specifically in the field of Petroleum Engineering is seen as demanding and highly respected, guaranteeing a very acceptable status in society. This is due to the fact that oil related industries generate the most money in the region and provide the main income of most Gulf States [9], contributing to both the growth of the economy and to national security [1]. As future employees in local petroleum engineering companies, students should be fully aware of the implications of the consequences of the quality of their work [9], which is guided by their basic epistemological beliefs [1]. These in turn affect the students' work ethics and the way they view the discipline of engineering. The aim of the current study is to understand what kinds of epistemological beliefs Gulf Arab female students have and whether they develop during their undergraduate studies.

Framework within which the study is situated

The beliefs can be measured at a general level using the scales in the Epistemic Belief Inventory EBI [1, 3]. The extent to which students have adopted engineering habits of mind, as established by the Royal Academy of Engineering in the UK [2], will be related to the current study in a subsequent follow up study. Moreover, the results of the female and male students will be compared to find out if there are any significant differences between the two types of students. The results of the study could have practical implications in the engineering college where the data were collected as well as in other similar institutes of higher education.

Methodology

The data for the current study were gathered from an engineering higher education institute (HEI) in the Arabian Gulf region. The case study consisted of a total of 39 female students enrolled in the ENGR 101 freshmen year engineering course and the sophomore Basic course on engineering design called STEPS 201. Most of the students involved in the study were from the Gulf region a minority of international students. Both courses were taught by the same instructors.

Epistemological beliefs were measured with the Epistemological beliefs inventory [3]. This quantitative measuring instrument is designed so that individuals respond using a 5-point Likert-type rating scale from strongly disagree (1) to strongly agree (5) to items concerning their beliefs about education and learning. The inventory was developed to measure five underlying constructs: Certain Knowledge, Innate Ability, Quick Learning, Simple Knowledge, and Omniscient Authority. The inventory, abbreviated as EBI, consisted of 32 Likert-type questions designed to measure five subscales of different types of knowledge. The subscales for the five categories included simple knowledge, which was set to define how complex knowledge is, certain knowledge regarding how tentative knowledge is, omniscient knowledge (how knowledge is acquired through authority), quick learning (how quickly knowledge is obtained), and innate ability (one's innate ability to gain knowledge) [3]. Table 2 below shows the categories of questions.

The EBI questionnaire, which was written in English, was piloted before it was officially administered. The students who participated in the study were non-native speakers of English, so based on the pilot study, it was decided that during the administration of the official survey students would be allowed to inquire about vocabulary, if they were uncertain about its meaning. This was done in order to further validate the results of the EBI study.

TABLE 2: Categories of questions

Simple Knowledge	1. It bothers me when instructors don't tell students the answers to complicated sustainable problems. 9. If a person tries too hard to understand sustainability, they will most likely end up being confused. 10. Too many theories just complicate things. 11. The best ideas are often the simplest.

	13. Instructors should focus on facts instead of theories on sustainability. 18. Sustainability is simpler than most professors would have you believe. 22. Sustainability is easy to understand because it contains so many facts. 24. The more you know about sustainability, the more there is to know.
Certain Knowledge	2. Sustainability means different things to different people. 6. Absolute moral truth does not exist. 7. Parents should teach their children all there is to know about sustainability. 19. If two people are arguing about sustainability, at least one of them must be wrong. 25. What is true about sustainability today will be true tomorrow. 31. Sometimes there are no right answers to debated sustainable problems.
Omniscient authority	4. People should always obey guidelines for sustainability. 14. I like teachers who present sustainability ideas and let their students decide which is best. 20. Children should be allowed to question their parents' belief in sustainability 23. The moral beliefs in sustainability that I live by apply to everyone. 27. When someone in authority tells me what to do, I usually do it. 28. People who question sustainability are careless.
How quickly knowledge is obtained	3. Students who learn sustainability are the most ones who appreciates sustainability 16. If you don't learn sustainability quickly, you won't ever learn it. 21. If you haven't understood an aspect about sustainability the first time through, going back over it won't help. 29. Working on a sustainability problem with no quick solution is a waste of time. 30. You can study sustainability for years and still not really understand it.
Innate ability to gain knowledge	5. Some people will never believe in sustainability no matter how much they know 8. Really smart students don't need a lot of guideline to follow sustainability 12. People can't do too much about how sustainable they are. 15. How well you perform in society depends on how much you comply to sustainability. 17. Some people just have a knack for sustainability and others don't. 26. Sustainable believers are born that way. 32. Some people are born with care and passion to future generation

Results and Discussion

After administering the EBI questionnaire to the 39 female students, the data analysis was completed using MiniTAB. MiniTAB is a tool for statistical analysis which was developed at Pennsylvania State University in the USA by [10]. The following two tables show the results for the freshman students (Table 3) and sophomore students (Table 4).

Table 3: Survey results for ENGR 101

Subscale	Range	Mean	SD
Simple Knowledge	2.92- 3.83	3.54	.335
Certain Knowledge	2.5- 3.83	3.26	0.45
Omniscient authority	2.92-3.67	3.17	0.14
How quickly knowledge is obtained	1.83-3.08	2.60	0.5
Innate ability to gain knowledge	2.42-4.00	3.00	0.58

Table 4: Survey results for STPS 201

Subscale	Range	Mean	SD
Simple Knowledge	3.22-4.28	3.65	.36
Certain Knowledge	2.72– 4.11	3.24	0.57
Omniscient authority	2.28-3.61	3.07	0.18
How quickly knowledge is obtained	1.56-3.39	2.28	0.77
Innate ability to gain knowledge	1.50– 3.78	2.65	0.77

As can be seen in Table 3 above, the students were strong in their opinions about simple and certain knowledge, as well as to a great extent on omniscient authority. The responses regarding latter issue can possibly be explained as being related to the strong, paternally authoritarian, close-knit family structure, which has managed to retain some traits of Bedouin tribalism in it, too. Moreover, as many children choose to live with their families until they are in their twenties, the authority of the father continues for some well into the children's college years. The responses coincide with the notion of dualism, the most basic form of credible knowledge on Perry's scale [7]. They are also is in accordance with [8], whereby most engineering undergraduate students fall into this category with regards to their views on knowledge. It is not, therefore, surprising that there is a wider range in the students' responses regarding the two latter categories, with the widest range being in their views on one's innate ability to gain knowledge. It could be because of the culturally appropriate somewhat preordained manner in which some people tend to perceive their existence and, as a result, the amount of control one has over matters such as one's ability to gain knowledge.

The results for the second year students are shown in Table 4. It is interesting to see that they are very similar to the results in Table 3. This is especially true in relation to the first three categories of epistemic knowledge and again coincides with the results in studies [7] and [8]. In other words there is very little difference between the epistemic views of Freshman and sophomore students. Considering the amount the students have studied and the level of difficulty they reach in their sophomore year, it can only be deduced that students continue to rely on their instructors for the right answers. It would be interesting to find out why they do not venture into more uncertain areas or towards higher order thinking skills as defined in Bloom's revised taxonomy [11] with all the knowledge they have acquired.

However, it is interesting to see that the standard deviation is slightly higher in the last two categories, as can be seen in Table 5. TABLE 5: Compilation of the results for the EBI
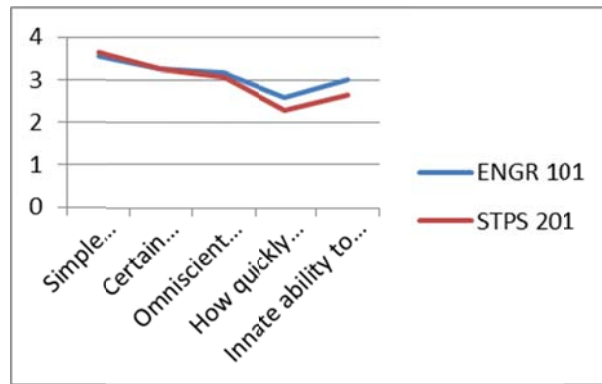

Fig (1) comparison between ENGR 101 and STPS 201

It would be interesting to interview second year students regarding this matter in future to develop a further understanding about this particular issue and to find out if there are ways in which to develop students' epistemic beliefs regarding uncertainty [7, 8] and higher order thinking [11].

Conclusion

Engineers use critical and creative thinking to solve all kinds of open-ended problems. [2] list the six main engineering habits of mind as systems thinking, problem-finding, visualizing, improving, creative problem-solving and adaptability. All these ways of thinking include an element of uncertainty in them. However, as shown in the small scale above, students are not prepared to reach into the unknown as readily as perhaps college instructors would like to think. As a result the matter becomes a curricular issue, because these kinds of thinking skills are required in industry and business to sustain economies. This is why is it vital that engineering students are able to develop these skills at college.

According to Rajala [4], engineers need to have strong technical skills, but they also need to be able to "demonstrate effective communication, creativity, entrepreneurial thinking, teamwork and understand business –all in a global context" [4]. The current study shows that students do not come to HEIs prepared with such skills, so it is the onus of engineering HEIs to instill such skills in students in order to empower them to be able to survive and flourish at work after graduating. This is why students need to be exposed to more and more real life problem-finding and -solving situations [2], as well as experiential learning where concrete results reveal the extent of their thinking [11]. Such skills can be taught using project-based learning, which also develops teamwork skills and gives rise to communicative situations in which students require higher order

thinking skills. In addition students' epistemic beliefs could be expanded on using curriculum infused methods in a variety of subjects taught in engineering HEIs, as long as faculty are aware of the importance of placing the emphasis on such thinking skills. Further studies in the development of students' epistemic beliefs and their beliefs about engineering will hopefully shed more light on the situation and hopefully we will be able to provide practical recommendations within the scope of the research.

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