AC 2012-5519: EPISTEMOLOGICAL DEVELOPMENT OF CHINESE ENGINEERING DOCTORAL STUDENTS IN THE U.S. INSTITUTIONS: A COMPARISON OF MULTIPLE MEASUREMENT METHODS

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Epistemological Development of Chinese Engineering Doctoral Students in the U.S. Institutions: A Comparison of Multiple Measurement Methods

Abstract

A large number of international doctoral students flow into the U.S. higher education system each year. Among the foreign countries/economies where students are from, China ranks top in the number of doctorate recipients from U.S. institutions in science and engineering fields. With the prominent representation of Chinese students among the science and engineering doctoral students in U.S. institutions, however, these Chinese scientists and engineers are understudied compared to their U.S.-born peers. Researchers propose to use Perry's cognitive development theory as a theoretical framework to understand the cognitive developmental profiles of Chinese Engineering doctoral students in U.S. institution. In this paper, the researchers conducted a comparison of multiple measures that are currently available among literatures to identify an appropriate quantitative measure for mapping the profiles of Chinese engineering doctoral students' epistemological development.

Background

The doctoral education system in the U.S. has been widely considered as the best of the world. It has experienced a large increase of foreign talents, evidenced by the large number of international doctoral students each year, especially in the science and engineering field. Specifically, according to the National Science Foundation's 2009 Earned Doctorate Survey, among science and engineering Ph.D. recipients, 37% of them are temporary visa holders. Among the foreign countries/economies, China ranks top in the number of doctorate recipients from U.S. institutions in science and engineering fields[1]. Between 1999 and 2009, 32,973 students graduated with science or engineering doctorate degrees were from China.

Despite the prominent representation of Chinese students among science and engineering doctoral students in U.S. institutions, these Chinese scientists and engineers are understudied compared to their U.S.-born peers and other traditionally underrepresented groups in science and engineering disciplines[2]. Among the current qualitative and quantitative researches on foreign-born scholars including China, major efforts are spent primarily on their job satisfaction, or adjustment issues, such as the sense of isolation, the issue of balancing family life and career, lack of collegiality, language barriers, etc.[3-5] These studies provided an overview of these foreign-born scholars' academic working status and social adjustment, which are related more to the feeling or the affective domains. However, considering the fundamental goal and the significant impact of higher education played in the knowledge aspect, i.e. cognitive domain and considering the direct impact of cognitive domain on their productivity and their development of professional skill sets, it is necessary to understand their cognitive developmental status to obtain a full picture about the lived experiences of the Chinese engineering doctoral students in US institutions.

In this paper, researchers propose to use Perry's cognitive development theory[6] as a theoretical framework to understand the cognitive developmental profiles of the Chinese Engineering

doctoral students in U.S. institutions. Multiple measurement methods for applying Perry's theory will be discussed and summarized based on a synthesis of current literatures. Justifications about the methodology of applying Perry's theory among the Chinese Engineering doctoral students in U.S. institutions will be presented.

Conceptualization of Personal Epistemology

In Kitchener's discussion about cognitive processing and dealing with ill-structured problems, he proposed a three-level model including *Cognition*, *Metacognition*, and *Epistemic Cognition*[7]. At the first level, *Cognition* refers to an individual's ability to read, memorize, compute, etc. *Metacognition* has to do with the monitoring of the first level processes; *Epistemic Cognition* is related with reflections on "the limits of knowledge", "the certainty of knowledge", and "the criteria for knowing"[7]. Prior findings suggest that cognitive and metacognitive processes emerge in young children and remain active throughout their life spans, whereas *Epistemic Cognition* begins to develop in late adolescence and continues to shift in the adult years[7-8]. In the context of solving ill-structured problems, Kitchener stated that, while *Metacognition* allowed one to choose different cognitive strategies for the purpose of tackling a specific task, *Epistemic Cognition* allows one to "interpret the nature of a problem and to define the limits of any strategy to solving it" (p. 226). *Epistemic Cognition* provides the foundation for adults by which they may deal with conflicting ideas in issues like logic, ethical choice, or career choice. *Personal Epistemology* or *Epistemic Cognition* of students is the domain where the researchers would like to focus on. The aim is to gain understanding about the Chinese engineering doctoral students' epistemological development.

Literature Review

Despite the high representation of Chinese engineering doctoral students and scholars across U.S. institutions, however, foreign-born including Chinese scientists and engineers are understudied when compared to their U.S. born peers and other underrepresented groups[2]. Most *quantitative research* in this area focused on the research productivity, job satisfaction, and career trajectory issues of foreign-born scientists and engineers [2, 9-12]. For example, Corley and Sabharwal, using the 2001 Survey of Doctorate Recipients data gathered from the NSF, compared productivity, work satisfaction, and career trajectories of foreign-born scientists and their U.S. peers[2]. They concluded that foreign-born scientists had a higher demonstrated level of productivity (measured by published articles, books, papers and patent activity) and lower salaries and work satisfaction levels than did their U.S. peers. Using the structural equation modeling of 2004 National Study of Postsecondary Faculty data, Mamiseishvili and Rosser showed that international faculty members were significantly more productive in research but were less productive in their teaching and service than were their U.S. born peers[11].

Among the limited *qualitative research* on foreign-born scholars, major efforts were spent primarily on the exploration of their adjustment issues, such as experiencing a sense of isolation, balancing family life and career, experiencing a lack of collegiality, or overcoming language barriers[3-5]. Very little attention has been devoted to studying the intellectual development or the epistemological development of these groups under the U.S. system, although epistemological development studies among their U.S. peers have been going on for nearly four decades.

In the realm of *epistemological development research*, significant efforts have been devoted to understanding young adults in their epistemological development through the higher education system, especially at the collegiate level, since the pioneering work by William Perry in the 1960s [6, 13-17]. Perry described a nine-position theory of the college student's epistemological development from a dualistic to a constructive view. Perry's nine-position theory can be summarized into four main developmental stages: *Dualism*, *Multiplicity*, *Relativism*, and *Commitment within Relativism* [18]. In the context of engineering education, researchers point out that engineering college students have shown slow development according to Perry's theory because of differing education methods and the context of engineering as compared to liberal arts [19]. Often, liberal arts students are given more opportunities to develop multiple perspectives and allowed greater tolerance towards ambiguity, which potentially facilitates this development. It is speculated that graduate students will develop further in this transition to a "constructive knower", which was indicated by a study on liberal arts students (Kitchener and King, 1981); however, no substantial evidence have been provided to support this claim among engineering students.

Perry and some later researchers, such as Belenky et al.[13], Baxter Magolda[14], and King and Kitchener [15] based their research and findings mostly on U.S. institutions and U.S. populations. Recently, epistemological development research has also been performed among Chinese college students from Chinese universities. Starting from 1995, Perry's theory has been applied to study U.S. and Chinese college students by Zhang and her colleagues[16-17]. However, students in Zhang et al.'s series of studies represented a variety of areas (e.g. education, liberal arts, science, sociology, etc.) [16-17, 20]. Despite these studies, there is still scarce information available exploring the epistemological development of graduate-level engineering Chinese students. Considering the prominent representation of Chinese students in doctoral engineering education, a significant expectation of students to develop cognitively in higher education, and current research focusing largely on Chinese students' adjustment and socialization and not on cognitive development, this proposed study shall attempt to examine the epistemological development of Chinese engineering doctoral students in U.S. institutions framed within the context of Perry's theory.

Project Rational

Perry's nine-position theory can be summarized into four main developmental stages: *Dualism*, *Multiplicity*, *Relativism*, and *Commitment within Relativism*, as shown in Figure 1[18]. Perry's theory describes a movement from a dualistic to a constructive view in the intellectual and ethical development of college students[6]. From Positions 1and 2 to Positions 3 and 4, a person modifies a view of dualistic absolutism (right-wrong) to make room for simple pluralism, or, so called *Multiplicity*. From Positions 3 and 4 to Position 5, a person changes from the "simple pluralism of Multiplicity" into "Contextual Relativism", and then comes to Position 6, in which that person foresees the necessity of positioning himself with some form of personal *Commitment* (as opposed to unquestioned commitment to simple belief) to in a relativistic world. In positions 7, 8, and 9, a person experiences a development of personal commitment.

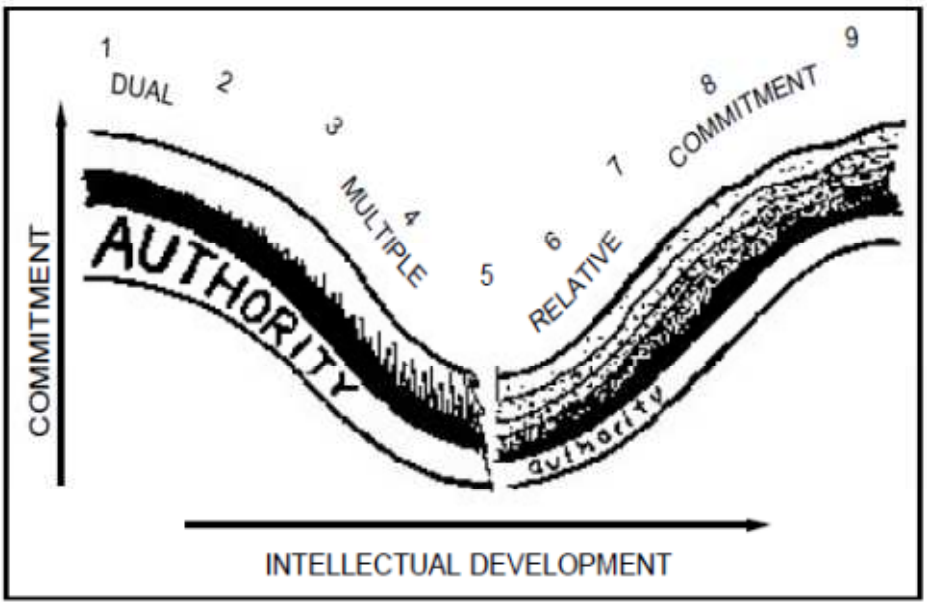

Figure 1. Perry's model of intellectual development (p. 223)[18]

Perry's theory and other later extensions by researchers such as Belenky et al. [13], Baxter Magolda [14], and King and Kitchener [15] have been adopted by multiple researchers in engineering education field to understand the cognitive development of engineering students[21]. In order to apply this theory among Chinese engineering doctoral students, the researchers conducted a comparison of multiple measures that are currently available among literature to identify an appropriate quantitative measure for mapping the profiles of Chinese engineering doctoral students' epistemological development.

Preliminary Results

In searching of appropriate quantitative measures to understand the profiles of Chinese engineering doctoral students' epistemological development, the main goal is to obtain data among large student populations and enable large-scale long-term experiments and comparisons. There have been several different pen-and-pencil based measurement methods since the first issue of Perry's intellectual and ethical model. This preliminary results will illustrate a cross comparison of multiple pen-and-pencil based ways to perform measurements.

Current pen-and-pencil based ways of measurement methods for epistemological development or epistemological beliefs include: Baxter Magolda's Measure of Epistemological Reflection (MER)[14, 22-23], Learning Environment Preferences (LEP) and Measure of Intellectual Development (MID)[24], King and Kitchener's Reasoning about Current Issues Test (RCI) [25], Schommer's survey of epistemological beliefs[26], and Zhang's Cognitive Development Inventory[16, 27].

These different measures have enabled large scale studies and provide some valuable empirical data about cognitive development across gender, ethnicity, and also other variables like

personality, critical thinking skills, learning styles, etc. However, most of these scales still require well-trained raters in order to effectively rank the results because these measures apply narrative-test responses to the pre-defined problems. This design largely limits the possible usage of most of these tests among larger population. Moreover, other limitations exist among some of these scales. For example, the RCI test has consistently provided scores that are more conservative than are interview measures[28]. In MER, Baxter Magolda used only Positions 1-5 from Perry's model, in that Position 5 was deemed to be a logical transition and milestone towards relativism[29]. Therefore, she only validated MER in terms of Perry's Position 1 to Position 5. However, no additional information is available to test the rest of Perry's positions (Baxter Magolda, 1987). The MID (Measure of Intellectual Development) was shown to give conservative scores, with possibly even one or two Perry positions lower (Pavelich and Fitch, 1988).

Schommer hypothesized a framework named Epistemological Beliefs. This framework uses a more quantitative view than all of the five above-mentioned models[26, 30]. Schommer developed a 63-item questionnaire (Epistemological Questionnaire, EQ) to measure the five hypothesized dimensions. The development of this method has allowed researchers to perform large-scale measurements because so far there are very few survey instruments available to measure epistemological beliefs. However, several researchers have expressed a number of methodological concerns with this instrument[31-32]. First, their factor analysis was performed using 12 subsets of items as variables organized by three educational psychologists prior to piloting (and not the original 63 items) [26]. Second, the factor analysis generated four factors (Fixed Ability, Quick Learning, Simple Knowledge, and Certain Knowledge) which were different from the original hypothesis.

So far, there are two other major instruments that were modified from EQ and have gained attention among researchers: (1) Epistemological Beliefs Inventory (EBI)[33], and (2) Epistemological Beliefs Survey (EBS) [34].

Researchers have tried to confirm the original framework by Schommer to a greater extent by organizing the items according to the original five structures[26, 30]. A 28-item EBI was constructed according to the definition of each epistemic dimension described by Schommer with seven items adapted from EQ via several pilot studies, content analysis, and revisions[33, 35].Their factor analysis among 160 undergraduates resulted in five factors, labeled as: Simple Knowledge, Certain Knowledge, Quick Learning, Fixed Ability, and Omniscient Authority. The internal consistency ranged from .58 to .68. However, other later study was not able to produce all five factors [36]. In addition, the sample sizes in these tests were modest, n was usually less than 200. Later, Debacker et al. used two samples (n1=378 and n2=417) to test the psychometric properties of both EBI and EBS. They found a slightly better internal consistency and factor loading ratio for EBS than EBI[32].

Developers of EBS retained Schommer's items[26] and tried to find a more stable factor structure among them in response to the concern raised by Hofer and Pintrich[31]. They combined all of Schommer's 63 items and a related measure by Jehng et al. [37] and ran a factor extraction of all items[34]. They also tried to examine whether these items would lead to the factors proposed by Schommer and to determine how the emergent factors would correlate with each other. The results among 793 participants lead to a five-factor solution. These five factors were labeled as: Speed of Knowledge Acquisition; Structure of Knowledge; Knowledge Construction and

Modification; Characteristics of Successful Students; and Attainability of Objective Truth. Some of these factors' descriptions were similar to Schommer's original factors. For example, the Speed of Knowledge Acquisition overlaps with Schommer's Quick Learning factor. However, some factors seem novel from the original factor list. For example, the Structure of Knowledge and Knowledge Construction and Modification were novel factors that were not clearly identified in the original test run through EQ.

A closer examination of the definition of these five factors has shown that higher scores in the *Knowledge Construction and Modification* factor relate closely to the participants' epistemic development from a dualistic view to a more constructivist view. Here is a direct excerpt from Wood and Kardash's descriptions of their emergent factors[34]:

> *(Factor 3) "Knowledge Construction and Modification" reflected participants' awareness that knowledge can be acquired and modified through strategies such as integrating information from various sources, reorganizing information according to a personal scheme, questioning information, and recognizing the tentativeness of information. High scores on this factor reflect the ideas that knowledge is constantly evolving,* ***is actively and personally constructed, and should be subjected to questioning. By contrast, low scores on this factor reflect a view that knowledge is certain, passively received, and accepted at face value.****"(p. 250)*

For their descriptions, this factor appears to be reflecting the epistemological trend repeatedly observed by Perry[5], Belenky et al.[13], Baxter Magolda [14], King and Kitchener [15]. Although EBS was not developed within Perry's framework, scores derived under this factor do serve as a useful indication for students' epistemological development in their knowledge construction and modification. The internal reliability for this subscale was reported in Debacker et al.'s study as .67 (Sample 1, n=380) and .65 (Sample 2, n=415)[32]. Therefore, this subscale is chosen for the use of mapping the profiles of Chinese engineering doctoral students' epistemological development.

In the past decade, several researchers applied Perry's theory among college students in China [16, 17, 38-41]. Zhang and her colleagues performed a series of five consecutive studies on the cognitive development of U.S. and Chinese college students over the past decade (See a review of these studies in Ref. 20). Zhang and her colleagues developed Zhang's Cognitive Development Inventory (ZCDI) based on Perry's theory. It is one of the few survey instruments based on Perry's model.

It has five subscales assessing three of the four positions in Perry's model as mapped in Culver and Hackos [18]. These three positions are Dualism, Relativism, and Commitment within Relativism. Dualism and Relativism were examined in two content areas, education and interpersonal relationship. Commitment or named, Life Responsibility in ZCDI reflects the last position in Perry's model, Commitment within Relativism. ZCDI has 75 short statements in all. For each statement, participants provide a response in a 7-point Likert scale indicating the degree to which they agree with the statement.

Zhang reported internal consistency reliability alpha coefficients ranging from 0.57 to 0.74 for the Chinese sample [20]. The validity of the measure was indicated by the subscale's correlation coefficients fitting their predicted direction. For example, Interpersonal Relationship/Dualism

(i.e. the Dualism position in an Interpersonal Relationship area) is supposed to be reversely correlated with Interpersonal Relationship/Relativism. The reported correlation was $r = -.32$, $p < .01$ for the Chinese sample. Education/Relativism was shown to be positively related with Life Responsibility/Commitment.

In summary, because ZCDI was developed based on Perry's theory and validated among both U.S. and Chinese college student populations for the first time. ZCDI can potentially serve as another tool for mapping the epistemological development within the Chinese population within the context of Perry's theory. ZCDI, along with the *"Knowledge Construction and Modification"* subscale under Epistemological Beliefs Survey (EBS), are identified from current methods for epistemological development measures for the purpose of mapping Chinese Engineering doctoral students' epistemological development.

Conclusion and Next Steps

Using the Perry's theory [6] and the identified quantitative instruments, the next step will be testing these two instruments among Chinese doctoral students in U.S. institutions. The initial quantitative profile will potentially provide a first-hand understanding about the cognitive developmental profiles of Chinese graduate students and allow further qualitative investigation regarding other factors and experiences that are related with students' cognitive developments.

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