Tolerance of Ambiguity (Work in Process)

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Abstract

Longitudinal and cross-sectional data is being collected at a Historically Black College (HBCU) to understand the cognitive development of students in their tolerance of ambiguity that may translate into their ability to solve open-ended problems. The data is expected to provide insight into the correlations between academic success, tolerance of ambiguity, intellectual development and development of a science, technology, engineering, and math (STEM) identity in undergraduate students. This work-in-progress paper provides preliminary data on tolerance of ambiguity in college students. Some results from the analysis of the data are included.

Keywords

HBCU, STEM identity, tolerance of ambiguity, intellectual development, academic success

Introduction

The low rates of persistence and graduation of students from underrepresented minorities in science, technology, engineering and mathematics (STEM) is a matter of concern. Many structural and pedagogical reasons have been identified for this trend. The development of a STEM identity has been reported as one of the important aspects influencing persistence and academic success [1], specially of students from underrepresented groups [2]-[5]. Identity is neither a monolithic construct nor its development is a one-dimensional process. An individual may have several intersecting identities such as a personal identity (individual characteristics), social identity (group characteristics, cultural characteristics), and professional identity [6]-[8]. The development of professional identity has been studied in context of various professions such as medicine [8], health care [9], pharmacy [10], and higher education [11], [12]. One definition of professional identity is "internalization of the norms of the profession into the individual's self-image . . . [and] the acquisition of the specific competence in knowledge and skills, autonomy of judgment, and responsibility and commitment of the profession" [11, p. 11] as cited by [12]. Ibarra [13] has summed up the definition of Schein [14] as professional identity to be the "relatively stable and enduring constellation of attributes, values, motives, and experiences in terms of which people define themselves in a professional role". Ibarra also stated that professional identity is "more adaptable and mutable early in one's career". It is not only what one wants to be, but also that peers, supervisors and subordinates must validate this identity [15, p.68]. Competence, performance and recognition as dimensions of identity have been reported by Carlone and Johnson [16].

One important dimension of STEM identity is the self-efficacy to function in a complex solution space. Research literature suggests that a continuum of intellectual understanding of the worldview exists. This continuum varies from a dualistic worldview on one end of the spectrum to a more

flexible pluralistic worldview on the other end. It is expected that students develop a more nuanced understanding of the problem spaces through their progression in college. However, movement along this spectrum is usually far from expectations. The problems to which STEM students are exposed during the majority of their college experience bear little resemblance to the challenges they will encounter as practicing professionals. Real life problems of significance rarely lend themselves to be accurately or completely modeled due to limitations in understanding of these problems or because of the sheer effort involved in determining solutions. Real life problems are the epitome of incomplete information. These incomplete and ambiguous models of reality coupled with the possibility of multiple feasible solutions make solving such problems a challenge. Jonassen, Strobe and Lee [17] noted that students need to learn how to 'develop adequate conceptual frameworks (make meaning) and apply those frameworks in solving complex ill-structured problems', a process requiring to function under ambiguity. Incorporating complexities of the real-life problem space of uncertainty and ambiguity in the learning environment however requires careful understanding of the cognitive development of students. An ill-designed learning environment can become a daunting experience for students [18]-[21]. However, before proceeding further, it is considered pertinent to operationalize the definition of ambiguity in context of problem solving. Schrader, Riggs and Williams [22] differentiate between 'uncertainty' and 'ambiguity' as follows:

"Uncertainty: Characteristic of a situation in which the problem solver considers the structure of the problem (including the set of relevant variables) as given, but is dissatisfied with his or her knowledge of the value of these variables.

Ambiguity level 1: Characteristic of a situation in which the problem solver considers the set of potentially relevant variables as given. The relationships between the variables and the problem solving algorithm are perceived as in need of determination.

Ambiguity level 2: Characteristic of a situation in which the set of relevant variables as well as their functional relationship and the problem-solving algorithm are seen as in need of determination."

It therefore seems reasonable to infer that to solve complex real-life problems in which ambiguity is inherent, the ability to form appropriate mental models is essential. The cognitive developmental process of moving from being ambiguity-intolerant to ambiguity-tolerant in the context of education can be viewed from the perspective of Perry's model of intellectual and ethical development [23]. The two opposing poles of Perry's model are 'a dualistic view' (right or wrong; black or white) and a 'relativistic view' (multiple solutions, explanations) of the world. Perry's model provides details on how the intellectual growth of students takes place over 9 positions on the spectrum from dualism to relativism. Dualism is associated with authority i.e. accepting what the teacher says, or in other words, what should be the answer that the teacher is looking for, while relativism is associated with agency. From a STEM education perspective, students who are more towards the relativistic position on the scale are able to better cope with an ill-defined problem space (unknown functional relationships between the variables) that lends itself to multiple possible solutions. Research into the development of cognitive models of engineering students [24], [25] have shown that students did not develop beyond an average of 2.8 on the Perry scale.

This is in strong contrast with the result of Perry's sample of liberal arts students who were in position 7 or 8 at graduation.

The common notion of mathematics being 'exact' is dispelled by Byers [26]. The challenges in development of cognitive models by math students [27], and the need for exposing math students to ambiguity [28]-[31] have been reported. For example [31] noted in their case study on student comfort with ambiguity in a Calculus 1 course that students "would prefer to attempt the more formulaic problems rather than the contextual problems, even when they found the contextual problems more interesting, because they were more confident in finding the "right" answer to the formulaic ones. This preference highlights their reliance on authority for epistemological certainty." This observation clearly places the math students' cognitive models in the classical dualistic location on the ambiguity spectrum.

The National Science Foundation (NSF) has funded a three-year project to study this important intellectual development of students in a typical STEM curriculum. Cross-sectional and longitudinal studies of STEM students as well as non-STEM students at a Historically Black College are being conducted to measure the influence of the current curriculum in context of the constructs of tolerance of ambiguity, intellectual mental models, and STEM identity.

This work-in-progress paper shares some preliminary results of the baseline data that has been collected during the first year of the NSF-funded project.

Method

The participants of this within-subject and between-group quasi-experimental study are students of a Historically Black College (HBCU). The tolerance to ambiguity is being measured using the modified Rydell-Rosen Scale (RRAT) with 20 True/False items [32] The survey consists of 16 items from the original Rydell and Rosen instrument [33], 2-items from the California Personality Inventory [34], and 2-items from the Barton's Conformity Scale [35]. This scale has a stability coefficient of 0.63 (based on a six- month retest). The modified Rydell-Rosen Scale has been shown to be free from the Marlowe-Crowne Social Desirability influence. Its construct validity has been demonstrated through significant correlations with the "Rokeach Dogmation" and the "Gough-Sanford Rigidity" scales. The RRAT was administered in Fall 2018 to students from the various STEM and non-STEM majors (engineering, mathematics, chemistry, biology, computer science, political science and English). The responding students included incoming freshmen, sophomores, juniors and seniors.

Two assessment instruments will be used to establish the intellectual development mental models of the students. The first one (B-D scale) is a 16-item scale developed by Bateman and Donald [36]. Their instrument is a questionnaire that measures the stages of development in four broader categories (dualism, multiplicity, relativism, and commitment) with four items for each stage. The second instrument is the Learning Environment Preference (LEP) Instrument developed by Moore [37] to measure the development positions 2-5 (Intellectual Development). Positions 6-9 are associated with commitment and are not measured by this instrument. This instrument also measures five different content domains related to learning [38] with each domain assessed through 13 statements ranging from simple to complex: view of knowledge and learning; role of

the instructor; role of the student/peers; classroom environment and activities; role of evaluation and grading.

Preliminary Results and Discussion

A total of 114 students (89 males and 25 females) responded to the RRAT survey. Of these respondents, 106 were engineering majors and 8 were other STEM majors. The z-statistic proportion test was used to determine statistically significant differences between the responses of the lower division (freshmen and sophomores, N=79, males = 65, females = 14) and upper division (juniors and seniors, N=27, all males) engineering students. The correct responses of the lower division students were 41% as compare to 45% of the upper division students yielding a statistically significant difference (one-tail, $p = 0.028$). The percentage correct responses to the RRAT are shown in Fig. 1. Statistically significant differences (two-tail, $p < 0.05$) between the responses of lower and upper division students were observed for following questions. The correct response A-agree (or True) or D-disagree (or False) is given in front of each question.

Q#4: I would rather bet 1 to 6 on a long shot than 3 to 1 on a probable winner. (A)

33% of Freshmen and Sophomores agreed to the statement while 77% of Juniors and Seniors agreed with this statement ($p < 0.0002$)

Q#5: The way to understand complex problems is to be concerned with their larger aspects instead of breaking them into smaller pieces. (A)

32% of Freshmen and Sophomores agreed to the statement while 77% of Juniors and Seniors agreed with this statement ($p < 0.0002$)

Q#6: I get pretty anxious when I am in a social situation over which I have no control. (D)

58% of Freshmen and Sophomores disagreed to the statement while 27% of Juniors and Seniors disagreed with this statement ($p = 0.006$)

Q#12: If I were a doctor, I would prefer the uncertainties of a psychiatrist to the clear and definite work of someone like a surgeon or X-ray specialist. (A)

33% of Freshmen and Sophomores agreed to the statement while 77% of Juniors and Seniors agreed with this statement ($p < 0.0002$)

Q#14: If I were a scientist, it would bother me that my work would never be completed (because science will always make new discoveries). (D)

41% of Freshmen and Sophomores disagreed to the statement while 77% of Juniors and Seniors disagreed with this statement ($p = 0.001$)

Q#19: I like to fool around with new ideas, even they turn out later to be a total waste of time. (A)

78% of Freshmen and Sophomores agreed to the statement while 21% of Juniors and Seniors agreed with this statement ($p < 0.0002$)

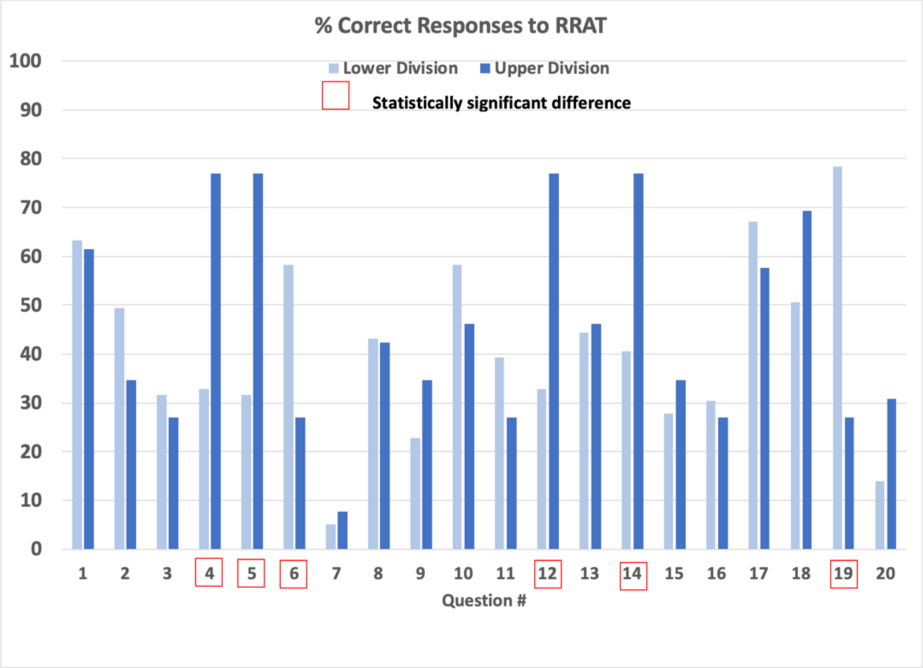

Figure 1: % Correct responses to the RRAT

Conclusions and Future Work

The preliminary analysis of the RRAT instrument indicates that in general the upper division engineering students develop an increased tolerance to ambiguity. The data is currently being analyzed from the latest RRAT administration (Spring 2029) which was primarily targeted non-engineering STEM and non-STEM disciplines. Impact of gender and capstone experiences will be looked at during additional analyses.

The B-D survey and LEP surveys will be administered cross-sectionally in Spring 2019 to measure the students' cognitive models as they relate to the location on the dualism – relativism spectrum.

A pilot intervention that will be implemented during the 2019 AY includes offering of a redesigned introductory aerospace engineering course and a redesigned calculus course. These courses will be designed to facilitate movement towards relativistic cognitive models promoting tolerance of ambiguity. The redesign of these two pilot courses will incorporate an authentic learning environment of which real-world relevance and an ill-defined problem space are the essential elements.

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