Intellectual Mental Models of Engineering and Non-Engineering Undergraduate Students

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Abstract
The traditional educational paradigm encourages the development of dualistic intellectual mental models of the world view. Students strive to get the correct answer as expected by the teacher. With the development of understanding of the world view and student agency, the mental models move towards multiplicity and finally to a relativistic understanding. This paper discusses the cognitive development of undergraduate students and the impact of duration of stay in college. A validated instrument was used to measure anchoring of student mental models across the spectrum of duality, multiplicity, relativity, and commitment. Data were analyzed to determine the differences between engineering and non-engineering students. The influence of gender was studied. The effect of the academic standing was also investigated. Results of these analyses are shared.

Introduction
The typical learning experience of students reinforce their perceptions of the teachers as authority figures. The students thus strive in general to respond to their teachers' questions with answers that they think the teacher is looking for. Thus, in their understanding, a question or a problem has either a right answer or a wrong answer. This binary world view of the students and their subsequent transition to a more nuanced understanding, was studied by Perry [1]. He identified nine positions of a young adult's understanding of the world, dividing it into four major grouping of dualism, multiplicity, relativity and commitment. Dualism is the belief that every problem is solvable, and the correct answer as determined by the teacher must be learned. The next level in this epistemological development is that there are problems which are solvable and there are others for which solutions may not be known yet. The category of relativism includes our understanding that a proposed solution must be supported by reason and is contextual. Commitment within relativism indicates the result of considering knowledge from various sources tempered with personal experience and reflection. Perry's model was followed by several other models such as that of Belenky et al. [2] which specifically looked at how females develop epistemologically. A review of the various epistemological models is given by Hofer and Pintrich [3].

The intellectual mental models based on Perry's taxonomy have been empirically studied in various domains [4] - [10] with the objective of understanding the students' current location on the Perry continuum or exploring strategies and measuring their impact on students' intellectual mental models. These studies have used interviews, as was the classical study of Perry [1] as

well as quantitative surveys such as the Learning Environment Preferences inventory [11], and Bateman-Donald questionnaire [12].

The study reported in this paper is part of larger research effort to identify and understand the linkages if any between academic success, intellectual mental models, tolerance of ambiguity and professional identity. The analysis of cross-sectional data to understand the impact of academic classification, and gender on the intellectual models of engineering and non-engineering undergraduate students is included.

Method

The participants of the study were a cross section of undergraduate students at an HBCU from various engineering and non-engineering majors, and academic standing. Participation in the study was voluntary. The study was approved by the IRB. The total number of participants in the study were 147 with 104 males and 43 females. The number of engineering students were 127 (female = 27, male = 99) and non-engineering students were 20 (female = 16, male = 4).

The Bateman-Donald questionnaire [3] was used to measure the participants' location in the four categories of duality (D), multiplicity (M), relativity (R), and commitment (C). The survey consists of 16 questions (Appendix A) with questions R5 and M19 reversed scored. The responses were measured on a 5-point Likert scale with 5 - strongly agree (SA), 4 - agree (A), 3 - neutral (N), 2 - disagree (D), and 1 – strongly disagree (SD). The survey was administered as an online fillable form. The items M19 and R5 were reverse scored i.e. "Strongly Agree", "Agree", "Disagree", and "Strongly Disagree" were converted respectively to "Strongly Disagree", "Disagree", "Agree", and "Strongly Agree" to determine the averages for the multiplicity and relativity dimensions..

Results and Discussion

The responses of the students were analyzed to understand their epistemological anchoring on the Perry scale. Fig.1 shows the overall percentages of agreement and disagreement with the various statements of the Bateman-Donald questionnaire. It was observed that the students on the average were towards the relativity and commitment (within relativism) of their understanding of the world. The average percentage (%) of responses agreeing with the statements of dualism was 48% while the % of responses disagreeing was 25%. The % responses that were neutral in the dualism dimension were 28%. The highest % of agreement in the dualism dimension was with the statement that the job of the student is to master the facts as given by the professor. The largest percentage (35%) of unsure responses in the dualism domain were of question number D17 which stated that "to get more out of the class, the instructor should just stick to the facts". In the multiplicity domain the largest % of unsure or neutral responses were 29% for M20 which pertained to everyone having their own opinion and that there was no such thing as right or wrong. The % responses that were neutral or unsure were 29% for M19 as well which stated that the successful student has figured out what the teacher wants. This statement (M19) also had a high agreement percentage (53%) as seen in Fig. 1 which is shown as reversed scored. The largest % of unsure responses (19%) which also had the lowest agreement (71%) in the relativity dimension, were for R9 which pertained to opinions and evidence. The highest agreement % was for R5 (which is shown as reverse scored) which pertained to ultimately making a decision.

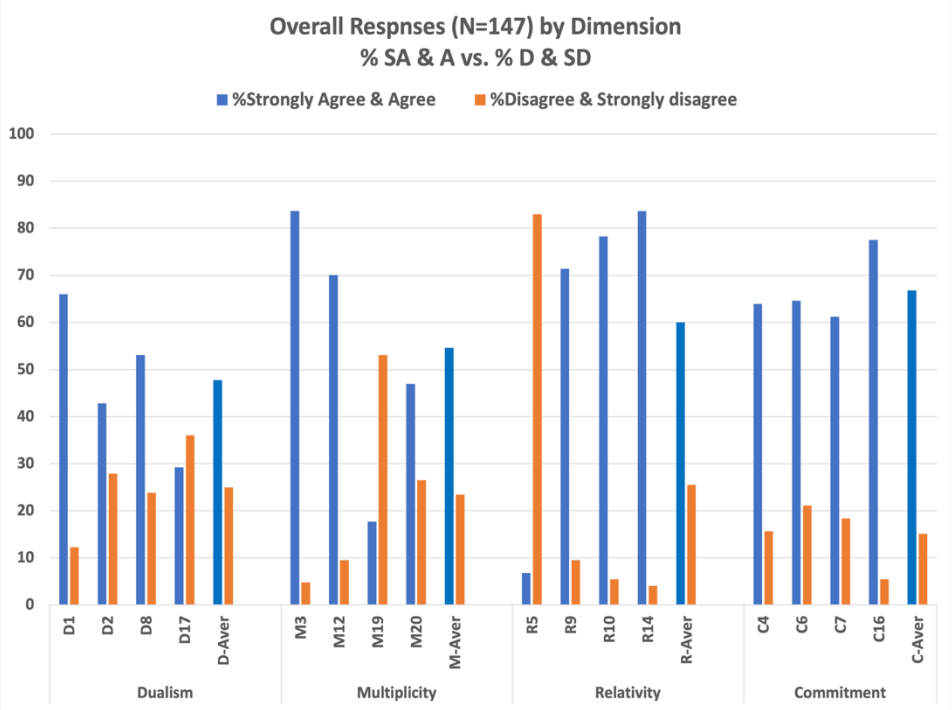

Figure 1: Overall % responses (M19, M19 reverse scored)

The moderating effect of gender is shown in Fig. 2. It was observed that on the average, a higher % of males (51%) was in agreement with the statements of the dualism dimension as compared to females (41%). The lowest % of agreement by both females and males in the dualism dimension was for D17 that stated that teachers should just stick to the facts. D17 also had the largest % of neutral responses (males 35% and females 40%). The females had higher % agreement to all questions in the multiplicity dimension than the males. The largest % of responses (30%) in the neutral range for the females was for M19 which stated that the successful student has figured out what the teacher wants, and for M20 which pertains to

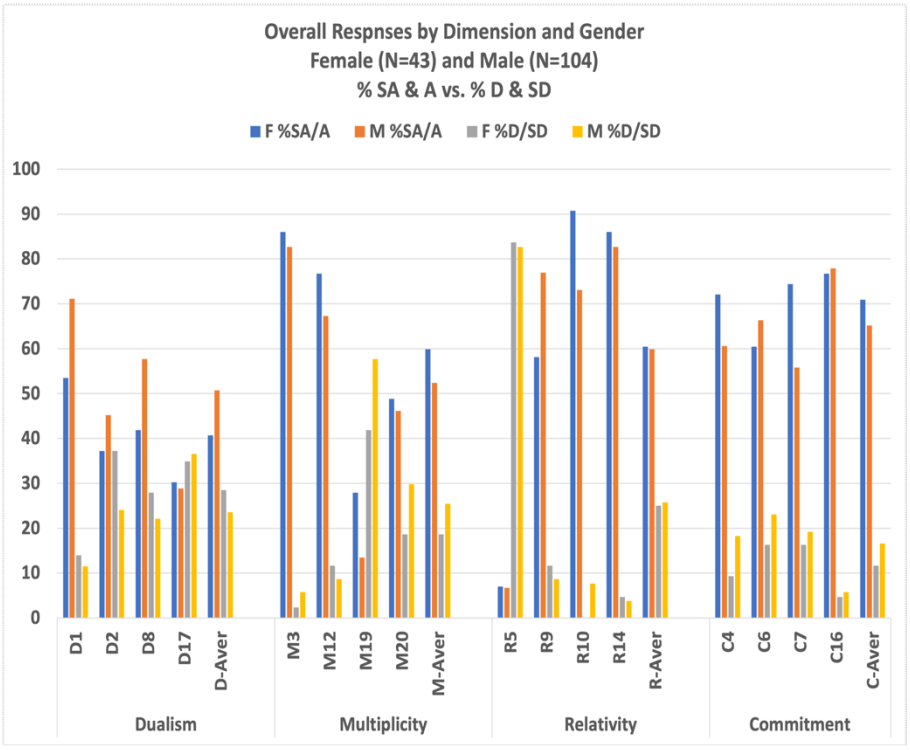

Figure 2: Effect of Gender (M19, R5 reverse scored)

the position that everyone has a right to an opinion and there are no right or wrong. The male respondents had the highest neutral responses (30%) to M19 while for the remaining three questions, females had a higher % agreement. The average % responses agreeing with the statements of the relativity dimension was almost the same for males and females. The females had a higher average % agreement with the statements of the commitment dimension. The average of the responses suggests that more females were in the multiplicity domain as compared to males. This analysis indicates that males tended to be more dualistic as compared to females.

The comparison between engineering and non-engineering respondents is given in Fig. 3. The data indicated that on the average, the % responses of non-engineering students agreeing with the statements of the dualism dimension was 8% less than the % responses of the engineering students. The % of neutral responses were 28% for engineering students and 24% for non-engineering students. The non-engineering students % agreement was lower than engineering students with all the statements of the dualism dimension.

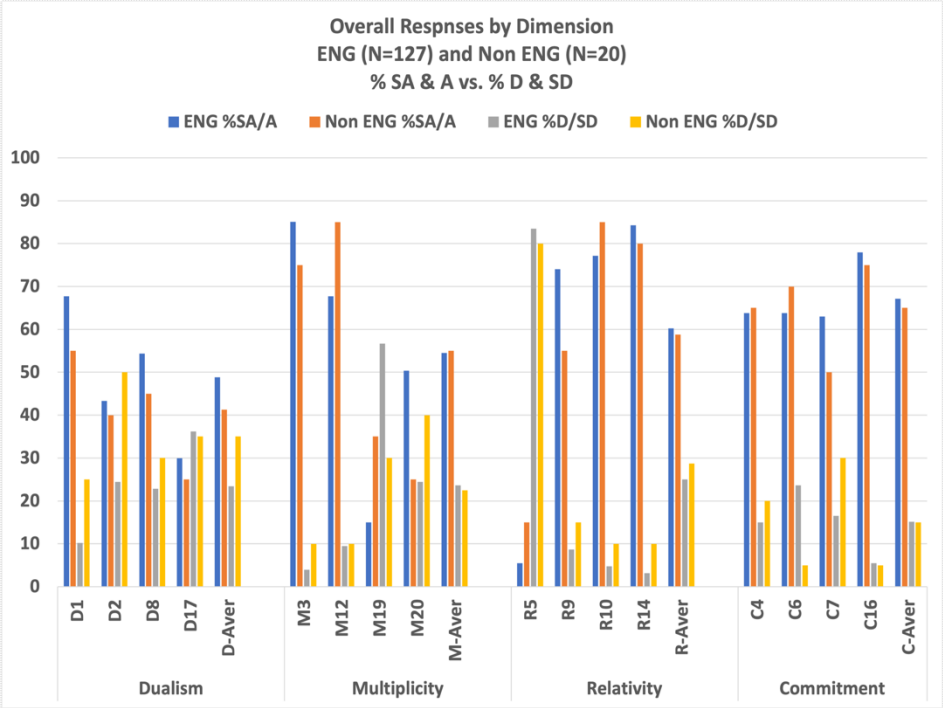

Figure 3: Comparison of engineering and non-engineering students (M19, R5 reverse scored)

The average % agreement to the statements of the multiplicity domain was almost the same (55%) for engineering and non-engineering students. The % of neutral responses was about 23%. The lowest % of agreement of the non-engineering students (24%) and engineering students (51%) was with statement M20 which pertain to having an individual opinion and there being no right or wrong. The average % of responses agreeing with the statements for the relativity dimension was about the same for both engineering and non-engineering students (~60%). The % agreement with R5 (reverse scored) which pertained to the need for ultimately making a decision, was high for both engineering and non-engineering students. The average of the %

agreement to the statements of the commitment dimension was the same for engineering and non-engineering students (~65%). The % of neutral responses was about 20%.

The effect of academic standing was investigated, and the analysis is shown in Fig. 4. The objective is to see if the duration of stay in college resulted in the move from dualism to commitment. It was noted that the underclassmen (freshmen - Fr, and sophomores - So) % average agreement with the statements of each of the dimension was slightly higher than the upperclassmen (juniors - Ju, and seniors - Se). While this was expected for the dualism dimension, the results were contrary to expectations for the other three dimensions. The % agreement though increased from dualism to commitment. The upperclassmen had higher % agreement with the D2 which stated that knowledge is to be able to figure out the right answer. In the multiplicity dimension, except for M3, the underclassmen had higher agreement with the remaining three statements. For the relativity dimension, the underclassmen had higher % agreement with the statements except for the statement of R14.

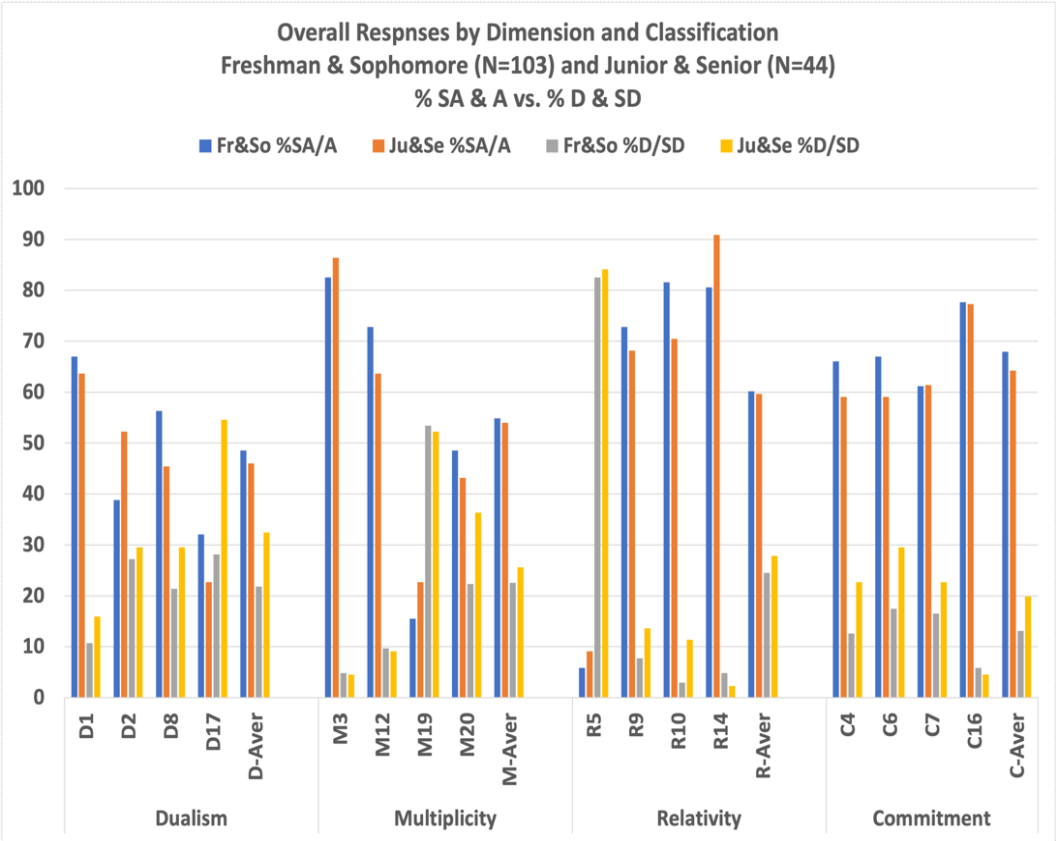

Figure 4: Impact of academic standing (M19, R5 reverse scored)

To get a better understanding of the impact of time spent in college, the responses of the freshmen were compared with those of the seniors (Fig. 5). As expected, freshmen had a higher % average agreement with the statements of dualism as compared to seniors. However, interestingly seniors had a higher % average agreement with the statement D2 that knowledge is the ability to figure out the right answer. It was observed that freshmen had a slightly higher

agreement with statements of the relativity and commitment dimensions which was contrary to expectation. The seniors had a slightly higher % average agreement with the statements of the multiplicity dimension.

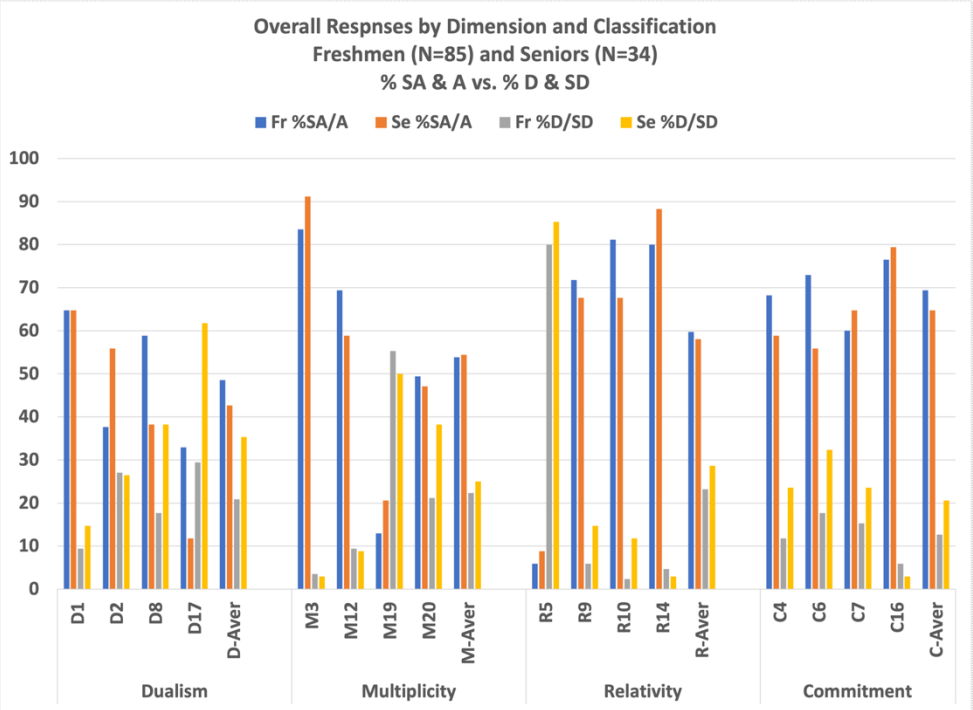

Figure 5: Impact of academic standing (freshmen, seniors) (R5, M19 reverse scored)

Conclusions and future work

The data analysis indicated that on the average, the students participating in the study seemed to have a complex worldview that is to recognize multiple viewpoints and a not simply a yes/no, true/false assessment of a situation. While to some extent, students had a dualistic mental model. They also exhibited a more nuanced understanding as evidenced by the higher agreement with the statements of multiplicity, relativity and commitment. It was noted that males were more dualistic as compared to females. The data indicates that the % of female respondents was higher in the multiplicity domain as compared to the % of male respondents. The % of male and female respondents was the same in relativistic domain. Engineering students had a higher % average agreement with the statements of dualism as compared to non-engineering students. Contrary to expectation, freshmen had higher % average agreement with the statements of relativity and commitment dimensions. This result shows that engineering students tended towards dualistic mental models with passage of time in college. The large % responses that were neutral indicates an opportunity to structure the learning experiences of the students so that their epistemological models are more towards the higher intellectual levels. The participants of this study are being tracked longitudinally to better understand the correlation between academic standing and their mental models. Data will be collected every year.

Acknowledgements

The research is supported by NSF Grant # 1832041.

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Appendix A
The Bateman-Donald Scale
D: Duality; M: Multiplicity; R: Relativity; C: Commitment

D1 When it comes to knowledge, facts are facts: that's basic. The student's business is to master the facts as the professor gives them.
D2 Knowledge is being able to figure out the right answer.
M3 Teachers present different points of view because they want us to think independently - to learn to find the answer for ourselves.
C4 The professor is not a giver of knowledge. The professor is a guide and a model for our own independent learning. The responsibility for learning or mastering a subject is the student's responsibility.
R5 You can't analyze, consider and balance things forever; sooner or later you have to decide and act. (reverse scored)
C6 Knowledge is being able to defend a position with solid argumentation, even though others might disagree.
C7 Learning is challenging when we must look at all the ideas and from these decide where we stand.
D8 Knowledge is being able to recall facts and data.
R9 Opinions are only as good as the evidence supporting them.
RI0 As long as students develop and support their answers they should not be penalized, even if their view differs from that of the professor.
M12 In areas where experts disagree, everyone has a right to his or her own opinion.
R14 Knowledgeable persons use what they know to judge ideas, data and values.
C16 Knowledgeable persons have identified their own point of view, recognize that it is their own and act according to it .
D17 If teachers stuck more to the facts and did less theorizing, students would get more out of their classes.
M19 The successful student has figured out what the teacher wants. (reverse scored)
M20 Everyone has a right to his or her own opinion. There is no such thing as right or wrong.