2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #40452

Tolerance of Ambiguity and Engineering Identity

Dr. M. Javed Khan, Tuskegee University

Dr. M. Javed Khan is Professor and Head of Aerospace Science Engineering Department at Tuskegee University. He received his Ph.D. in Aerospace Engineering from Texas A&M University, M.S. in Aeronautical Engineering from the US Air Force Institute of Technology, and B.E. in Aerospace Engineering from the PAF College of Aeronautical Engineering. He also has served as Professor and Head of Aerospace Engineering Department at the National University of Science and Technology,Pakistan. His research interests include experimental aerodynamics, aircraft design and engineering education.

Dr. Chadia Aji, Tuskegee University

Chadia Affane Aji is a Professor in the Department of Mathematics at Tuskegee University. Dr. Aji received her Ph.D. and M.S. in Mathematics from Auburn University and a Bachelor in Chemical Engineering from Texas A&M University. Her research interests lie in the areas of numerical analysis, computational applied mathematics, complex analysis, and on improving students' learning in STEM disciplines. Dr. Aji is involved in retention activities at Tuskegee University. She helps designing strategies to assist incoming freshmen cope with first year mathematics classes. She developed teaching modules to improve students' learning in mathematics using technology.

Tolerance of Ambiguity and Engineering Identity

An understanding of the determinants of academic success of engineering students is important to improve the learning environment. The identity of a person is composed of several component identities. These various identities include but are not limited to, personal, identity, social identity, and professional identity. The correlation between professional identity and professional success as indicated by research has prompted the focus on development of engineering identity in engineering students. The tolerance of ambiguity of problem spaces is also being explored to move the learning environment closer towards a real-world problem space. This paper provides results of a study conducted at an HBCU to determine a correlation between tolerance of ambiguity, engineering identity. The responses of a cross-section of engineering students to validated surveys on engineering identity and tolerance of ambiguity were collected. The study indicated that the length of stay in college enhanced the engineering identity of the students. However, it was observed that the length of stay in college did not impact the tolerance of ambiguity.

Introduction

The primary objective of education is to develop the critical thinking skills of students so that they can use their knowledge and skills in real life to solve problems hitherto unsolved. Critical thinking is a process to solve problems through "conceptualizing, applying, analyzing, synthesizing, and/or evaluating" relevant information [1]. The higher education environment in general and engineering education environment in particular incorporate to some degree critical thinking-based pedagogies such as open-ended problems, and design exercises [2], [3]. Recognizing relevant information and identifying dependencies are essential elements of critical thinking. The process of critical thinking becomes intellectually more demanding if the dependencies between various pieces of information are either ill-defined or not defined. The real-life problem space spans the spectrum of full information about the variables, to a probabilistic understanding of the relations to no knowledge of the dependencies. In other words, the problem space spans the ambiguity spectrum [4] - [6]. Tolerance of ambiguity has been termed as a "critical future fit skill" [7] and can be discriminator between entrepreneurs and managers [8]. Students are usually averse to solving problems that have incomplete information, that is they exhibit an intolerance of ambiguity. The impact of duration of stay in college on tolerance of ambiguity as well as age have been studied in the past [9]. Intolerance of ambiguity can lead to poor academic performance and persistence [10]. Appropriately structured learning experiences that provide a scaffolding, can increase tolerance of ambiguity [11], [12].

Another important construct that impacts academic success and persistence in a major is professional identity. An individual's identity consists of several sub-identities [13] such as personal identity, social identity, and professional (engineering) identity [14]. The impact of engineering identity on retention in the profession has been reported [15] - [17]. Research indicates that professional identity is malleable [17] - [20].

The contents of this paper are based on a study to establish baseline understanding of tolerance of ambiguity, and engineering identity of undergraduate students and the impact of duration of stay in college.

Method

The participants of the study were undergraduate engineering students enrolled at an HBCU. A total of 154 students responded to the modified Rydell-Rosen Ambiguity Tolerance survey (RRAT) (Appendix A, [21]). Of the 154 respondents, 116 were freshman while 38 were graduating seniors. The survey has 20 true/false items. The Godwin [22] Engineering Identity (EI) (Appendix B) survey was also administered to the students. The EI survey which measures the responses on a 5-point Likert scale (Strongly Agree (SA) =5; Agree (A) = 4; Neutral (N) = 3; Disagree (D) = 2, and Strongly Disagree (SD) = 1) has 11 items that measure three dimensions namely, Acceptance (3 items), Interest (3 items), and Competence (5 items). A total of 292 freshmen and 35 graduating seniors responded to the EI survey. The data was collected using Google forms. The surveys were administered to freshmen at the start of their first semester in college and to the graduating senior towards the end of their graduating semester.

Results and Discussion

The analysis of the responses to the RRAT survey for the freshmen is given in Fig.1. There are several observations that can be made based on these responses. The average percentage of the correct responses to the survey items is 46%. There were only 8 items to which the percentage correct responses 50% or higher and only two items to which the percent correct answers were greater than 70%. The highest percentage of correct responses was to item Q19 which pertained to “fooling around with new ideas”. The lowest percentage response was to item Q7 that asserted that “every problem has a solution”. Q20 elicited about 20% correct responses to the statement that a good composition must have balance. Q16 for which the correct responses were 28% gauged the student satisfaction with getting to a solution which in the case was placing the last piece of the jigsaw puzzle.

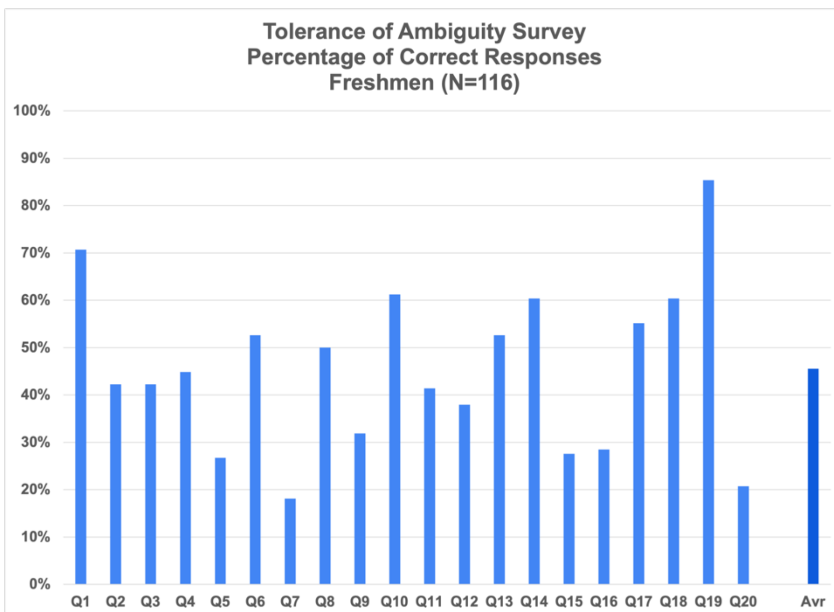

Figure 1. Correct responses to RRAT Survey by Freshmen

The percentage correct responses for graduating seniors are shown in Fig. 2. The average of the percent correct responses to the survey is 43%. The percentage of correct answers for only 8 items of the survey were higher than 50%. The percentage correct answers were higher than 70% for only two questions

(Q14 and Q19). The highest percentage of correct answers was for Q19, similar to but lower than the percentage correct answers of freshmen. The next highest percentage of correct answers was for Q14 indicating that the students were likely to accept the incompleteness of their work i.e., without any solution. Like the responses of freshmen, the lowest percentage of correct answers was for Q7. Interestingly, Q8 which pertained to ambiguity in social interaction had the next lowest percentage of correct responses.

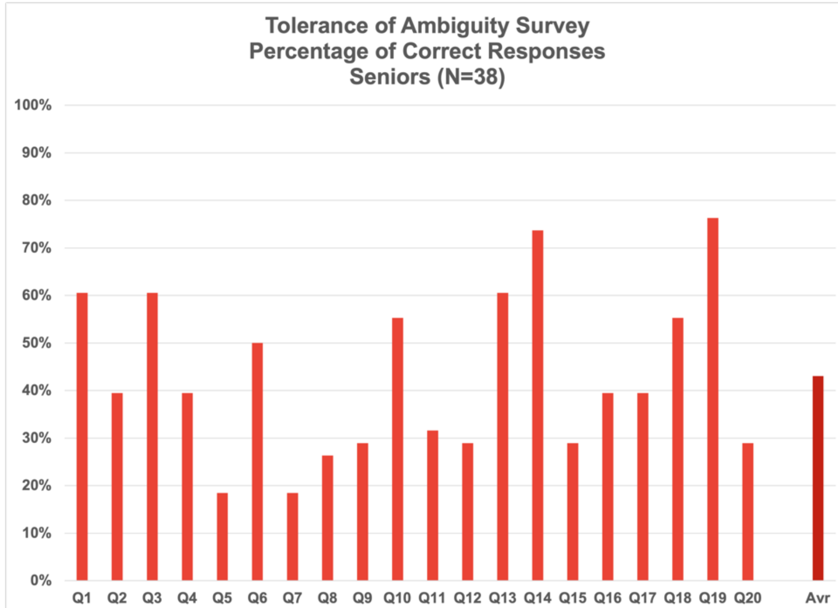

Figure 2. Correct responses to RRAT Survey by Graduating Seniors

A comparison of the responses between the freshmen and graduating seniors is provided in Fig. 3. This comparison captures the impact of the duration of stay in college. It was noted that there was no statistically significant difference ($p < 0.05$) between the averages of the percentage of correct responses for freshmen (46%) and seniors (43%). The freshmen had higher percentage of correct responses than the graduating seniors on 13 of the 20 items of the survey. The trend of the correct responses was in general similar. For example, both freshmen and seniors had the lowest percentage of correct responses (about 18%) for Q7 which indicated that a little over 80% felt that every problem must have a solution. An almost 25%

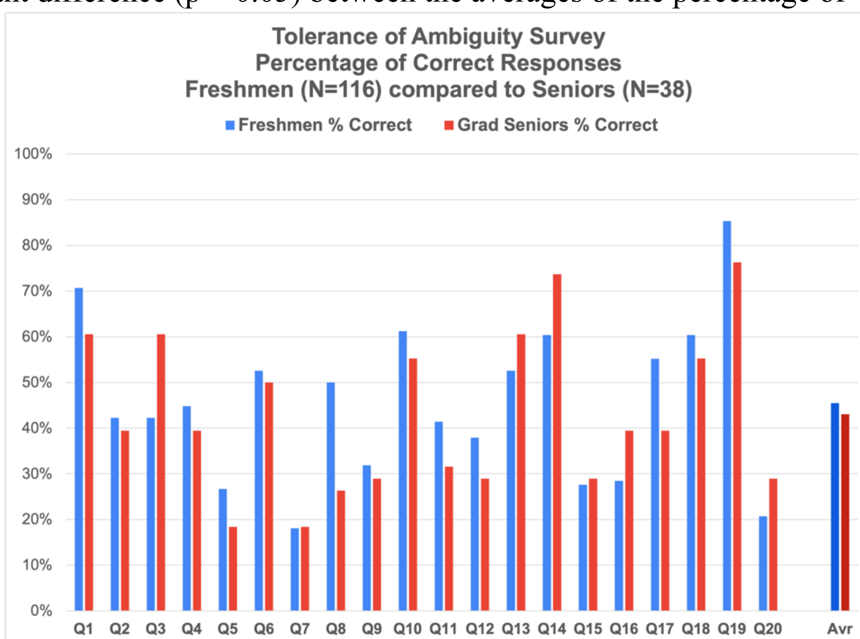

Figure 3. Comparison of Correct responses to RRAT

difference was noted in the correct responses to Q8 which indicated the seniors were less comfortable with their inability to follow another person's train of thought.

The data analyses to determine the impact of duration of stay in college on the engineering identity of the participants of the study are discussed next. The responses of the freshmen to the EI survey are shown in Fig. 4. The analysis of freshmen responses identified opportunities. While the average percentage of "strongly agree" and "agree" responses for the Interest dimension as the highest of the three dimensions, and the lowest percentage was for the Recognition dimension. The highest percentage of SA & D responses was for Q1 (81%) which was about respondents being recognized as engineers by their parents. The lowest percentage of SA & D responses was for Q2 (58%) which pertained to the respondents' perception of their instructors recognizing them as engineers.

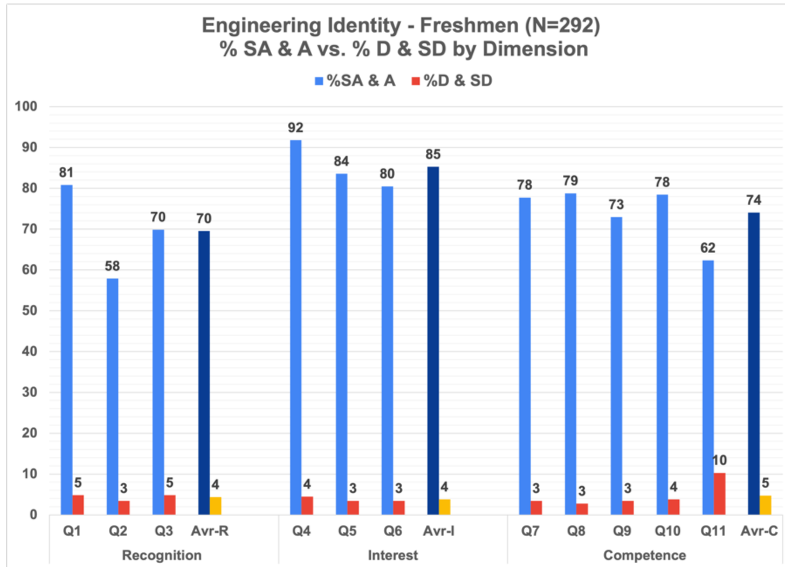

Figure 4. Responses of Freshmen to Engineering Identity Survey

The responses of the graduating seniors are shown in Fig. 5. It was observed that the students' perception of their instructors' recognition had significantly improved. There was an increase in the students' strong agreement and agreement with the items in all three dimensions to 90% or higher.

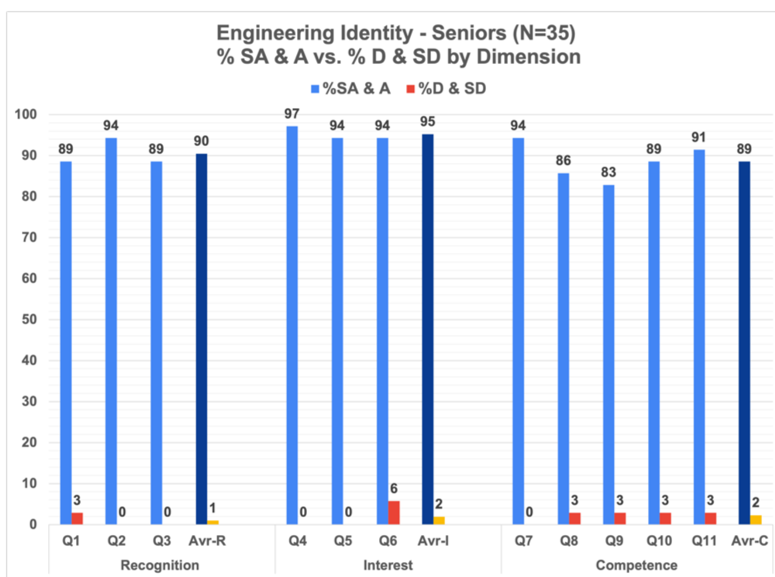

Figure 5. Responses of Freshmen to Engineering Identity Survey

A comparison of freshmen and graduating seniors' responses to the EI survey is shown in Fig 6. The impact of duration of stay can be clearly observed. The graduating seniors had significantly improved their perception of being recognized as engineers by the instructors as well as peers. The seniors recorded a higher interest in engineering and reported increased perception of their technical competence as engineers.

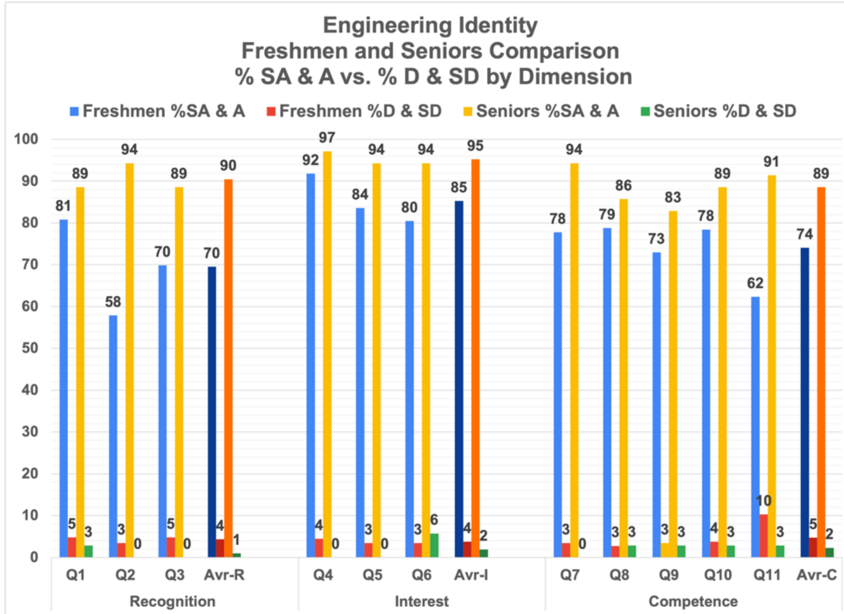

Figure 6. Comparison of responses of Freshmen and Graduating Seniors to Engineering Identity Survey

Conclusions and Future Work

The analysis of the RRAT survey indicated that on the average there was not much difference in the correct responses between freshmen and graduating seniors. The less than 50% average of the correct answers to the RRAT survey signifies an opportunity to design curricular materials and the learning environment to enhance the students' tolerance of ambiguity. Thus, several hands-on activities are being designed which have incomplete information to simulate real-life problem spaces. These interventions are being implemented in the introductory aerospace engineering course in the Spring and Fall 2023 semesters. Data will be collected using the RRAT survey to determine the impact of these interventions on participants tolerance of ambiguity as measured by the instrument. The EI survey identified that freshmen students felt that their instructor did not recognize them as engineers. This observation provides as opportunity to instructors to proactively improve students' perception of professional recognition by faculty.

Acknowledgement

The research is supported by the NSF Grant # 1832041

References

[1] https://www.criticalthinking.org/pages/defining-critical-thinking/766

[2] Barak Miri & Ben-Chaim David & Zoller Uri (2007). Purposely Teaching for the Promotion of Higher-order Thinking Skills: A Case of Critical Thinking Res Sci Educ (2007) 37:353–369 DOI 10.1007/s11165-006-9029-2

[3] Oermann, M. H. (1999). Critical thinking, critical practice. Nursing Management, 30(4), 40C-40F, 40H-40I. Retrieved from https://www.proquest.com/scholarly-journals/critical-thinking-practice/docview/231387045/se-2

[4] S. Schrader, W. M. Riggs, & R. P. Smith (1993). Choice over Uncertainty and Ambiguity in Technical Problem Solving, Journal of Engineering and Technology Management, 10, 1993, https://dspace.mit.edu/bitstream/handle/1721.1/46980/choiceoveruncert00schr.pdf?s

[5] Furnham, A. & Ribchester, A. (1995). Tolerance of Ambiguity: A Review of the Concept, Its Measurement and Applications. Current Psychology: Developmental ° Learning • Personality ° Social, Fall, 1995, Vol. 14, No. 3, 179-199

[6] Furnham, A., & Marks, J. (2013). Tolerance of ambiguity: A review of the recent literature. *Psychology*, *4*(09), 717-728.

[7] Albertini, E (2022). https://www.linkedin.com/pulse/tolerance-ambiguity-critical-future-fit-skill-evolved-eric, published July 2022

[8] Schere, J. L., (1982). Tolerance of Ambiguity as a Discriminating Variable Between Entrepreneurs and Managers. Academy of Management Proceedings. Vol. 1982, No. 1

[9] Tatzel , M. (1980). Tolerance for ambiguity ln adult college students. Psychological Reports, 1980,47, 377-378

[10] Yu, M., Wang, H. & Xia, G. (2021). The Review on the Role of Ambiguity of Tolerance and Resilience on Students' Engagement. Front. Psychol., 13 January 2022
Sec. Educational Psychology, Volume 12 - 2021, https://doi.org/10.3389/fpsyg.2021.828894

[11] DeRoma, V. M, Martin, K. M., Kessler, M., L. (2003). The Relationship Between Tolerance for Ambiguity and Need for Course Structure. Journal of Instructional Psychology; Milwaukee, Wis. Vol. 30, Iss. 2, (Jun 1, 2003): 104

[12] Mohammed S., Okudan G., & Ogot, M. (2006). Tolerance For Ambiguity: An Investigation On Its Effect On Student Design Performance. June 2006, ASEE Annual Conference: Chicago, Illinois
DOI: 10.18260/1-2--909

[13] Stryker S. & Burke P. J. (2000). The past, present, and future of an identity theory. Soc Psychol Q. 2000:284-297

[14] Godwin, J. (2003). Students' perspectives on debate exercises in content area classes. Communication Education. 52(2). 157-163

[15] Ross, M. S., Godwin, A. (2016), Engineering Identity Implications on the Retention of Black Women in the Engineering Industry Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.26652

[16] Pierrakos, O., Beam, T. K., Constantz, J., Johri, A., & Anderson, R. (2009). On the development of a professional identity: Engineering persistors vs. engineering switchers. Proceedings of the Frontiers in Education Conference. https://doi.org/10.1109/FIE.2009.5350571

[17] Verdín, D., Godwin, A., Kirn, A., Benson, L., and Potvin, G., (2018), Understanding How Engineering Identity and Belongingness Predict Grit for First-Generation College Students. School of Engineering Education Graduate Student Series. Paper 75. https://docs.lib.purdue.edu/enegs/75

[18] Akkerman S.F., Meijer P.C., (2011). A dialogical approach to conceptualizing teacher identity. Teach Teach Educ 2011; 27(2): 308-19

[19] Tonso, K. L., (2006). Student engineers and engineer identity: Campus engineer identities as figured world. Cultural Studies of Science Education, 1(2), 273–307. https://doi.org/10.1007/s11422-005-9009-2

[20] Capobianco, B. M., Diefes-Dux, H. A., Mena, I., & Weller, J. (2011). What is an engineer? Implications of elementary school student conceptions for engineering education. Journal of Engineering Education, 100(2), 304–328. https://doi.org/10.1002/j.2168-9830.2011.tb00015.x

[21] Macdonald, A. P. (1970). Revised scale for ambiguity tolerance: Reliability and validity. Psychological Reports, 1970, 26, 791-798

[22] Godwin A. (2016). The development of a measure of engineering identity. ASEE 123rd Annual Conference and Exposition, New Orleans, LA, Jun 26-29, 2016

Appendix A

RRAT Scale (McDonald, 1970) with ‘correct’ responses

1. A problem has little attraction for me if I don't think it has a solution (FALSE)
2. I am just a little uncomfortable with people unless I feel that I can understand their behavior. (FALSE)
3. There is a right way and a wrong way to do almost everything. (FALSE)
4. I would rather bet 1 to 6 on a long shot than 3 to 1 on a probable winner. (TRUE)
5. The way to understand complex problems is to be concerned with their larger aspects instead of breaking them into smaller pieces. (TRUE)
6. I get pretty anxious when I am in a social situation over which I have no control. (FALSE)
7. Practically every problem has a solution. (FALSE)
8. It bothers me when I am unable to follow another person's train of thought. (FALSE)
9. I have always felt that there is a clear difference between right and wrong. (FALSE)
10. It bothers me when I don't know how other people react to me. (FALSE)
11. Nothing gets accomplished in this world unless you stick to some basic rules. (FALSE)
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. (TRUE)
13. Vague and impressionistic pictures really have little appeal for me. (FALSE)
14. If I were a scientist, it would bother me that my work would never be completed (because science will always make new discoveries). (FALSE)
15. Before an examination, I feel much less anxious if I know how many questions there will be. (FALSE)
16. The best part of working a jigsaw puzzle is putting the last piece. (FALSE)
17. Sometimes I rather enjoy going against the rules and doing things I am not supposed to do. (TRUE)
18. I don't like to work on the problem unless there is a possibility of coming out with a clear cut and unambiguous answer. (FALSE)
19. I like to fool around with new ideas, even they turn out later to be a total waste of time. (TRUE)
20. Perfect balance is the essence of all good composition. (FALSE)

Appendix B

Engineering Identity (Goodwin 2016)

Recognition	1	My parents see me as an engineer
	2	My instructors see me as an engineer.
	3	My peers see me as an engineer.
Interest	4	I am interested in learning more about engineering.
	5	I enjoy learning engineering.
	6	I find fulfillment in doing engineering.
Competence	7	I am confident that I can understand engineering in class.
	8	I am confident that I can understand engineering outside of class.
	9	I can do well on exams in engineering.
	10	I understand concepts I am studying in engineering.
	11	Others ask me for help in engineering/math subjects