Exploring Computing Identity and Persistence Across Multiple Groups Using Structural Equation Modeling

Abstract
Despite the projected growth of computer and information technology occupations, many computing students fail to graduate. Studying students' self-beliefs is one way to understand persistence in a school setting. This paper explores how students' disciplinary identity sub-constructs including competence/performance, recognition, interest, and sense of belonging contribute to academic persistence. A survey of 1,640 students as part of an NSF grant was conducted at three South Florida metropolitan public universities. A quantitative analysis was performed which included a structural equation model (SEM) and a multigroup SEM. The study examined different groups of students such as male versus female, and freshman versus senior students. Results suggest identity sub-constructs contribute differently to academic persistence among freshman and senior students; however, no significant differences were found between male and female students. The findings, such as the significance of particular aspects of computing identity on academic persistence, can have implications for educators and college administration.

1- Introduction

Computer science and modern technologies empower individuals and undoubtedly have a monumental impact on many areas of society. According to national statistical projections, computing employment is estimated to increase in the future [1], and will continue to be one of the most lucrative fields. University education in computer science, computer engineering, and information technology is providing students with abundant future job opportunities. Although the lack of a formal computing degree cannot stop young people from securing a lucrative job in technology, an academic computing degree can be a big advantage for a candidate. Industry statistics suggest companies and startups are more likely to recruit someone skilled with a bachelor's degree [1], [2]. In spite of the increasing demand for computing jobs, computer science dropouts are still the highest among STEM disciplines [3]. In addition, despite the emphasis on diversity [3] in technology, the gender gap in computing education and jobs has worsened over the past 30 years [1], [2], [4].

Prior studies showed that there are many factors involved in students' academic retention and persistence such as family background, vision for a career, demographic characteristics, institutional type, curriculum [5], [6] , classroom related factors, grade performance [7], friendship support, academic engagement, attitudes, and satisfaction, as well as many more [8], [9]. Early studies [10] examined the effect of students' characteristics and their interactions on their persistence. Other researchers [5] studied other factors like career goals and commitments. These studies are framed using many theoretical frameworks. One such framework is social cognitive career theory (SCCT) [9], [11]. SCCT was developed to explain how some educational and career choices are made. SCCT shows the impact of interest and self-efficacy, learning experiences, personal inputs and environmental influences on choice actions, persistence and satisfaction.
Likewise, disciplinary identity theory [12], [13] describes how students' perceived feelings of their competence/performance, recognition, interest, and sense of belonging form their identities.

In this framework (Figure 1), identity has been defined using four sub-constructs including competence/performance, recognition, interest, and sense of belonging [14]. Student interest is defined by their engagement with respect to a topic. Competence/performance refers to a student's self-confidence in understanding a particular topic and feeling accomplished (or able to become accomplished) in that topic. Recognition is defined by measuring the internalized feelings of recognition of a student when he/she communicates with his/her teacher, family members, or friends. Sense of belonging relates to a student's feelings of belonging to a community or group related to the topic and discipline. In the past, researchers studied identity theory and its impact on various disciplines including mathematics, physics, and general science students [15], [16]. They also examined the effect of identity sub-constructs on choice of careers [13], [17]. In general, computing identity is not defined as just being good at a computing-related test or homework; it is defined by a student's interest and the other previously mentioned self-beliefs in computing.
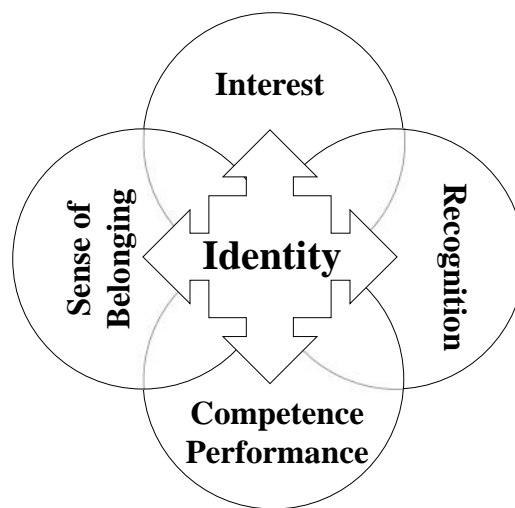

Figure 1: Disciplinary identity sub-constructs including competence/performance, recognition, interest, and sense of belonging

Due to the lack of rigorous research on the identity sub-constructs in computing education, in this paper, we concentrated on students' identity self-beliefs and their impacts on persistence. For this purpose, we designed a survey, and a quantitative research study as part of the Florida IT Pathways to Success (Flit-Path) NSF grant. The Flit-Path grant supports student scholarships, curricular/co-curricular activities, and research studies on evidence-based practices on persistence, success, and graduation in IT-related and computing disciplines. A survey was designed and conducted, and a multi-group SEM was performed to further investigate diverse demographics and contexts such as gender and level of school education.

2- Theoretical framework
This study is guided by two theoretical frameworks. Disciplinary Identity theory was the main driving theory, and social cognitive career theory was used to understand some of the results. Identity has been a topic of particular interest in psychology, philosophy, and social science since the 1900s [18], [19]. Identity has been defined in many different ways but it is usually closely tied with a simple, yet complicated question: "who are you?" [20], [21]. A person may identify

in a variety of ways and hold several different roles in his/her daily life such as female, student, sister, and wife. In 2000 [22], identity was framed as an analytic lens for research in education and was defined by Gee as "being recognized as a certain kind of person in a given context" (p.99). Gee described the characteristics of identity based on social and cultural views.

In 2007, Carlone and Johnson [12] conducted a qualitative research study and developed a framework for STEM and science education. This model included performance, competence, recognition of self, and recognition by others. They provided evidence that identities are formed and developed in practice and that identity is not solely constructed by an individual. They did not have interest as a sub-construct since they studied scientists who already were successful and interested in science. When we consider students in a classroom, their interest level may vary and play a vital role in their identities.

In 2010, researchers [13] developed a theoretical framework that measured identity across physics and mathematics students. They followed up with several case studies trying to understand how identity development occurs, how students conceptualize identity and how to quantify thinking around identity [23]–[25]. They defined disciplinary identity as how a student identifies himself/herself with respect to a specific discipline, for example, when a student mentions he/she sees himself/herself as a "computer person." Also, they theorized that the competence/performance sub-construct was a more appropriate sub-construct for identity compared to self-efficacy since it covers a broader range of students' beliefs in accomplishing things, and is not limited to a specific task [13], [17].

What prior scholars developed as a model allowed other researchers to predict students' choices. Choices can include taking a class in the next semester, decisions to persist, and even future career intentions. Other researchers [15]–[17], [26] conducted additional identity studies to further explore the identity development for different genders. They examined gender as a specific identity to investigate the intersection of having a physics identity and an identity as a female. They also found that students' math and physics identities are significant factors and predictors of their engineering identity.

The research questions guiding this work are: 1) how do the identity sub-constructs contribute to the academic persistence of computer science students who are male versus female? 2) how do the identity sub-constructs contribute to the academic persistence of computer science freshman versus upper-level undergraduate students? To address the research questions, we conducted a survey and performed a mutigroup SEM.

3- Methodology
In order to answer the research questions, a quantitative research method was utilized for this study. After the IRB approval, a survey was administered to students in information technology (IT), computer science (CS), and computer engineering (CE) at three South Florida metropolitan public universities (Florida International University (FIU), University of Central Florida (UCF), and University of South Florida (USF)). The survey consisted of 22 questions that included demographics, students' intention to pursue a CS career, students' intentions to persist to a bachelor's degree in computing, as well as items measuring constructs related to their identities.

For the purpose of this study, persistence refers to the willingness and the continuation of an effort to graduate with career intentions in computing-related areas.

The constructs included computing competence/performance beliefs (two items), computing recognition (three items), computing interest (two items), and sense of belonging (two items) (factor loadings >0.5) (Table1) [27]. These items were drawn from previously validated and reliable instruments in engineering and science. However, the reliability and validity of the constructs were further tested including establishing face, content, and construct validity. Face and content validity were established through pilot testing with 95 students and focus groups. Construct validity was established through factor analysis. Internal consistency (reliability) was assessed using Cronbach's alpha with all constructs having a reliability greater than 0.7 [23], [25], [27]. Survey questions consisted of Likert scale, multiple choice, and categorical questions.

In total, 1640 survey responses were collected in Fall 2017 including 78% male and 22% female respondents. In terms of year in college, 37% were 4th year or more, 27% were 3rd year, 13% were 2nd year, and 23% were 1st year. For students' race and ethnic identities, there were 31 students who identified as American Indian/Alaska Native, 254 Asian students, 198 Black/African American students, 505 Hispanic students, 40 Middle Eastern/North African students, 11 Native Hawaiian/Other Pacific Islander students, 857 White students, and 41 other race/ethnicity students.

To examine the contribution of the identity sub-constructs on computing persistence we utilized a structural equation model analysis. In SEM both latent and observed variables can be evaluated simultaneously [28]. The final SEM model was based on a theoretical understanding of identity and persistence. In addition, our experiences of working in a computing academic setting and working with computing students for several years added more perspective and insight into our analysis. For running the SEM, we first performed a confirmatory factor analysis (CFA) to assure the measurements for this model were valid. All factor loadings were within the acceptable range (>0.5) [27], [29]. After factor analysis, the relationships among latent variables including competence/performance, recognition, interest, sense of belonging, and computing persistence were evaluated. The model fit was measured and validated accordingly. We handled the missing data using the maximum likelihood approach [27] which utilizes all the information into the analysis and provides an unbiased parameter estimation [27]. The whole analysis was performed in R using the SEM and Lavaan package [29], [30].

After we completed the basic SEM analysis, we compared the model for different groups including male and female students, and freshman and senior students (multigroup SEM). For this purpose, we performed the model invariance test to identify significant differences between groups. For the invariance measurement testing, all of the factor loadings and regression coefficients in our measurement/structural model were constrained to be equal. Then, we unconstrained one path at a time to determine which paths are significantly different. First, we focused on gender dynamics across all paths including measurement and structural coefficients. A Chi-square difference test was established to see if the difference was significant ($p < 0.05$) [27], [30]. After comparing the model between males and females, we analyzed senior students versus freshman students with the same approach to investigate the differences.

4- Results

Our results include a CFA, an SEM analysis and multigroup SEM across groups. We first describe the CFA results, and then we focus on the SEM and mutigroup SEM. The CFA results (Table 1) show that our measurement model fit the data. It indicates that the theorized sub-constructs are well-measured and our measurement model shows that the selected measurement variables represent the latent variables. The RMSEA or the "root mean square error of approximation" value was 0.056. The GFI or "Goodness of fit index" value was 0.976. The AGFI or "adjusted goodness of fit index" value was 0.955. SRMR or "standardized root mean square residual" value was 0.026. The NNFI or "non-normed fit index" value was 0.978. All the relevant fit indices were within the acceptable ranges which indicates that the measurement model (i.e. survey items indicating latent identity sub-constructs) was well fit. While the Chi-square was significant (214.733, df = 35), this is not an issue since a significant Chi-square for a large sample size does not indicate a weak fit [27].

Table 1: List of variables in this study, and Confirmatory Factor Analysis (CFA) results. Acceptable values: Item reliability > 0.50, Construct reliability > 0.70, Average variance extracted > 0.50

Latent variable	Indicator variable	Standardized factor loading	Standard error	Item reliability (R^2)	Construct reliability	Average variance extracted
Interest	**q9j**: Topics in computing excite my curiosity	0.877	0.020	0.769	0.927	0.808
	q9l: I enjoy learning about computing	0.948	0.017	0.899		
	q9m: I like to know what is going on in computing	0.87	0.019	0.757		
Performance/ Competence	**q9h**: I can do well on computing tasks	0.864	0.025	0.746	0.875	0.778
	q9i: I understand concepts underlying computer processes	0.9	0.024	0.810		
Recognition	**q9a**: I see myself as an exemplary student in computing fields	0.843	0.021	0.711	0.885	0.719
	q9c: Other students see me as an exemplary student in computing	0.852	0.021	0.726		
	q9d: My teachers see me as an exemplary student in computing fields	0.849	0.021	0.721		
Sense of Belonging	**q10a**: I feel like you are part of the community	0.885	0.026	0.783	0.869	0.768
	q10b: I feel valued and respected	0.868	0.025	0.753		

Furthermore, the CFA results confirm that individual and overall reliability of our underlying constructs are within the acceptable ranges [27], [31]. The squared multiple correlation represents the reliability of an individual measure. The average variance extracted (AVE) values were within acceptable ranges [27], [31]. In addition, this measure is used for the convergent and discriminant validity. Convergent validity and discriminant validity are subtypes of the construct validity. Convergent validity along with factor loading is used to show that two items measuring a construct are related. Discriminant validity is used to show that there is no relation between two items which are not from the same construct.

4.1- Multigroup SEM results across genders

As we described, 1) we performed the CFA, and we built the SEM model based on the prior literature, our experience and understanding of the computing students' self-beliefs on persistence. 2) Then, we validated the model with the fit indices. 3) Next, to answer the research questions, we established the multigroup SEM (Figure 2, 3) to validate the model for different groups. 4) Finally, we performed an invariance measurement test to examine the statistically significant difference between groups.
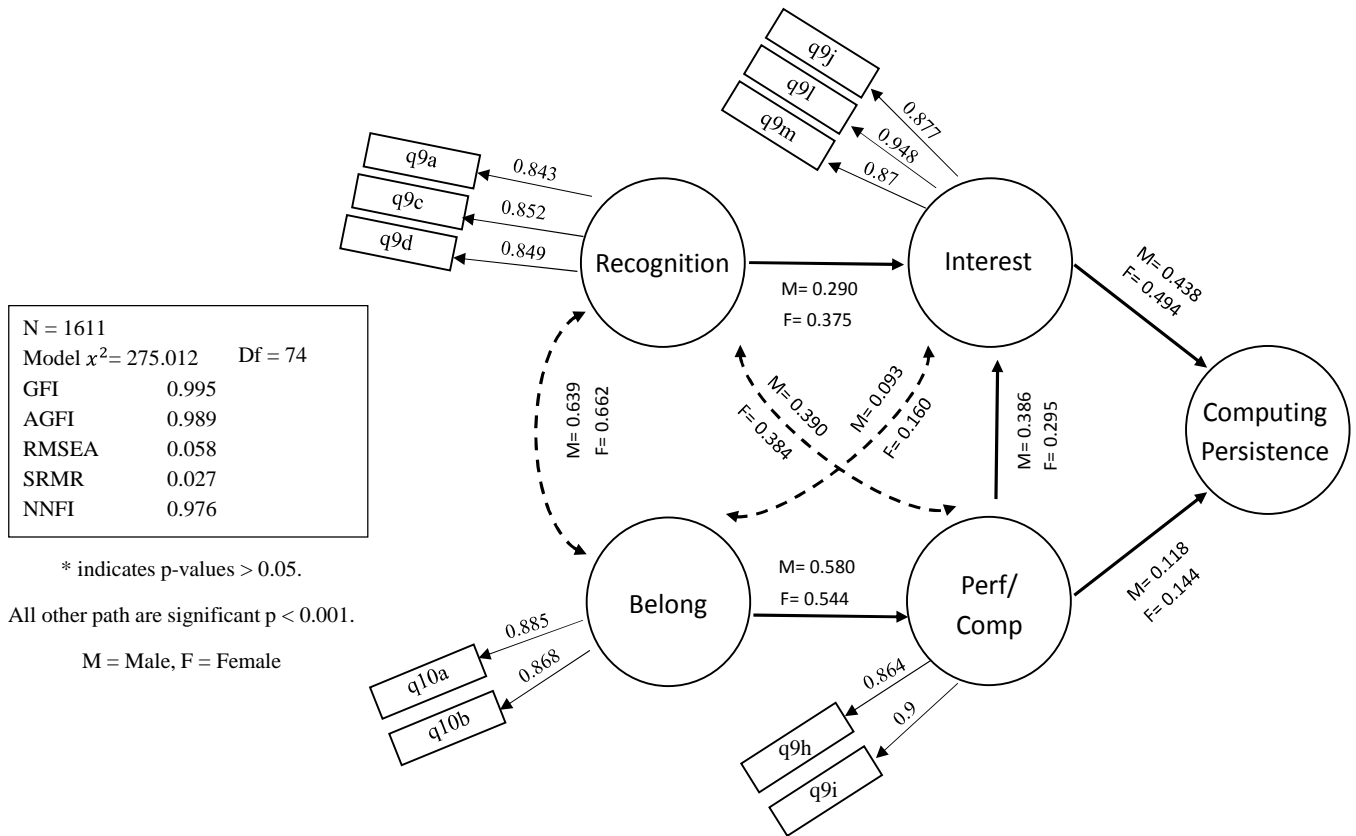

Figure 2. Multigroup Structural equation modeling results among male and female students. GFI: goodness of fit; AGFI: adjusted goodness of fit; RMSEA: root mean square error of approximation; SRMR: standardized root mean square residual; NNFI: non-normed fit. (Acceptable values: GFI (p>0.90), AGFI (p>0.90), RMSEA (p<0.08), NNFI (p>0.90), SRMR (p<0.08)). No significant difference was found between male and female students.

The measurement invariance test was based on the modification indices. We built the model by allowing all the factors and regression coefficients to be constrained equally. We released each path one at a time, and examined the Chi-squared distribution. Due to a non-significant difference across genders, we concluded that the equally constrained model is similar to the unconstrained model. Therefore, there was not a significant difference between males and females on the path coefficients. In general, interest and competence/performance beliefs each had a substantial direct effect on persistence. This indicates that maintaining interest is likely the most crucial factor in computing persistence (factor loading of male=0.438 and female=0.494). Competence/performance had a substantial impact on persistence both directly and indirectly through interest (factor loading of male=0.386 and female=0.295). The structural model also indicated the importance of recognition on persistence indirectly through interest (factor loading of male=0.290 and female=0.375). This means recognition predicted interest and impacted persistence through interest. Finally, the model also showed the importance of a sense of belonging on persistence which is mediated by indirect paths through competence/performance (factor loading of male=0.580 and female=0.544). This shows that feeling a sense of belonging may increase one's competency beliefs.
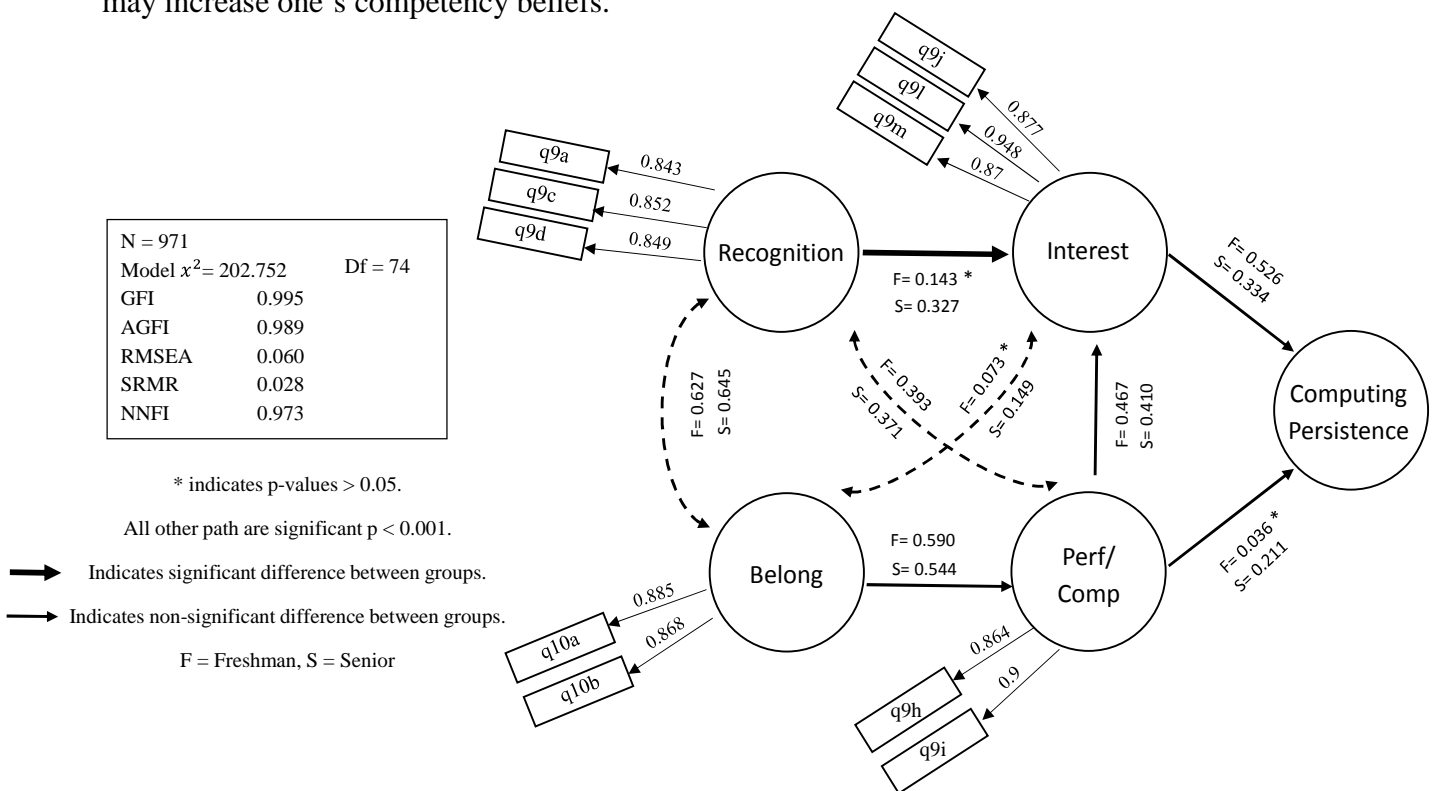

Figure 3. Multigroup Structural equation modeling results among freshman and senior students. GFI: goodness of fit; AGFI: adjusted goodness of fit; RMSEA: root mean square error of approximation; SRMR: standardized root mean square residual; NNFI: non-normed fit. (Acceptable values: GFI (p>0.90), AGFI (p>0.90), RMSEA (p<0.08), NNFI (p>0.90), SRMR (p<0.08)).

4.2- Multigroup SEM results across level of education (freshman/senior)
For senior students versus first-year students, we performed the same analysis. We discovered some interesting paths and then conducted the measurement invariance test to determine whether the paths were significantly different between groups. Due to the significant difference of the constrained and the unconstrained model, we concluded that the model was not equivalent for both groups, and there is a significant difference (Figure 3). The difference between freshmen and seniors was for the path between recognition and interest (F = 0.143, S = 0.327). There was not a significant difference for the other paths between freshman and senior.

The influence of interest on persistence was strong for both groups (p<0.001) (F = 0.526, S = 0.334). The other interesting paths were the path between a sense of belonging and competence/performance (p<0.001) (F = 0.590, S = 0.572), and the path between competence/performance and interest (p<0.001) (F = 0.467, S = 0.410). Although all sub-contracts directly or indirectly predict persistence, for both freshman and senior students, interest was the most critical contributor to their persistence.

5- Discussion
Our SEM analysis showed that interest had the most direct impact on computing students' persistence for all categories including male, female, freshman and senior students (p<0.001). After interest, competence/performance had the most direct effect on persistence (p<0.001). The impact of interest and competence/performance on persistence and the relation between interest and competence/performance have been shown in prior studies [11], [13], [23]. Our results confirm the findings of prior research studies. Recognition also had an impact on persistence through interest. As an example, if a student is recognized and conceptualizes a feeling of recognition, he/she is more likely to develop or maintain an interest in computing and persist throughout their degree program.

Sense of belonging had a significant impact on competence/performance. This path is exciting as it is the strongest path in this model. In 2012, a study [32] indicated a lack of belonging had been identified as an essential reason for engineering dropouts. Tinto also mentioned that sense of belonging was one of the impactful factors on academic persistence [6], [7]. As an instance, when a student joins to a computing group/community, he/she may start communicating with peers and friends, and realize that his/her own skills and struggles are comparable to others, thus, lending to his/her own competency beliefs. Besides, by participating in computing communities and clubs, not only can students learn new computing tools and methods, but he/she also develops a feeling of support which consequently may increase his/her competency beliefs.

The male/female multigroup SEM analysis showed that the model was equivalent for both males and females and there was no significant difference. Thus, we addressed the first research question which was the identity sub-constructs contribution to the academic persistence among male and female students. These results indicated that women in computer science at the target universities may have developed their interest, competence/ performance and consequently identity, similar to the men in their respective programs. The STEM/computing programs in these schools may have had a substantial impact on developing students identities.

The freshman/senior multigroup SEM analysis in addressing the second research question showed that there was a significant difference between these two groups. The measurement invariance test showed a significant difference for the path between recognition and interest. The other structural paths were not statistically different. The relationship between recognition and interest indicates that providing sources of recognition is an effective way to increase interest and persistence. Students' interest is a good predictor of persistence for both groups. This outcome also explains the importance of extra activities, and engaging courses in their degree programs [33], [34].

In general, the analysis showed that although male and female students have developed the same beliefs, students in different levels of their college education may have different predictors. For university staff and professors in computing who are involved in teaching and organizing events or managing programs, understanding the importance of developing self-beliefs is valuable. They can help students as soon as a student starts his/her degree program. This may increase students' persistence toward graduation in university and eventually, toward a successful career in computing.

In our model, considering some specific relationships are vital; for example, interest, sense of belonging, and recognition can be considered priorities. Instructors can engage students and help them by recognizing them as a programmer, computer engineer, computer scientist, software engineer and so on [35], [36]. They can use any opportunity to recognize students by celebrating a student who has worked hard in gaining more knowledge and experience. This can be verbal, or by writing a note or email, or even by awarding a certificate of achievement [37], [38]. It is essential that students internalize the recognition that ultimately reinforces and shapes their own identity [39]. Educators also can increase interest as the intrinsic motivation for learning in class or at school by making topics relevant to real-life problems and future careers [40]. They can make the classroom a space of engagement with gamification [41]–[43], competitions, teamwork, and having fun in a way that encourages meaningful learning and students' participation [44]. One practical approach may be to realize what students are already interested in and then connecting the teaching material to topics that already build upon existing interests [45], [46].

Furthermore, administrators and staff can positively help students by organizing computing events and clubs like the Association for Computing Machinery (ACM), Upsilon Pi Epsilon (UPE) to promote the sense of belonging at school. Communities which often organize hackathons, coding bootcamps, and programming/engineering competitions are useful in increasing the sense of belonging and persistence in computing programs. Sense of belonging not only has an impact on identity and persistence, but it also helps students feel happier, and it encourages them to have a positive relationship with both friends and teachers [47], [48]. Instructors and professors can also play an important role in improving the sense of belonging in the classroom by being respectful, creating a supportive learning environment, creating mutual respect among classmates, and fair treatment [49]–[51].

What a student experiences in an academic setting clearly impacts his or her behavior and choices, in particular, if those choices enable students to build a feeling of identity or belonging to the community. We confirmed that developing computing identity has a positive impact on

persistence; but understanding the persistence factors in computing across time have not been well studied. A future longitudinal research study may help us to discover new insights. Our future work seeks to perform a time-series SEM analysis to evaluate how the identity sub-constructs and persistence interact over a prolonged period of time. In addition, there are many factors that affect a student's persistence such as prior academic performance, family support, and education level of parents which are not included in this study since this research is focused on the identity sub-constructs' contributions to persistence. In our future work, we will include other factors in our analysis.

6- Conclusion
While approximately sixty percent of all available STEM jobs are in computing, the total numbers of computing graduates are among the lowest. Many students drop out or switch to other majors due to a lack of interest or other self-belief factors. The issue is more critical for gender diversity and for students in different levels of education. Students computing identity or the way students see themselves with regards to computing is directly related to their choice of actions. Studying students' self-beliefs is one way to better understand what leads students to persist. This paper presents a multigroup structural equation model to examine the contribution of identity sub-constructs that include competence/performance, recognition, interest and sense of belonging to the persistence across groups.

In answering the first research question, we reviewed and analyzed the interesting paths between females and males. There was not a significant difference across male and female students. To address the second research question, we found that there are differences between senior students and first-year students, and the differences are significant. In other words, the results of multigroup SEM analysis showed that the identity sub-constructs are equally predictive of persistence for men and women, while not equally predictive for freshmen and seniors.

Finally, our results showed that all the sub-constructs to some extent have a significant impact on increasing persistence. Interest in this model is the vital component for increasing computing persistence. Fostering the activities that contribute positively to self-beliefs of competence/performance, recognition and a sense of belonging directly/indirectly have an impact on both interest and persistence. We also had two full mediation paths including the sense of belonging through competence/performance and recognition through interest. These correlations indicate that if students do not feel competent or interested at first, feeling recognized or like they belong could be a first step to their becoming interested and feeling capable. Measuring the quantitative impact of the identity sub-constructs on persistence among genders and college levels in computing may have some implications in better understanding a students' identity. This may increase the likelihood of their persistence in their degree program. Finally, the analysis across groups helps to explore the diversity gap in tech and computing education.

References

[1] A. Hogan and B. Roberts, "Occupational employment projections to 2024," *Mon. Labor Rev.*, 2017.

[2] "Bureau of Labor Statistics, U.S. Department of Labor, Occupational Outlook Handbook, Computer Programmers, on the Internet at https://www.bls.gov/ooh/computer-and-information-technology/computer-programmers.htm (visited January 29, 2019)." .

[3] X. Chen, *Stem Attrition: College Students & apos Paths into and Out of StemFields. Statistical Analysis Report. Nces 2014-001.* 2013.

[4] T. D. Snyder, C. de Brey, and S. A. Dillow, "Digest of Education Statistics 2016," *Natl. Cent. Educ. Stat.*, Apr. 2017.

[5] V. Tinto, "Dropout from Higher Education: A Theoretical Synthesis of Recent Research," *Rev. Educ. Res.*, vol. 45, no. 1, pp. 89–125, Mar. 1975.

[6] V. Tinto, *Leaving college: Rethinking the causes and cures of student attrition.* 1987.

[7] V. Tinto, "To cite this article: Vincent Tinto (1997) Classrooms as Communities," *J. Higher Educ.*, vol. 68, no. 6, pp. 599–623, 2016.

[8] R. W. Lent, S. D. Brown, and K. C. Larkin, "Relation of self-efficacy expectations to academic achievement and persistence.," *J. Couns. Psychol.*, vol. 31, no. 3, pp. 356–362, 1984.

[9] R. W. Lent, S. D. Brown, and G. Hackett, "Toward a Unifying Social Cognitive Theory of Career and Academic Interest, Choice, and Performance," *J. Vocat. Behav.*, vol. 45, no. 1, pp. 79–122, Aug. 1994.

[10] K. . Feldman, "What matters in college: Four critical years revisited," *Four Crit. years revisited. J. High. Educ.*

[11] G. H. RW. Lent, SD. Brown, "Social cognitive career theory," in *Career choice and development 4*, 2002, pp. 255–311.

[12] H. B. Carlone and A. Johnson, "Understanding the science experiences of successful women of color: Science identity as an analytic lens," *J. Res. Sci. Teach.*, vol. 44, no. 8, pp. 1187–1218, Oct. 2007.

[13] Z. Hazari, G. Sonnert, P. M. Sadler, and M.-C. Shanahan, "Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study," *J. Res. Sci. Teach.*, vol. 47, no. 8, Oct. 2010.

[14] M. Taheri *et al.*, "A Structural Equation Model Analysis of Computing Identity Sub-Constructs and Student Academic Persistence," in *2018 IEEE Frontiers in Education Conference (FIE)*, 2019, pp. 1–7.

[15] Z. Hazari, C. Cass, and C. Beattie, "Obscuring power structures in the physics classroom: Linking teacher positioning, student engagement, and physics identity development," *J. Res. Sci. Teach.*, vol. 52, no. 6, pp. 735–762, Aug. 2015.

[16] J. D. Cribbs, Z. Hazari, G. Sonnert, and P. M. Sadler, "Establishing an Explanatory Model for Mathematics Identity," *Child Dev.*, vol. 86, no. 4, pp. 1048–1062, Jul. 2015.

[17] C. A. P. Cass, Z. Hazari, J. Cribbs, P. M. Sadler, and G. Sonnert, "Examining the impact of mathematics identity on the choice of engineering careers for male and female students," in *2011 Frontiers in Education Conference (FIE)*, 2011, p. F2H–1–F2H–5.

[18] J. E. Stets and P. J. Burke, "Identity Theory and Social Identity Theory," *Soc. Psychol. Q.*, vol. 63, no. 3, p. 224, Sep. 2000.

[19] J. E. Stets and R. T. Serpe, "Identity Theory," Springer, Dordrecht, 2013, pp. 31–60.

[20] R. Jenkins, *Social identity*. Routledge, 2014.

[21] E. H. Erikson, "Autobiographic notes on the identity crisis," *Daedalus*, 1970.

[22] J. P. Gee, "Chapter 3 : Identity as an Analytic Lens for Research in Education," *Rev. Res. Educ.*, vol. 25, no. 1, pp. 99–125, Jan. 2000.

[23] A. Godwin and Allison, "The Development of a Measure of Engineering Identity," in *2016 ASEE Annual Conference & Exposition Proceedings*, 2016.

[24] M. Shanahan, "Identity in science learning: exploring the attention given to agency and structure in studies of identity," *Stud. Sci. Educ.*, vol. 45, no. 1, pp. 43–64, Mar. 2009.

[25] A. Godwin, G. Potvin, Z. Hazari, and R. Lock, "Identity, Critical Agency, and Engineering: An Affective Model for Predicting Engineering as a Career Choice," *J. Eng. Educ.*, vol. 105, no. 2, pp. 312–340, Apr. 2016.

[26] Z. Hazari, E. Brewe, R. M. Goertzen, and T. Hodapp, "The Importance of High School Physics Teachers for Female Students' Physics Identity and Persistence," *Phys. Teach.*, vol. 55, no. 2, pp. 96–99, Feb. 2017.

[27] R. Lomax and R. Schumacker, *A beginner's guide to structural equation modeling*. 2012.

[28] R. B. Kline, *Principles and Practice of Structural Equation Modeling, Fourth Edition*. Guilford publications, 2015.

[29] Y. Rosseel, "lavaan: an R package for structural equation modeling and more Version 0.5-12 (BETA)," 2012.

[30] Y. Rosseel, "The lavaan tutorial," 2018.

[31] W. R. Dillon and M. Goldstein, "Multivariate analysismethods and applications," *Probab. Math. Stat.*, 1984.

[32] R. M. Marra, K. A. Rodgers, D. Shen, and B. Bogue, "Leaving Engineering: A Multi-Year Single Institution Study," *J. Eng. Educ.*, vol. 101, no. 1, pp. 6–27, Jan. 2012.

[33] R. W. Lent *et al.*, "Social Cognitive Predictors of Academic Interests and Goals in Engineering: Utility for Women and Students at Historically Black Universities.," *J. Couns. Psychol.*, vol. 52, no. 1, pp. 84–92, 2005.

[34] U. Schiefele, "Interest, Learning, and Motivation," *Educ. Psychol.*, vol. 26, no. 3–4, pp. 299–323, Jun. 1991.

[35] B. R. Allen, *An analysis of student success predictors for technical college persistence*. 2014.

[36] J. L. White, J. W. Altschuld, and Y.-F. Lee, "Persistence of Interest in Science, Technology, Engineering, and Mathematics: A Minority Retention Study," *J. Women Minor. Sci. Eng.*, vol. 12, no. 1, pp. 47–64, 2006.

[37] S. Hepplestone, G. Holden, B. Irwin, H. J. Parkin, and L. Thorpe, "Using technology to encourage student engagement with feedback: a literature review," *Res. Learn. Technol.*, vol. 19, no. 2, Jul. 2011.

[38] M. Kitchen, "Facilitating small groups: how to encourage student learning," *Clin. Teach.*, vol. 9, no. 1, pp. 3–8, Feb. 2012.

[39] K. R. Wentzel and A. Wigfield, "Academic and Social Motivational Influences on Students' Academic Performance," *Educ. Psychol. Rev.*, vol. 10, no. 2, pp. 155–175, 1998.

[40] R. W. Lent, A. M. Lopez, F. G. Lopez, and H.-B. Sheu, "Social cognitive career theory and the prediction of interests and choice goals in the computing disciplines," *J. Vocat. Behav.*, vol. 73, no. 1, pp. 52–62, Aug. 2008.

[41] A. Amriani, A. F. Aji, A. Y. Utomo, and K. M. Junus, "An empirical study of

gamification impact on e-Learning environment," in *Proceedings of 2013 3rd International Conference on Computer Science and Network Technology*, 2013, pp. 265–269.

[42]   A. Stott and C. Neustaedter, "Analysis of Gamification in Education," Surrey, BC, Canada, 2013.

[43]   T. Amiel and B. Wilson, *Ed-media : world conference on educational media & technology, June 26-29, 2012 Denver, Colorado*, vol. 2012, no. 1. Association for the Advancement of Computing in Education (AACE), 2012.

[44]   R. M. Felder, G. N. Felder, and E. J. Dietz, "A Longitudinal Study of Engineering Student Performance and Retention. V. Comparisons with Traditionally-Taught Students," *J. Eng. Educ.*, vol. 87, no. 4, pp. 469–480, Oct. 1998.

[45]   M. R. Reyes, M. A. Brackett, S. E. Rivers, M. White, and P. Salovey, "Classroom emotional climate, student engagement, and academic achievement.," *J. Educ. Psychol.*, vol. 104, no. 3, pp. 700–712, 2012.

[46]   R. Pekrun and L. Linnenbrink-Garcia, "Academic Emotions and Student Engagement," in *Handbook of Research on Student Engagement*, Boston, MA: Springer US, 2012, pp. 259–282.

[47]   C. Goodenow, "The Sense of Belonging and Its Relationship to Academic Motivation among Pre- and Early Adolescent Students." Apr-1991.

[48]   K. F. Osterman, "Students' Need for Belonging in the School Community," *Rev. Educ. Res.*, vol. 70, no. 3, pp. 323–367, Sep. 2000.

[49]   X. Ma, "Sense of Belonging to School: Can Schools Make a Difference?," *J. Educ. Res.*, vol. 96, no. 6, pp. 340–349, Jul. 2003.

[50]   T. M. Freeman, L. H. Anderman, and J. M. Jensen, "Sense of Belonging in College Freshmen at the Classroom and Campus Levels," *J. Exp. Educ.*, vol. 75, no. 3, pp. 203–220, Apr. 2007.

[51]   M. Meeuwisse, S. E. Severiens, and M. P. Born, "Learning Environment, Interaction, Sense of Belonging and Study Success in Ethnically Diverse Student Groups," *Res. High. Educ.*, vol. 51, no. 6, pp. 528–545, Sep. 2010.