Gender Differences in Computer Science Education: Lessons Learnt from an Empirical Study at NTNU

Ilias O. Pappas, Trond Aalberg, Michail N. Giannakos, Letizia Jaccheri, Patrick Mikalef, Guttorm Sindre
Department of Computer and Information Science (IDI), NTNU

Abstract

Research in Computer Science (CS) education has focused on gender differences and there is high interest in increasing female participation in CS. The present study reviews important factors that influence CS students' decision to complete their studies in CS (retention), and empirically examines how these factors differ for males and females. To this end, we identify cognitive and non-cognitive gains, cognitive and affective engagement, motivation to study, and three different barriers as critical factors in CS students'. We test these factors on 236 Norwegian CS students in order to find any potential gender differences. The findings indicate a gender difference for cognitive gains, affective engagement, motivation to study, and satisfaction with learning effectiveness. On the other hand, no difference was found for non-cognitive gains, cognitive engagement, personal values/teaching quality, and students' intention to dropout from their studies. The study concludes with implications that will guide both research and practice towards a better understanding of both male and female CS students.

Introduction

Computer, Information Science and Technology degrees have seen an enrolment increase in the past decade (Zweben & Bizot, 2015), and research in this area has focused on explaining behaviour for both students and educators at different levels (Giannakos, Doukakis, Pappas, Adamopoulos, & Giannopoulou, 2015; Pappas, Giannakos, & Jaccheri, 2016; Wilson et al., 2012), since the need for Computer Science (CS) professionals is increasing rapidly. The European Commission predicted that by 2020, in Europe, there will be a shortage of more than 800.000 professionals in the field of CS (EuropeanCommission, 2015). Norway faces a similar problem since the need for IT professionals being expected to rise to over 55.000 by 2030 (from 17.000 by 2000) (IKT-kompetanse, 2014). With a projection of the current rhythm of IT graduates, the public and private sector will lack more than 10.000 IT professionals by 2030 (IKT-kompetanse, 2014). Although the number of CS candidates is increasing, CS is the only science, technology, engineering, and math (STEM) field in which a drop has occurred in the number of women working or studying in it (Beyer, 2014). Recent reports suggest that significantly fewer women intend to choose a CS major compared to men (Lehming, Gawalt, Cohen, & Bell, 2013), thus increasing the poor representation of women in the field. Adding to the reduced intention to major in CS, female students have shown higher dropout rates in the past than males in CS (Cohoon, 2006).

Previous work in the field has examined students' behavior and dropout intentions from CS studies, pointing out the need to reduce dropout rates and increase students' retention (Giannakos, Pappas, Jaccheri, & Sampson, 2016; Pappas et al., 2016; Rosson, Carroll, & Sinha, 2011). Furthermore, various factors have been identified as important in explaining students' behavior and dropout, including gains in learning and development (Pike, Kuh, McCormick, Ethington, & Smart, 2011), engagement with studies (Archambault, Janosz, Fallu, & Pagani, 2009), and motivation for studying (Barker, Hovey, & Thompson, 2014). Also, literature has reported on various factors that contribute to increasing dropout rates, including personal values, quality of teaching and satisfaction with learning effectiveness (Biggers, Brauer, & Yilmaz, 2008).

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Studies in the area have also investigated the difference in the behavior of male and female CS students(Krieger, Allen, & Rawn, 2015), as well as the reasons why women are underrepresented in CS, and the findings indicate that it is not a matter of ability, instead further work is needed to identify factors that can help reducing gender differences in CS (Beyer, 2014). Thus, the question remains on why women are underrepresented in computer science. To this end, it is essential to better understand and explain how male and female students perceived differently the aforementioned factors. This study aims *to investigate gender differences between CS students, in order to identify reasons that may increase female representation in CS*. In detail, we test how cognitive and non-cognitive gains, cognitive and affective engagement, interest in school work and CS, barriers, and intention to continue studies in CS, may differ between male and female students.

This study is organized into six sections. The next section presents the background followed by the methodology. Section four describes the data analysis, while section five presents the findings of the study. Finally, the last section discusses the findings along with implications, limitations and suggestions for future research.

Background

CS education provides students with increased knowledge, skills and competences that are required by the industry. Such skills include project management, problem solving, and understanding human behaviour in addition to classic computer science skills such as programming and computational thinking. CS education literature has focused highly on understanding multiple factors that influence students' intention to major in CS, and studies show that there is a quite large difference between the number of male and female professionals in the field. For example in the United States of America, women make up only 26% of Computer Science and Mathematical Science professionals (National Science Foundation, 2012). Although the overall number of women in STEM is increasing, their representation in CS has declined. And although there has been an increase in the number of students taking a CS major, this number is still considerably far from what it was in the past (Zweben & Bizot, 2015).

There are various factors that influence students towards choosing to major in a certain discipline. These can be categorized into three broad groups, that are (1) academic environment and resources, (2) perceptions of the discipline and career and (3) experience (Hein et al., 2012). Related work in CS has identified multiple factors that affect or explain students' behavior in STEM disciplines like motivation for studying and the various learning styles (Marra, Rodgers, Shen, & Bogue, 2012) or the perceived gains from the studies (Li, Swaminathan, & Tang, 2009). Students' perceived gains are very important since they are able to explain academic success and help towards reducing students' dropout (Bjorklund, Parente, & Sathianathan, 2004). Students' cognitive and non-cognitive gains play a critical role when students choose a study program, since they are needed for academic achievement and choice behavior in the demanding STEM subjects (Chow, Eccles, & Salmela-Aro, 2012)

Students' engagement has been emphasized in research about student behavior and dropout intentions (Tinto, 1975), focusing on how much students feel attached to their institution or on what level they develop a sense of belonging there. Engagement is an ongoing process that evolves over time and is related with behavioral as well as motivational elements (Archambault et al., 2009). Engagement is a multidimensional factor (Archambault et al., 2009; Fredricks, Blumenfeld, & Paris, 2004) and in this study we examine its cognitive and affective dimensions. The cognitive dimension refers to students' intellectual investment in learning and the use of self-regulation strategies, such as students' willingness to engage and put effort in learning activities. The affective dimension of engagement refers to feelings, perceptions, and attitudes towards CS studies. Both dimensions are related to students' interest in their studies (Archambault et al., 2009). Motivation to study describes students' reasons for pursuing CS and influences graduates' behavior (Pirker, Riffnaller-Schiefer, & Gütl, 2014). Here, motivation to study refers to students' interest in school work and students' interest in CS.

Regardless of students' gains, engagement, and motivation there are still various barriers that may influence negatively their decisions towards studying CS, (Rosson et al., 2011; Xenos, Pierrakeas, & Pintelas, 2002). Such barriers include negative beliefs towards CS as well as professional, academic, or personal issues. Students' behavior may be influenced when they are part of a group, and depending on how much they feel that they belong to that group, the influence on behavior may be either positive or negative (Barker, McDowell, & Kalahar, 2009). Furthermore, teaching activities may be a reason for students and especially women to dropout from CS studies (Clark Blickenstaff, 2005), such as low quality lectures, the format of the lectures or the format of the study program. Additionally, the effectiveness of the learning activities and their difficulty have an impact on students' satisfaction and behavior, and their role has been examined widely by previous studies identifying various gender differences (Jacobs, 2005). The increased difficulty of a course may reduce the perceived effectiveness of learning activities (Araque, Roldán, & Salguero, 2009), as is the case with CS introductory courses.

In order to improve and increase students' interest towards CS education, different approaches are needed and the gender differences between students should be examined further. Here we focus on perceptions of male and female students in CS education and examines how critical factors identified in the literature differ between them.

Methodology

Sampling

The research methodology includes a survey conducted through the delivery and collection of individual questionnaires. The survey was delivered to 1145 CS students at NTNU, 972 males and 173 females, out of which 236 responded. The respondents were students from the Bachelor in Informatics, the 5-year integrated Master in CS and from two 2-year Master programs. Table 1 presents the demographics of the sample. In detail, it consists of 180 (76.3%) males and 56 (23.7%) females.

Table 1. Demographics

		N			**N**
Gender	Male	180	**Study program**	Bachelor in Informatics	94
	Female	56		5 year Master in CS	105
Age	19	14		2 year Master in CS	14
	20	28		Master in Informatics	22
	21	48		Master in Information Systems	1
	22	30	**Year of studies**	1^{st}	50
	23	39		2^{nd}	60
	24	32		3^{rd}	50
	25	19		4^{th}	35
	26+	26		5^{th}	41

The age of the respondents varies from 19 to 31, with half of the sample (51%) being 22 years old or younger, 30% being 23 or 24 years old, and the rest (19%) between 25 to 31 years old. Regarding their study program, about 40% of the students were enrolled in the Bachelor in Informatics, 45% in the 5-year Master in CS, and the rest (15%) in the three 2-year Master programs. Further, in terms of their year of study the sample is almost equally distributed for the first three years, 21%, 25%, 21% respectively. Also, 15% is in the fourth year, 18% in their fifth year or more.

Measures

The questionnaire has four parts. First, questions on the demographics of the sample (e.g., age, gender) are presented, followed by measures of constructs that the previous literature has identified as important: gains, engagement, and motivation to study. Next, questions are presented with various reasons students may have to leave their studies (barriers). Finally, we included questions about students' future behavioral intentions regarding their studies.

Student gains are either cognitive or non-cognitive. Next, engagement may be cognitive or affective. Motivation to study includes students' interest in school work and their interest in CS. Barriers includes students' personal values, teaching quality, and their satisfaction with learning effectiveness. Table 2 lists the operational definitions of the constructs in this study, as well as the studies from which we adopted the measures.

Table 2. Construct definitions

Construct	Definition	Source
Gains		
Cognitive	General education, writing and speaking effectively and critical thinking	(Toutkoushian & Smart, 2001)
Noncognitive	Working with others, developing ethical standards, and civic/community engagement	
Engagement		
Cognitive	Students' willingness to spend time, effort, and energy to learn CS.	(Archambault et al., 2009)
Affective	Students' perceptions about how much the like, enjoy, and have fun when studying CS.	
Motivation to study		
Interest in school work	Students' interest towards the work done in class.	(Archambault et al., 2009)
Interest in CS	Studying CS out for interest for the subject, or for other reasons such as career perspectives and reputation.	(Xenos et al., 2002)
Barriers		
Personal Values	Students sense of belonging, fulfillment and social norms	(Biggers et al., 2008)
Teaching Quality	The quality of teaching provided to students during their studies	
Satisfaction with Learning Effectiveness	Students' satisfaction with their studies	
Retention	Students' intention to continue studying CS	(Barker et al., 2014)

In all cases items were rated on seven-point Likert scales (1 = Not at all to 7 = Very much), except for the interest in CS. Especially for interest in CS we asked the students what was the reason for studying CS. The reasons we presented were career perspectives, reputation, and interest in the subject. The option “other” was also included. Almost 70% of the students chose interest in the subject as the main reason for studying CS. Thus, we coded this factor based on “interest in CS” with the value 2 and “other” with the value 1. All measures are presented in the appendix.

Data Analysis

In order to identify the gender differences between our students on the aforementioned constructs, independent sample t-tests were performed for each one. Since the sample sizes are not equal here, we used the unequal variance t-test, also referred in the literature as the Welch test, which is not affected by unequal sample sizes (Ruxton, 2006).

To test for reliability the composite reliability was assessed, which requires to be higher than 0.7 for the factor. Also, the item validity was assessed by measuring the loading of every item on the construct. The loadings are suggested to be higher than 0.7 (Hair, Tatham, Anderson, & Black, 2006). Next, establishing construct validity requires that average variance extracted (AVE) is greater than 0.50 and that the correlation between the different variables in the confirmatory models does not exceed 0.8 points, as this suggests low discrimination (Hair et al., 2006). The analysis was performed with the use of the SPSS Version 20.0 software.

Findings

Reliability testing, based on the composite reliability, suggests acceptable indices of internal consistency, as the constructs of retention is above the cut-off threshold of .70. Further, the loading of items into the construct, should be over .7, suggesting validity at the item level. The AVEs for all constructs is above the cut-off threshold of .50. The findings are presented in Table 3.

Table 3. Descriptive statistics, reliability and validity of latent variables

Construct	Mean	S.D.	CR	AVE
Cognitive Gains	4.95	.93	.85	.58
Non-cognitive Gains	3.87	1.13	.83	.62
Cognitive Engagement	5.75	1.02	.93	.76
Affective Engagement	5.67	1.05	.95	.84
Interest in school work	5.17	.97	.84	.73
Interest in CS	1.31	.46	-	-
Personal Values	5.34	1.15	.83	.62
Teaching Quality	2.15	1.07	.84	.64
Satisfaction with Learning Effectiveness	3.47	1.45	.87	.69
Retention	3.04	1.42	.95	.82

Note: S.D.; Standard Deviation, CR; Composite reliability, AVE; Average Variance Extracted

Further, the correlation among the constructs is examined, and as indicated in Table 4, all correlations are significant and lower than .80. The opposite would have suggested low discrimination among the constructs. Also, the study tested for multicollinearity (O’Brien 2007) along with the potential common method bias by utilizing Harman’s single-factor test (Podsakoff et al. 2003). The variance inflation factor for each variable was below 3, indicating that multicollinearity was not an issue. The results also suggest an absence of common method bias in that the first factor did not account for the majority of the variance and no single factor occurred from the factor analysis.

Table 4. Correlations of latent variables

	Construct									
Construct	1	2	3	4	5	6	7	8	9	10
1.Cognitive Gains	**.76**									
2.Noncognitive Gains	.45	**.79**								
3.Cognitive Engagement	.35	.14	**.87**							
4.Affective Engagement	.47	.31	.63	**.91**						
5.Interest in school work	.36	.22	.61	.60	**.86**					
6.Interest in CS	-.01	.01	-.17	-.13	-.21	-				
7.Personal Values	-.22	-.12	-.3	-.49	-.25	.16	**.78**			
8.Teaching Quality	-.27	-.21	-.20	-.44	-.19	.09	.42	**.8**		
9.Satisfaction with Learning Effectiveness	-.21	-.07	-.29	-.41	-.32	.23	.46	.41	**.83**	
10.Retention	.15	.17	.14	.27	.17	-.01	-.2	-.23	-.13	**.90**

Note: Diagonal elements (in bold) are the square roots of the AVE. Off-diagonal elements are the correlations among constructs (correlations of 0.1 or higher are significant, p< 0.01). For discriminant validity, diagonal elements should be larger than off-diagonal elements.

To examine the gender differences we performed independent t-tests and the results are presented in table 5. For five out of the ten examined factors there is a significant difference between male and female CS students. In detail, regarding gains, only cognitive gains are significantly different between males and females. Male students perceive higher cognitive gains from studying CS than female students. On the other hand, female students perceive higher non-cognitive gains, however not significantly higher than males. Further, regarding students' engagement, only affective engagement is perceived significantly differently by males and females. Males show higher perceptions for both cognitive and affective engagement than females, however only for the latter the difference is significant.

Table 5. Testing gender differences for the selected variables

Independent Variables	**Mean (S.D.)**		**F**
	Gender		
	Male	Female	
Gains			
Cognitive	5.04 (0.91)	4.71 (0.98)	**4.73***
Non-Cognitive	3.84 (1.07)	4.00 (1.35)	0.69
Engagement			
Cognitive	5.81 (1.02)	5.59 (1.03)	1.91
Affective	5.77 (1.04)	5.36 (1.06)	**6.46***
Motivation to study			
Interest in school work	5.31 (0.97)	4.74 (0.88)	**16.45****
Interest in CS	1.24 (0.43)	1.54 (0.5)	**15.26****
Barriers			
Personal values	2.09 (1.04)	2.38 (1.16)	2.91
Teaching quality	3.45 (1.46)	3.54 (1.45)	0.18
Satisfaction with learning effectiveness	2.75 (1.34)	3.67 (1.51)	**13.18****
Behavior			
Retention	6.63 (0.88)	6.51 (0.81)	0.87

** $p<0.001$, * $p<0.05$

Next, motivation to study CS differs significantly between male and female students, both for their interest in school work and CS. Male students express a higher interest towards school work, while female students report a higher interest in CS. Regarding the barriers towards completing their studies, only satisfaction with learning effectiveness has a significant difference between male and female students, while for personal values and teaching quality no significant differences were found. Females report a higher level of all barriers towards completing their studies than males, however the difference is significant only for their satisfaction with learning effectiveness.

Discussion and conclusion

Previous work in Computer Science education has focused in investigating various factors in order to identify reasons that students choose to major in CS [e.g., (Barker et al., 2009)] and to explain students' behavior towards finishing or continuing their CS studies [e.g.,(Barker et al., 2014; Biggers et al., 2008)). This work offers insight on how male and female CS students perceive differently important factors, that have been identified as predictors of behavioral intentions. The objective of this study is to empirically examine the gender differences among CS students' gains, engagement, motivation to study, barriers and behavioral intentions.

Observing Figure 1, we can summarize the contribution of our study into the following aspects. We found that CS students pay particular attention to cognitive gains compared to non-cognitive gains; although the latter have been found equally important in the job market [sometimes refereed as soft-skills (Joseph, Ang, Chang, & Slaughter, 2010)]Students engagement (both cognitive and affective) was found to be very high, which is something we expected mainly because of the fact that these students have already selected CS as a career, thus their engagement is quite high.

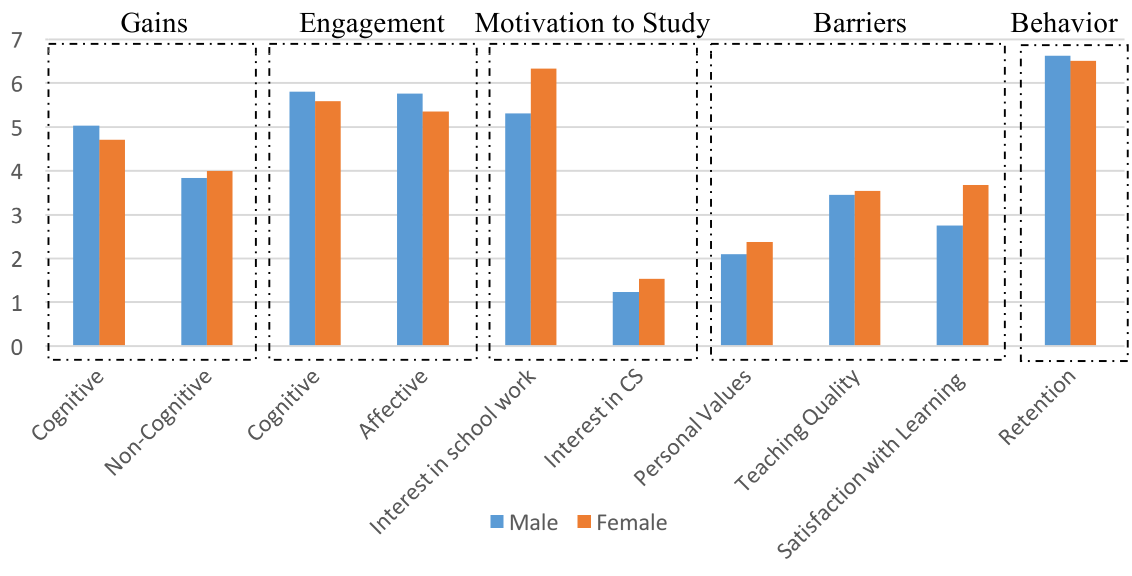

Figure 6. Gender differences in various attitudes regarding CS education

Looking at the motivation to study category we found that interest in school work is very high for all students, and especially for females. Regarding interest in CS, we cannot make a similar observation due to the way it was measured. Nonetheless, it is evident that compared to males, most females that decide to study CS, do it out of interest in the subject. As for the barriers we found that personal values scored low, with teaching quality and satisfaction with learning being higher and in approximately the same levels. Last but not the least, retention was found to be very high, this is again an expected finding since the surveyed students have already decided to follow CS careers.

As per the differences between the two genders, the results suggest that male and female CS students perceive differently cognitive gains, affective engagement, motivation to study, and satisfaction with learning effectiveness. On the other hand, non-cognitive gains, cognitive engagement, personal values, teaching quality and students' retention do not have a significant difference between male and female students. In detail, male students perceive higher cognitive gains than female students, suggesting that problem solving, critical thinking and the opportunity to learn effectively on their own is more important for males than females. However, we notice that non-cognitive gains are not significantly different between genders, indicating that working effectively with others and creating a code of values and ethics is considered similarly important for both male and female students. Also, in general non-cognitive gains are considered less important than cognitive gains.

As opposed to the gender difference found for cognitive gains, there is no difference for cognitive engagement, suggesting that both male and female students are willing to spend a similar amount of time, effort, and energy to learn CS. Interestingly, the two genders have significantly different perceptions regarding affective engagement, showing that male students enjoy, like, and have more fun when studying CS compared to female students. This might be linked with the fact that the majority of the professors are males, and also male professors might organize the course that feels more fun to males than females. Regarding motivation to study CS the findings indicate that a substantial gender difference exists for both interest in school work and interest in CS. Curiously enough, although male students expressed a higher interest in school work, more female students chose to study CS out of interest on the subject and not due to the career perspectives and reputation it offers. The difference in motivation, confirms previous findings that have identified a gender difference on how interested students are in CS (Beyer, 2014).

Regarding the barriers to study CS, the findings show gender differences for satisfaction with learning effectiveness, with female students stating that this barrier is considerably more important for them compared to male students. In addition, both males and females alike find personal values and teaching quality to be equally important for them. Personal issues related with career and life goals are important for all students and may explain their behavior towards CS (Beyer, 2014; Frome, Alfeld, Eccles, & Barber, 2006). Unsurprisingly, teaching quality is equally important for both genders, as when professors and teaching assistants are good and the lectures are of high quality both male and female students want to continue studying CS (Beyer, 2014). It is interesting to note that although both genders perceive teaching quality and personal values in the same way, they are not satisfied as such, indicating that difficult courses and increased workload are more likely to drive female students away from CS than male students. Finally, we examined for gender differences on students' intention to continue studying in CS and the results show that both genders have the same level of intentions, consistent with recent studies that found no relation between gender and students' retention (Pappas et al., 2016), however contradicting older studies that that found females to have higher dropout rates than males (Cohoon, 2006). Also, we should note that both genders expressed a very high intention to continue their studies in CS. Thus, an overall change may have happened in CS students the past decade, which would explain the similar and high levels of behavioral intentions for both male and female students.

Our research suggests that it is important to focus on different factors when attempting to reduce gender differences and increase women representation in CS. As our findings show, examining perceived gains in learning and development and students' engagement is not enough, since male and female students perceive differently certain aspects of those factors. Specifically, cognitive gains and affective engagement seem to be more important factors that should be addressed in order to increase women in CS. Also, although the majority of women in our sample chose to study CS out of interest, with a significant difference from men, their levels of gains and engagement remain lower suggesting that there is still work to be done towards increasing reducing the differences.

This work contributes to the CS education literature by analyzing the gender differences among CS students on important factors that are able to influence their behavior towards studying in the field. Previous studies have examined differences between male and female students (Bao, Xiong, Hu, & Kibelloh, 2013; Beyer, 2014; Rosson et al., 2011), however it is very interesting to examine them in a country such as Norway, which has been "haven for Gender Equality" by CEDAW[1]. Furthermore, the findings provide insight to professors and administrators that will aid them in addressing gender differences towards increasing women representation in CS.

This study, as any empirical work, has some limitations. The sample was collected only from a single survey and only from one CS department and institution. Hence, the generalization of the findings should be done with caution. Moreover, future studies should include larger sample, from more departments, universities and even countries. It is interesting to examine the gender differences among different countries with different educational systems and cultures. In addition, further research may include former students that dropped out from their studies, graduates that continue their studies in the same or different field and pre-university students. Further qualitative studies, via interviews and focus groups, need to investigate the reasons behind the identifies gender differences and identify strategies for increasing equality and gender balance in CS education.

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Appendix

Construct and Scale Items	Mean	SD	Load.
Cognitive Gains			
1. Acquiring a broad general education	5.12	1.05	0.73
2. Acquiring job or work-related knowledge and skills*	4.96	1.23	0.56
3. Thinking critically and analytically	4.91	1.30	0.80
4. Analyzing quantitative problems	4.82	1.20	0.77
5. Learning effectively on your own	5.36	1.34	0.73
6. Solving complex real-world problems*	4.58	1.38	0.61
Non-cognitive Gains			
1. Working effectively with others*	4.89	1.28	0.52
2. Developing a personal code of values and ethics	4.22	1.46	0.86
3. Developing a deepened sense of spirituality	2.51	1.59	0.87
Cognitive Engagement			
1. How willing are you to learn CS.	6.05	1.11	0.89
2. How much time are you ready to spend in CS?	5.59	1.09	0.90
3. How much effort are you ready to put into CS?	5.70	1.16	0.93
4. How much energy are you willing to put into CS?	5.68	1.12	0.93
Affective Engagement			
1. I like studying CS.	6.05	1.06	0.87
2. I have fun studying CS.	5.71	1.24	0.92
3. What we learn in CS studies is interesting.	5.64	1.14	0.83
4. I enjoy what we do in CS studies.	5.30	1.38	0.88
Interest in School Work			
1. I am happy when the work is quite challenging	5.22	1.24	0.68
2. Often, I do not want to stop working at the end of a class.	3.87	1.75	0.92
3. I am very happy when I learn something new that makes sense.*	6.42	0.80	0.59
Personal Values			
1. I do not feel as if I belonged in CS	2.14	1.63	0.80
2. A non-computer science career would be more fulfilling to me	2.21	1.46	0.89
3. Classes were unfriendly	2.25	1.41	0.67
4. Few of my friends are studying CS*	2.03	1.40	0.57
Teaching Quality			
1. Poor teaching by CS faculty or teaching assistants	3.81	1.89	0.89
2. Classes were boring	3.71	1.82	0.87
3. The classes are too big	2.90	1.75	0.62
Satisfaction with Learning Effectiveness			
1. I am unhappy with my grades	3.17	1.90	0.85
2. Excessive workload	3.17	1.60	0.81
3. Overall curriculum was too difficult or too lengthy	2.81	1.58	0.84
Intention to continue your studies in CS			
1. I plan to study in CS in the future	5.24	1.94	0.92
2. I intend to continue my studies in CS in the future	5.38	1.90	0.94
3. If I have to select where to study in the future, I will choose CS.	5.08	1.81	0.82
4. I expect to continue my studies in CS in the future	5.28	2.01	0.94
*Item deleted due to low loading			