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Validating a CS Attitudes Instrument

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ABSTRACT

This paper discusses the validation of a modified computer science attitudes instrument. Dorn and Tew's Computing Attitude Survey was modified by adding questions on gender issues and questions regarding students' perceptions of the utility of computing. Current trends indicate an increasing gap in the genders graduating with degrees in computer science. The new questions explore student attitudes and perceptions of women in computing while items related to computer science utility explore the importance of CS in students' lives and careers. These modifications necessitated the re-validation of the new revised instrument and comparison of the results obtained with in the original instrument by Dorn and Tew.

KEYWORDS

Assessment; Validity; Replication; Gender

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1 INTRODUCTION

Included as one of the five challenges in Sahami's article on more inclusive computing [17], computer science researchers need to promote computing education research to be a more accepted research field. Sahami pointed out that in order to achieve this goal, computing education research needs "benchmarks that can consistently and objectively be measured to make studies more comparable and show progress in the field". This paper discusses the validation of a modified computer science attitudes instrument as an attempt to establish a stepping stone towards such benchmarks on student attitudes to be used for computing education research.

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Student attitudes towards computing are important factors related to students' success in learning computing [26]. Previous research points to important attitudes including "confidence, interest, usefulness, and professional[ism]" [11] and "self-efficacy, attitudes toward computers, and desirability of learning computing skills" [26]. Students with poor self-efficacy often struggle more in computing courses [4]. Gender differences can shape or exasperate attitudes toward computing [18], while successful experiences in computing for pre-college and college students also shape student success in computing [5, 24].

The percentage of females graduating with a bachelor's degree in computer science reached its peak in 1984 at 37.1%. A decade later the female graduation rate dropped by 10% and by 2012 only 18% graduates with a bachelor's degree in computer science were women [1, 21]. As the gender gap further increases we need a better understanding of why it is happening. To do so, we need to start by asking the right questions about students' perceptions of women and role of gender in computing.

This paper details our experiences modifying and revalidating a computing attitudes instrument. In modifying an already validated instrument one must reestablish validity and reliability. Validity is the extent to which an instrument measures what it is supposed to measure and performs as it is designed to perform, while reliability is the idea of, does the instrument consistently measure what it is intended to measure? [2].

1.1 CS Attitudes Surveys

Ramalingam and Wiedenbeck [15, 16] created and validated the Computer Programming Self-Efficacy Scale in 1998. Their goal was to create and validate an instrument that examined students' self-efficacy and confidence about their own ability to learn how to program. The instrument was written primarily in regard to C++ programming language, as C++ was the most widely used programming language taught in introductory CS courses at the time. Exploratory Factor analysis (EFA) was conducted on the 32 questions and indicated 4 factors (independence and persistence, complex programming tasks, self-regulation and simple programming tasks).

Wiebe et al. [23] created a computer science attitudes instrument derived from the Fennema-Sherman mathematics attitudes scales [9], modified to reflect programming and computer science rather than mathematics. It consists of 57 questions on self-confidence, motivation, attitudes toward success, females in CS, and usefulness

of CS. Despite an initial study, the validity of this instrument was never fully established.

Hoegh and Moskal [12] created another computer science attitudes survey that measures undergraduate student perceptions of computer science who were enrolled in Calculus II, a first year required mathematics course for all students. This allowed the population to represent first year students across the entire institution. The initial survey started with 52 question and 5 pre-defined factors on confidence, interest, gender, usefulness, and professionalism.

Dorn and Tew [7] developed the Computing Attitudes Survey (CAS), an extension of the Colorado Learning Attitudes about Science Survey (CLASS) [3]. The researchers identified 4 differences in the design of the CAS instrument compared to the others discussed above. First, the CAS statements are designed to elicit attitudes about knowledge and problem solving in the CS discipline. Second, the CAS statements are written to measure attitudes about CS more generally and not restricted to attitudes about a specific course, pedagogy or programming language. Third, the CAS items have been selected and tested to provide clear and concise statements with a single interpretation. Fourth, the CAS establishes categories of attitudes and sub scales on the survey based on an empirical analysis of the student responses themselves, rather than determining categories upfront based on the researchers' areas of interest.

The CAS was revised four times from 2011-2015. The first version was created by adapting the original questions of the CLASS to a more computing-focus survey. Version 2 was based on think-aloud interviews with faculty and students which were piloted during the fall of 2011 with 447 introductory students [22]. The second version, CASv2, consisted of 53-Likert type questions, which resulted in 8 factors found during an EFA. These were problem solving - transfer, problem solving - strategies, problem solving - fixed mindset, real world connections, problem solving - confidence, problem solving - sense making, abstraction and personal interest/enjoyment. These were further revised in version three (CASv3) which was administered as a pre-post format over three semesters across two universities with a total number of 2873 survey responses. The researchers ran an EFA on CASv3 revealing 7 latent factors. A confirmatory factor analysis (CFA) was run on each of the 7 factors, and the survey was then revised again based on the results of the CFA. The latest version, CASv4, has 26 questions and five factors: problem solving - transfer, personal interest, problem solving - strategies, real-world connections, and problem solving - fixed mindset [7].

2 COMPUTING ATTITUDES DESIGN

Dorn and Tew's CASv4 consists of 26 questions, using a 5-point Likert scale. To their survey, we added a subset of 9 questions from Wiebe et al.'s survey [23] representing a range of attitudes relating to gender issues. We note that these questions have a possibility of introducing stereotype threat [19, 20]. An additional five questions were added probing students' attitudes towards the utility of computing. Cooper et al.'s [6] study noticed that their student attitudes survey did not fully capture the results from individual interviews, particularly of Latinas, about the importance of student views concerning gender equality issues and the utility of computing. All added questions also used a 5-point Likert scale.

With permission from Dorn and Tew, CASv4 was modified by adding questions focusing on students perceptions concerning the utility of computing and on their thoughts about gender issues. As the instrument CASv4 was modified, it was necessary to establish the new instrument's reliability.

3 METHODS

Data was collected in a pre-post format in introductory computing classes across three universities; University of Nebraska - Lincoln, University of North Carolina, and Texas Woman's University, during the spring, summer and fall of 2018. All student participation was voluntary, with incentives used to encourage students to participate. The instruments were available for students to take online during the first 3 weeks of class as a pre-test and offered during the final 3 weeks as a post-test. A total of 827 students took the modified CS attitudes survey (585 males, 232 females and 10 students who did not identify themselves as either male or female).

4 ANALYSIS

Factor analysis was used to determine underlying factors that might be in the survey item design. An EFA was conducted on all questions and used calculations of Ordinal α to test reliability of the modified version of the CASv4 [10]. An acceptable minimum value of .70 is considered acceptable for an Ordinal α in educational research [14]. The broad purpose of factor analysis is to summarize data so that relationships and patterns can be easily interpreted and understood [25]. More technically, a factor analysis is a data reduction technique that takes a collection of observed random variables and groups them into common factors based on their correlation patterns.

Eigenvalues are used to determine how many factors to retain. The eigenvalue for a given factor measures the variance in all the questions. Eigenvalues are calculated by summing the squares of all the loading values for a given factor. If a factor has a low eigenvalue, it is contributing little to the explanation of variance in the factor. Kaiser's rule suggests retaining all factors that are above the eigenvalue of 1 [13]. Other ways of determining when to remove a factor is when it contains less than three questions or when it consists of many complex loading values, e.g. questions that are associated with more than one factor (cross-loading) [25].

After establishing factors, we investigated the correlations between the factors using a correlation matrix and a Pearson correlation coefficient, to determine the strength of the correlation between each of the factors.

5 RESULTS

5.1 Exploratory Factor Analysis

A factor analysis was conducted on the modified CASv4 and the results were compared to the results Dorn and Tew obtained.

The original CASv4 contained 5 factors: Problem Solving - Transfer, Personal Interest, Problem Solving - Strategies, Real-World Connections, and Problem Solving - Fixed Mindset [7]. Scoring high in the Personal Interest factor suggests a student has a higher interest in computing. Scoring high in Problem Solving - Strategies suggests a student considers him/herself to have strong problem-solving strategies when it comes to CS. Scoring high in Real-World Connections suggests a student has a strong relationship between

Table 1: Pattern Matrix

		Factors					
		1	2	3	4	5	6
DT	Q20	.768					
DT	Q24	.685					
DT	Q15	.640					
DT	Q2	.565					
DT	Q23	.561					
DT	Q6	.552					
DT	Q21	.516					
DT	Q3	.464					
DT	Q25	.444					
DT	Q18	.432					
DT	Q22	.399					
DT	Q1	.355					-.326
W	Q28		.976				
W	Q29		.918				
W	Q27		.858				
W	Q30		.843				
W	Q35		.667				
W	Q31		-.349			.334	
N	Q38			.931			
N	Q37			.929			
N	Q36			.924			
DT	Q26			.745			
DT	Q10				.643		
DT	Q16				.599		
DT	Q5				.561		
DT	Q17				.547		
DT	Q12				.483		
DT	Q7				.452		
DT	Q8				.426		
DT	Q9				.374		
W	Q32					.694	
W	Q34					.588	
W	Q33					.511	
DT	Q4						.697
DT	Q13			.408			.564
DT	Q11						.425

DT = From Doren and Tew’s original survey

W = From Weibe’s original Survey

N = Newly added questions

relating CS concepts to the real world. Scoring high in the Problem Solving - Fixed Mindset factor suggests a student has a narrower mindset when it comes to CS concepts. Scoring high in Problem Solving - Transfer suggests a student has a lower ability to see or apply connections between ideas and concepts.

An EFA was performed on the modified instrument (Principal Axis Factory and a Promax rotation) yielding seven factors with eigenvalues greater than 1. The total number of factors were further reduced to 6 by removing factors with multiple loadings or having fewer than three questions associated with the factor. Table 1 displays the pattern matrix of each factor and the loading values

of each question. (Any loading value with absolute value less than .32 is depicted as blank.) Table 4 in the appendix shows the wording of each question.

5.2 Factor Breakdown

Factor 1, named Problem Solving - Fixed Mindset, has a eigenvalue of 10.35, accounting for 26.6% of the variance. It contains 12 questions (20, 24, 15, 2, 23, 6, 21, 3, 25 ,18, 22 and 1). Question 1 has a negative loading value on factor 6 but a positive loading value on factor 1, so we removed it from factor 6 and kept it in factor 1. Factor 1 contains all questions found in both Dorn and Tew’s factor Problem Solving - Fixed Mindset and Problem Solving - Transfer [7].

Factor 2, named Gender Equity, has an eigenvalue of 4.61, accounting for 11.8% of the variance. It consists of 5 questions (28, 29, 27, 30 and 35). Question 31 had a negative loading value with factor 2 and a positive loading value with factor 5, so we removed it from factor 2 and kept it in factor 5. All questions are from Wiebe’s original study [23]. All questions in this factor explore students’ opinions concerning the equity between males and females in CS.

Factor 3, named Importance, had an eigenvalue of 2.63, accounting for 6.75% of the variance. It consists of 4 questions (38, 37, 36 and 26). Question 26 was the only questions that was in Dorn and Tew’s original work [7]. All questions in this factor highlights the importance of computing in one’s life and the desire to learn more about computation.

Factor 4, named Problem Solving - Strategies (as in Dorn and Tew’s work) has an eigenvalue of 1.9, accounting for 4.88% of the variance. It consists of 8 questions; 10, 16, 5, 17, 12, 7, 8 and 9. It was consistent with the CASv4 factor of Problem Solving - Strategies questions plus 3 extra questions from CASv4 Real-World Connections. Our factor consists of slightly different questions from the original Problem Solving - Strategies found in Dorn and Tew’s work [7]. We believe that our factor captures the same concept as the original Problem Solving - Strategies within our data set. We decided that it was appropriate to keep the factor name the same.

Factor 5, named Gender Bias, has an eigenvalue of a 1.33 accounting for 3.4% of the variance. It consists of 4 questions (31, 32, 34, and 33) exploring gender biases towards females in CS; All question are from Wiebe’s original study [23].

Factor 6, was named Personal Interest, has an eigenvalue of 1 accounting for 2.58% of the variance and consists of 3 questions (4, 13 and 11). Question 13 had both a positive loading value on both factor 3 and factor 6. As it had a higher loading value on factor 6 (.564 vs . 408), we decided to keep it in factor 6. Our factor 6 consisted of 3 out of the 4 questions originally found in Dorn and Tew’s Personal Interest factor. We decided that it was appropriate to keep the factor name the same.

5.3 Reliability

The reliability of the factors found in our data set and the reliability of Dorn and Tew’s original factors were compared in Table 2. Column 1 shows the reliabilities (as Ordinal α) calculated for the factors Dorn and Tew found in their study [7]. The reliabilities of all but one factor found in Dorn and Tew’s study had similar reliability in our data set (column 2). Real-World Connections had

Table 2: CASv4 Factor Reliabilities

Factor	Original (Ordinal α)	Original w/ our data (Ordinal α)	Our Factors (Ordinal α)
Problem Solving - Fixed Mindset	.90	.83	.88
Gender Equity	N/A	N/A	.96
Importance	N/A	N/A	.95
Problem Solving - Strategies	.80	.78	.82
Gender Bias	N/A	N/A	.85
Personal Interest	.90	.87	.84
Problem Solving - Transfer	.71	.74	N/A
Real-World Connections	.90	.77	N/A

Table 3: Correlation Matrix

Factors	Problem Solving Fixed Mindset	Gender Equity	Importance	Problem Solving Strategies	Gender Bias	Personal Interest
Problem Solving - Fixed Mindset	1.00	-.399*	-.488*	-.480*	.565*	-.469*
Gender Equity	-.399*	1.00	.266*	.205*	-.662*	.024
Importance	-.484*	.266*	1.00	.625*	-.167*	.608*
Problem Solving - Strategies	-.480*	.205*	.625*	1.00	-.167*	.733*
Gender Bias	.565*	-.662*	-.278*	-.167*	1.00	-.117*
Personal Interest	-.469*	0.24	.608*	.733*	-.117*	1.00

*significant correlation at the 0.01 level

the highest decrease in reliability (.90 -> .77) and this could explain why it did not show up in our EFA. Both factors that were found from Wiebe’s survey, Gender Equity and Gender Bias, had high reliability. Gender Equity has an Ordinal α of .96, and Gender Bias has an Ordinal α of .85. The Importance factor, that was mostly comprised of our added questions, also had a high reliability with an Ordinal α of .95.

5.4 Factor Correlations

We calculated a correlation matrix (Table 3) to determine correlations among the factors themselves. Calculating a Pearson’s Correlation Coefficient using Evan’s suggested scale can determine the strength of the correlations. Evan suggests that a Pearson’s Correlation Coefficient between 0.0 and .19 is considered very weak, 0.2 - 0.39 is weak, 0.4 - 0.59 is moderate, 0.6 - 0.79 is strong, and .80 - 1.0 is very strong [8].

The Problem Solving - Fixed Mindset factor has a moderate negative correlation with the Importance factor ($r = -.488$), the Problem Solving - Strategies factor ($r = -.480$), and the Personal Interest factor ($r = -.469$), a moderate positive correlation with the Gender Bias factor ($r = .565$) and a weak negative correlation with the and the Gender Equity factor ($r = -.399$). The Gender Equity factor has a strong negative correlation with the Gender Bias factor ($r = -.662$) and a weak negative correlation with the Problem Solving - Fixed Mindset factor ($r = -.399$). The Importance factor has a strong positive correlations to both the Problem Solving - Strategies factor ($r = .625$) and Personal Interest factor ($r = .608$) and a moderate negative correlation to Problem Solving - Fixed Mindset factor ($r = -.484$). The Problem Solving - Strategies factor has a strong

positive correlation with the Personal Interest factor ($r = .733$) and a moderate negative correlation with the Problem Solving - Fixed Mindset factor ($r = -.480$). The Gender Bias has a moderate positive correlation with the Problem Solving - Fixed Mindset factor ($r = .565$) and a strong negative correlation with the Gender Equity factor ($r = -.662$). The Personal Interest factor has a strong correlation with both the Problem Solving - Strategies factor ($r = .733$) and the Importance factor ($r = .608$) and a moderate negative correlation with the Problem Solving - Fixed Mindset factor ($r = -.469$).

Two out of the three original factors have similar correlations to what Dorn and Tew found in their study. Our Personal Interest and Problem Solving - Strategies factors have a strong correlation of 0.733 while Dorn and Tew also had a strong correlation of 0.78. Problem Solving - Strategies and Problem Solving - Fixed Mindset have a moderate correlation of 0.480 while Dorn and Tew also had a moderate correlation of 0.56. Personal interest and Problem Solving - Fixed Mindset have a weak correlation of 0.469, while Dorn and Tew had a strong correlation of a 0.63.

6 DISCUSSION

Similar results to Dorn and Tew [7] were obtained. Like Dorn and Tew, we found the Personal Interest factor to have a strong positive correlation with the Problem Solving - Strategies factor suggesting that introductory computing students who have strong problem-solving strategies show more interest in CS. We found a negative correlation with both the Personal Interest factor and the Problem Solving - Strategies factor to the Problem Solving - Fixed Mindset factor, suggesting students who score higher in problem solving

strategies are more open minded and have a higher ability to transfer ideas and concepts.

Adding the 9 extra questions from Wiebe's survey [23] resulted in two new factors, Gender Equity and Gender Bias. The Gender Equity and the Gender Bias factors produced a strong negative correlation ($r = -.662$) suggesting they are the opposite of each other. Gender Bias factor also had a moderate positive correlation with the Problem Solving - Fixed Mindset factor suggesting that introductory computing students who have a strong bias towards males in computer science have more of a fixed mindset when trying to solve problems.

There is a positive correlation between the Personal Interest, the Problems Solving - Strategies, and the Importance factors. This suggests that for students who have a higher interest in computation, computation is more important in their lives, and they have developed higher problem-solving skills when working on computation.

7 LIMITATIONS

Several factors could have impacted the validity of our research. The first factor is that our survey data was collected on a combination of both pre- and post-tests while Dorn and Tew collected data over several semesters and ran their factor analysis on only post-test data [7, 22]. It is unclear whether the inclusion of both pre- and post-test data within the factor analysis impacted the emerging factors. We will continue collecting data using the modified instrument and conduct exploratory and confirmatory factor analysis to determine if the constructs remain stable.

The second factor is that the questions targeting students' attitudes towards females in computing could have imposed a stereotype treatment [19, 20]. It is unclear whether a stereotype treatment exists in our study, but moving forward we will work to create questions that equally ask students' attitude towards both male and female. Hopefully reducing any chance that a stereotype treatment is imposed by our survey.

8 CONCLUSION

The development of the modified computer science attitude survey incorporated items on CS utility, women, and gender bias to the CASv4 producing a new instrument that built upon the strengths of CASv4. The EFA conducted on the modified survey resulted in 6 factors: Problem Solving - Fixed Mindset, Gender Equity, Importance, Problem Solving - Strategies, Gender Bias and Personal Interest.

All six factors tested above the .70 Ordinal α and account for 56% of the overall variance. While three new factors (Gender Equity, Gender Bias and Importance) were produced, two of the original factors found in Dorn and Tew's work (Problem Solving - transfer and Real World Connections) [7] were not preserved. This is not surprising based on the inclusion of new items in the survey.

With continuing measurement of the validity and reliability of this new CS attitude survey, it is our hope to inform CS educators and researchers to better understand the attitudes and perceptions of CS students and use the information to guide the design of more inclusive, real world problem based CS instruction, reduce gender bias, promote equality, and increase and retain women entering the field.

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Table 4: Attitude Survey Questions

Number	Question	Factor
Q1	After I study a topic in computer science and feel that I understand it, I have difficulty solving problems on the same topic.	1
Q2	Errors generated by computers are random, and when they happen there's not much I can do to understand why.	1
Q3	If I want to apply a method used for solving one computer science problem to another problem, the problems must involve very similar situations.	1
Q4	I can usually figure out a way to solve computer science problems.	6
Q5	When I solve a computer science problem, I break it into smaller parts and solve them one at a time.	4
Q6	I do not spend more than five minutes stuck on a computer science problem before giving up or seeking help from someone else.	1
Q7	There are times I solve a computer science problem more than one way to help my understanding.	4
Q8	I think about the computer science I experience in everyday life.	4
Q9	Tools and techniques from computer science can be useful in the study of other disciplines (e.g., biology, art, business).	4
Q10	When working on a computer science problem I find it useful to brainstorm about solution strategies before writing code.	4
Q11	I find the challenge of solving computer science problems motivating.	6
Q12	When studying computer science, I relate the important information to what I already know rather than just memorizing it the way it is presented.	4
Q13	I enjoy solving computer science problems.	6
Q14	Reasoning skills used to understand computer science can be helpful to me in my everyday life.	N/A
Q15	Learning computer science is just about learning how to program in different languages.	1
Q16	When I am working on a computer science program, I try to decide what reasonable output values would be.	4
Q17	When I'm trying to learn something new in computer science, I find it useful to write a small program to see how it works.	4
Q18	A significant problem in learning computer science is being able to memorize all the information I need to know.	1
Q19	We use this statement to discard the surveys of people who are not reading the questions. Please select "Agree" for this question to preserve your answers.	N/A
Q20	Understanding computer science basically means being able to recall something you've read or been shown.	1
Q21	If I get stuck on a computer science problem, there is no chance I'll figure it out on my own.	1
Q22	The subject of computer science has little relation to what I experience in the real world.	1
Q23	There is usually only one correct approach to solving a computer science problem.	1
Q24	To learn computer science, I only need to memorize solutions to sample problems.	1
Q25	I worry that mistakes I make when writing a program may damage my computer.	1
Q26	I am interested in learning more about computer science.	3
Q27	Females are as good as males at programming.	2
Q28	Studying computer science is just as appropriate for women as for men.	2
Q29	I would trust a woman just as much as I would trust a man to figure out important programming problems.	2
Q30	Women certainly are logical enough to do well in computer science.	2
Q31	It's hard to believe a female could be a genius in computer science.	5
Q32	It makes sense that there are more men than women in computer science.	5
Q33	I would have more faith in the answer for a programming problem solved by a man than a woman.	5
Q34	Women who enjoy studying computer science are a bit peculiar.	5
Q35	Women and men can both excel in careers that involve computing.	2
Q36	I would like to take more courses in computing.	3
Q37	The skills in this class will be useful in my life.	3
Q38	The skills in this class will be useful in my career.	3
Q39	I know how to use programming to communicate with others.	N/A
Q40	I know how to use programming to communicate with programmers.	N/A

Q1-Q26 are from Dorn's and Tew's original questions [7].

Q27-Q35 are from Weibe's original questions [23].

Q36-Q40 are our five added questions focusing on the utility of computing.