BOARD # 95: WIP: Students' reflections on their attitude and how it affects their performance in a CS Discrete Math course.

Dr. Juan Alvarez, University of Illinois at Urbana - Champaign

Juan Alvarez joined the Department of Electrical and Computer Engineering at University of Illinois faculty in Spring 2011 and is currently a Teaching Assistant Professor. Prior to that, he was a Postdoctoral Fellow in the Department of Mathematics and Statistics at York University, Canada, a Postdoctoral Fellow in the Chemical Physics Theory Group at the University of Toronto, Canada, and a Postdoctoral Fellow in the Department of Mathematics and Statistics at the University of Saskatchewan. He obtained his Ph.D. and M.S. from the Department of Electrical and Computer Engineering at the University of Illinois in 2004 and 2002, respectively. He teaches courses in communications, signal processing and probability.

Max Fowler, University of Illinois at Urbana - Champaign
Cheryl Ann Cohen
Jennifer Martinez
Dr. Jennifer R Amos, University of Illinois at Urbana - Champaign

Dr. Amos is a Teaching Professor in Bioengineering at the University of Illinois Urbana-Champaign. She performs research in engineering education including related research in identity formation and how first-year students choose their majors.

Yael Gertner, University of Illinois at Urbana - Champaign

Dr Gertner joined the Computer Science Department at the University of Illinois in 2020 as a Teaching Assistant Professor. She received her B.S. and MEng in Electrical Engineering and Computer Science from MIT, and Ph.D. in Computer and Information Science at the University of Pennsylvania. She was a Beckman Fellow at the University of Illinois Urbana-Champaign. Her current focus is on broadening participation in Computer Science and Computer Science Education She has been developing materials and teaching for iCAN, a new program for broadening participation in CS for students who have a bachelor's degree in a field other than computer science.

WIP: Students' reflections on their Sense of Belonging and Motivation in a CS Discrete Math course.

1 Introduction

Researchers found that motivation and sense of belonging play a role in course performance[5, 6]. In this work we focus on a Discrete Math course which is a required gateway course in the computing sequence. Given the nature of the conceptual problem solving required in Discrete Math is unique compared to early programming, this different environment might have a differential impact on students' sense of belonging and motivation. Specifically, we focus on two aspects of motivation from Expectancy-Value Theory[2]: students' expectation for success and the value they place in the course. For sense of belonging [3, 7], we focus on whether students see themselves as computer scientists, and whether they think their instructors, parents and friends see them as computer scientists.

We divide our students into four groups based on their final grade to find out about each groups' sense of belonging and motivation and ask the following research questions:

RQ1: Do students in different groups differ in their expectancy of success, value for the course, and sense of belonging at the beginning of the course?

RQ2: Do students in different groups differ in how they view the importance of these attributes to their success and in their goals for the course?

RQ3: Do students in different groups differ in how much their interest, value, and sense of belonging changes during the course of the semester?

RQ4: For which of these attributes do students with below-average measures at the start of the course change their attitudes in a way that correlates with positive course outcomes?

RQ5: What can we learn about the relationships between these attributes and final grades from students' reflections?

2 Methods

During Fall 2023 we surveyed students in a Discrete Math course at a large state R1 University. Survey 1 was used to get information about students' motivation and belonging as they enter the course in the first week of the semester. In the middle of the semester, students were then given an additional survey to measure how much they thought these attributes lead to their success in the course so far, and whether each of these attributes increased since the beginning of the year. Before administering the second survey we discussed the results of the first survey, defined these "mindset" attributes, explained how they can be related to their success in the course, and provided students with a plot that depicted their score on

each attribute as it relates to the mean in the entire class. We then proceeded to ask them the questions in the second survey.

The Course. The Discrete Math course is a required course in the Computer Science sequence. It has enrollment of many non-majors who are trying to switch into CS. It is a sixteen week course with seven "low-stakes" exams given every two weeks. These exams constitute 90% of the grade. The rest of the grade depends on homework. Students are provided with an online textbook and prerecorded lecture videos. The 75 minute weekly meeting time is devoted to a problem solving session in which students work in groups. Attendance is not required and solutions are available after the session.

Participants. During Fall 2023, we surveyed over 400 students for each of our surveys out of 829 students enrolled in the course. However, not all students completed both surveys. In total 238 students consented to and answered both IRB approved questionnaires. Students received extra credit for completing the questionnaires.

2.1 Measures

Expectancy was measured in Survey 1. It is a measure based on participants' intrinsic motivation designed based on self-determination theory [1]. It focuses on the aspect of motivation that comes from their expectation of how enjoyable this class will be as well as how well they can do in it. Students respond on a 5 point Likert scale of "Strongly agree" to "Strongly Disagree" to the following questions and the measure corresponds to the average of the answers while reversing the scale for the first and last one: "I think this class is going to be boring", "I think this class is going to be enjoyable", "I think that I am going to be pretty good at this class", "This is a class that I cannot do very well in".

Value was measured in Survey 1. It is a measure based on participants' intrinsic motivation designed based on self-determination theory [1]. It focuses on the aspect of motivation that comes from the importance and effort that they attribute to this class. Students respond on a 5 point Likert scale of "Strongly agree" to "Strongly Disagree" to the following questions and the measure corresponds to the average of the answers. "I plan to put a lot of effort into this class", "It is important to me to do well in this class", "I believe this class could be of some value to me", "I believe doing this class is important".

Belonging was measured in Survey 1. Students respond on a 5 point Likert scale of "Strongly agree" to "Strongly Disagree" to the set of the following 4 questions: "my teachers see me as a computer scientist", "my friends/classmates see me as a computer scientist", "my family sees me as a computer scientist", "I see myself as a computer scientist".

Increased Value/Interest/Belonging was measured in Survey 2. Students respond to the following True/False questions: In your mind, "did the class become more valuable"/"did the class become more interesting"/"do you feel a stronger sense of belonging" since the beginning of class when you filled out the survey?

Effect of Motivation was measured in Survey 2. Students respond on a 5 point Likert scale of "Not at all" to "A great deal" to the following question: How much do you feel that your mindset has affected your performance in the class so far?. Note that this question was asked

in the context of an explanation of what we mean by "mindset", and linked it to the attributes for which we asked if the students experience an increase Value/Interest/Belonging.

Pleased with Performance/Understanding was measured in Survey 2. Students respond on a 6 point Likert scale of "Extremely Pleased" to "Extremely Displeased" to the following question: How pleased are you with your performance/understanding in the class?

Final Grade. This is the final calculated percent score that students were assigned at the end of the semester.

2.2 Data Analysis

We conducted a statistical analysis on the quantitative measures in our data set. The data was split into two sub-groups for comparison. A Mann-Whitney U test conducted to analyze the differences between the two sub-groups of students and a p-value cutoff of 0.05 was chosen as a cutoff for statistical significance.

We also collected openended responses from students to the question: "How do you feel the attributes discussed above are going to affect your performance going forward?" Prior to asking this question we introduced students to our measures. We read through the responses finding all responses that talked about belonging. These quotes are presented in a table later in the results section. We marked each quote with a positive or negative sentiment. If the student identified difficulties either with the course or their sense of belonging we marked it with negative sentiment otherwise we marked it as positive. Positive sentiment included students who belonged but also those who mentioned that they increased their sense of belonging.

3 Results and Discussion

In order to learn more about our students and how their grades correlate with their mindset, we divided the students into four groups based on the grade they received. As seen in Table 1, there were 127 students in the "A" group, 70 in "B", 25 in "C" and 12 in "D".

To answer RQ1, we found that there were no differences between the groups in students' value or sense of belonging at the start of the course, suggesting that these measures alone at the beginning are not strong enough to predict course outcomes. However the A students had higher expectations to do well. This is perhaps because some students come in with prior background knowledge, which increases their Expectancy measure and performance. It is also possible that students who expect to do well will do better - Expectancy-Value Theory tends to support this outcome.

Towards RQ2, we wanted to rule out the possibility that our findings regarding value, expectancy and sense of belonging might be due to differences in how much these groups appreciate their mindset in affecting their performance in the class. When we asked the students how important their mindset was, there were no significant differences between these groups with the following means for each grade group: (A,3.21; B,3.21; C,3.20: D:3.25). This suggests that across all groups, students perceived mindset as affecting their outcome equally.

	A (n:127)	B (n:70)	C (n:25)	D (n:12)
Expectancy	3.68*	3.38	3.38	3.25
Value	4.25	4.29	4.29	4.21
Belonging	3.29	3.15	2.98	3.23

Table 1: Average means for each measure per grade group with the two groups of consecutive grades was calculated and is marked with * if $p < .05$

	A (n:127)	B (n:70)	C (n:25)	D (n:12)
Interest Increase	.70	.69	.60	.42
Value Increase	.67	.70*	.52	.42
Belonging Increase	.56*	.40	.28	.33

Table 2: Percent of students that indicated that their measure increased with the two groups of consecutive grades is marked with * if $p < .05$

Given that previous work demonstrates the important role motivation plays in course performance, towards RQ3, we wanted to understand whether these measures increase as the semester progresses and whether there are differences between the groups. As seen in Table 2, when we asked students which of these measures increased since the beginning of the year, we found that the majority of D students did not have an increase in any of these measures. The majority of A, B, and C students had an increase in value and interest. However, only the A students showed an increase in Belonging. When we compare these groups we see that the B students increased in Value as compared to the C students but their Belonging did not increase in comparison with that group. The A students had similar increase in value to the B students but their Belonging increase was different than the Bs. This suggests that it might take more to ensure an increase in Belonging even as other motivational measures are increasing.

We wanted to rule out the possibility that our findings regarding value, expectancy and sense of belonging might be due to the different goals and expectations these students have with regard to their course performance. It is possible that C students do not value their outcome as much as B students do and are pleased with their grade. This turns out not to be the case. When we asked the students how satisfied they were with their performance and understanding in the course there was a significant difference between these groups. The means for each group is as follows for the measure of Performance: A,4.01*; B, 3.09*; C,2.64; D, 2.25 and Understanding: A, 3.98*; B,3.43; C,3.32*; D, 2.75. The * marks a significant difference between the group and the grade below. This suggests that students' difference in grades are not due to their difference in goals in performance and understanding.

Next, towards RQ4, we wanted to know not only whether students increased their measures but how grades differed between students who started out below average on a measure and increased the measure as compared to those that started out low and did not increase it. As seen in Table 3, students who started out low on the 'value' measure but indicated that their 'value' of the course increased have significantly higher grades than those who started out low and did not increase their value. This is consistent with prior findings [4] about

Measure	Group	Increase	No-increase
Value	High	88.37 (80)	87.37 (30)
	Low	89.13* (73)	86.04 (52)
Expectancy	High	89.86 (89)	87.71 (24)
	Low	87.20 (69)	85.91 (53)
Belonging	High	91.37 (63)*	85.91 (61)
	Low	87.57 (48)	86.85 (63)

Table 3: Means for Final Grades for High (above the mean) and Low (below the mean) groups for students with increase and those that did not in that same measure. The number of students in group is placed in parentheses next to the mean. * indicates that it is different than the means of the other group in its row.

increasing student motivation through the course is linked with positive course outcomes. In contrast, students who started out below average in Belonging and Expectancy and increased these measures did not differ in grades as compared to the students who started out low in these measures and did not increase them. In future work we plan to study this contrasting pattern further.

Finally, we wanted to understand what students say when they reflect about their Belonging and how it influences their performance. As see in Table 4 we see that students talked about Belonging when asked about how these mindsets affect their performance. The A students had a positive sentiment towards their belonging and the B and C students talked about it negatively as not belonging enough. This was the case whether or not they started out above or below average in their Belonging measure at the beginning of the semester and whether or not it increased as the semester went on. Students in the A group talked about their belonging as something that causes them to perform better in the course and that it was something that they can work on increasing. This suggests that a strong sense of belonging could potentially lead to higher course outcomes. The students in the B group also talked about belonging as something that they can increase. They mentioned that their lack of belonging can affect their grades but also that their less than desirable performance negatively affected their belonging. This suggests that performance can in turn affect their sense of belonging. The relationship between performance and belonging is complex and deserves further attention which we plan to explore in future work.

4 Conclusions

In this paper, we focused on sense of belonging and two aspects of motivation from Expectancy-Value Theory[2]: students' expectation for success and the value they place in the course. We compared students in a Discrete Math course in a CS sequence with different course outcomes for their sense of belonging, value, and interest at the beginning of the semester and whether they increased as the semester continued. Our work adds to prior findings [4] in introductory CS courses that developing student interest is important to course outcomes. We found that students in different groups did not differ in their sense of belonging or value at the beginning of the semester. The B students increased in value as compared to the

C students but their sense of belonging did not increase in comparison with that group. Students who started out low on the value measure but indicated that their value of the course increased have significantly higher grades than those who started out low and did not increase their value. This suggests that the relationship between course performance, value, and belonging is complex and deserves further attention. In future work, we plan to explore this relationship further as well students' understanding of these mindset concepts and the role they play in their learning.

References

[1] E.L. Deci and R.M. Ryan. 2012. Self-determination theory. In *Handbook of theories of social psychology*, P.A.M. van Lange, A.W. Kruglanski, and E.T. Higgins (Eds.). Sage Publications Ltd., 416–436.

[2] Jacquelynne S. Eccles and Allan Wigfield. 2020. From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology* 61 (2020), 101859. https://doi.org/10.1016/j.cedpsych.2020.101859

[3] Sophia Krause-Levy, William G. Griswold, Leo Porter, and Christine Alvarado. 2021. The Relationship Between Sense of Belonging and Student Outcomes in CS1 and Beyond. In *Proceedings of the 17th ACM Conference on International Computing Education Research* (Virtual Event, USA) *(ICER 2021)*. Association for Computing Machinery, New York, NY, USA, 29–41. https://doi.org/10.1145/3446871.3469748

[4] Alex Lishinski and Joshua Rosenberg. 2021. All the Pieces Matter: The Relationship of Momentary Self-efficacy and Affective Experiences with CS1 Achievement and Interest in Computing. In *Proceedings of the 17th ACM Conference on International Computing Education Research* (Virtual Event, USA) *(ICER 2021)*. Association for Computing Machinery, New York, NY, USA, 252–265. https://doi.org/10.1145/3446871.3469740

[5] Adrian Salguero, William G Griswold, Christine Alvarado, and Leo Porter. 2021. Understanding sources of student struggle in early computer science courses. In *Proceedings of the 17th ACM Conference on International Computing Education Research* (Virtual Event USA). ACM, New York, NY, USA.

[6] Duane F Shell, Leen-Kiat Soh, Abraham E Flanigan, and Markeya S Peteranetz. 2016. Students' initial course motivation and their achievement and retention in college CS1 courses. In *Proceedings of the 47th ACM Technical Symposium on Computing Science Education - SIGCSE '16* (Memphis, Tennessee, USA). ACM Press, New York, New York, USA.

[7] Nanette Veilleux, Rebecca Bates, Cheryl Allendoerfer, Diane Jones, Joyous Crawford, and Tamara Floyd Smith. 2013. The relationship between belonging and ability in computer science. In *Proceeding of the 44th ACM Technical Symposium on Computer Science Education* (Denver, Colorado, USA) *(SIGCSE '13)*. Association for Computing Machinery, New York, NY, USA, 65–70. https://doi.org/10.1145/2445196.2445220

Sentiment	Student Reflections on Belonging	G	Belong	Increase?
positive	I do feel like increasing my sense of belonging was important. Having never studied discrete before, there was always a slight fear of not being cut out.	A	Low	Yes
positive	Expectancy and belonging	A	Low	Yes
positive	I think having a sense of belonging help people to get more involved in their work and willing to work harder.	A	Low	Yes
positive	I'll continue to feel invested and interested in the class and feel like I am someone who belongs and can do well.	A	High	Yes
positive	My highly above average belonging here may helps me be more motivated during the rest of the semester.	A	High	No
negative	I find it difficult to stay motivated in a class where I have almost no interaction with professors or other students.	A	High	No
negative	I think my belonging part is a little bit less than the classroom's average. I believe I would build up more belonging to our computer science communities.	B	Low	Yes
negative	Getting a lower grade than I expected on examlets has been a bit discouraging about how I fit in the CS community but it has motivated me too change my study ways to improve.	B	Low	No
negative	although I don't fully feel like I belong, I don't really think that will affect my performance	B	Low	No
negative	I feel that I believe that I can still grow and learn the content better but whether the class feels right for me is an ongoing issue.	B	High	No
negative	I feel a similar sense of belonging but I do feel more confident in my ability to succeed in this class, which I had struggled with before.	B	High	No
negative	I hope that my performance is going to improve but I find it difficult to grow and improve with my rollercoaster schedule. I also don't have many people to reach out to personally in the class	B	High	No
negative	my sense of belonging in the CS program is very low, which is still the case. I think this pushes me away from opportunities I would like to pursue, which would negatively affect my growth and performance growing forward.	C	Low	Yes
negative	I feel I can still do well in CS but it odes give me some feelings about not belonging in it as mostly I do feel a bit clueless at times.	C	Low	No

Table 4: Students' reflections on how their sense of belonging affects their performance. Their grade, sense of belonging at the beginning of the semester, and whether it increased or not. Sentiment marks our coding of their response as positive or negative