

Student Perceptions of Their Abilities and Learning Environment in Large Introductory Computer Programming Courses

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Abstract

Over the past 30 years, women completing computer science and computer engineering undergraduate degrees have been a minority compared to their male counterparts. We chose three obstacles to gender diversity in computer science and computer engineering that we wished to lessen the effects of: stereotyped traits, perceived abilities, and learning environment. Identifying implicit bias as a component of these obstacles, we implemented a series of activities designed to lessen the impact of implicit bias on our students.

Alongside discussing implicit bias with our students, we wished to gather current information on students' perceptions of their own abilities and the overall learning environment in introductory programming courses. This information would then be used to guide future course development and other possible interventions.

Entry and exit surveys were administered to students in two different large-enrollment (~700 students/semester) intro to computer programming courses at a large, midwestern research university. Course 1A is for first-year engineering students only; Course 1B is open to all students in the university. The surveys were also administered to students in the follow-up computer programming course (designated here as Course 2 and consisting of mostly first- and second-year engineering students) to see if there were any changes in student perceptions after taking two programming courses. This paper reports the results and analysis of these surveys.

Overall, the differences in perceived abilities and learning environment between women and men were not as large as we had feared at the beginning of this study. This may indicate that our efforts to combat implicit bias were partially successful, although since we do not have pre-implicit bias activity data, we cannot be certain. While there is definite room for improvement in our classes, it is encouraging to note that the women's responses are somewhat similar to the men's responses.

These introductory programming courses are some of the largest engineering classes offered at this institution; therefore, an improved understanding of student experiences in these classes will provide guidance on creating and sustaining a welcoming environment for all students.

Introduction and Motivation

Over the past 30 years, women completing computer science and computer engineering undergraduate degrees have been a minority compared to their male counterparts¹. The reasons for this gender gap are complex, but they can be generalized into the problems of recruitment and retention.

Stereotypes certainly play a role in whether a woman will feel welcome and valued in a field,² and hence choose to major in that field. STEM self-efficacy is sometimes held up as a reason for the gender gap, but some studies find that women have lower self-efficacy in STEM fields³ while others show almost no gender gap⁴. In computer programming, women may have lower computer self-efficacy initially, but they may have a faster rate of increase over the semester than their male counterparts⁵.

The Computing CARES initiative at the University of Michigan focused on three obstacles to gender diversity in the computer science and computer engineering undergraduate programs:

- *Stereotyped Traits*: the assumed traits of a computer scientist are not appealing to women, affecting entry-level enrollment (recruitment)
- *Perceived Abilities*: women have lower self-efficacy in STEM fields than their male peers; i.e., women view an A-/B+ as an indicator that they are *not* performing at a level sufficient to complete the degree successfully, whereas males view an A-/B+ as an indicator that they *are* performing at a level sufficient to complete the degree successfully (recruitment & retention)
- *Learning Environment*: women's experiences in freshman and sophomore-level courses are often negative (isolation, harassment, etc.), with the result that many decide to change majors (retention)

These particular obstacles interested us as we would like our introductory programming classes to help lessen or remove these obstacles that hinder enrollment and retention of female students in computer science and computer engineering.

Research shows that implicit bias is a contributing factor underlying these obstacles to gender diversity in STEM fields⁶. Therefore, we introduced a series of activities to highlight and combat the effects of implicit bias. In semester chronological order, they are:

1. *Student staff training*: graduate and undergraduate teaching assistants were led through a 1 hour workshop focused on bettering teaching skills through knowledge of implicit bias
2. *Implicit Association Test (IAT)*: students were assigned Harvard's Gender-Science IAT and were required to submit a form reflecting on taking the IAT (students did not submit the results from taking the IAT)
3. *Implicit bias presentation*: a lecture was given to all classes revisiting implicit bias, discussing why students took the IAT, showing interviews with women from industry, and

suggesting possible ways to address implicit bias; students shared their own stories during lecture and via online form

Along with these implicit bias activities, we wanted to know how our students' perceptions of stereotyped traits, learning environment, and perceived abilities changed over the course of the semester. Student cohorts can change drastically even from semester-to-semester, so it was important to us to know where our students currently stood in terms of these potential obstacles. This paper details the entry and exit surveys used to gather this data, the results, and our comments on the comparisons between women and men/beginning and end of the term.

Methods

We conducted entry and exit surveys to investigate the change in students' perceptions of their abilities and the learning environment in their large introductory programming course. Our hope was that women's perceptions of their abilities and learning environment would show a positive change from the entry survey to the exit survey if our implicit bias activities were effective. Entry and exit surveys already existed for each of the introductory programming courses participating in this study; therefore, we added the questions we needed to the existing surveys. The participants and specific questions added are detailed in the next sections.

Participants. The entry and exit surveys were administered to students in two different large-enrollment introductory computer programming courses at a large, midwestern research university. Course 1A is for first-year engineering students only; Course 1B is open to all students in the university. The surveys were also administered to students in the follow-up computer programming course (designated here as Course 2 and consisting of mostly first- and second-year engineering students) to see if there were any changes in student perceptions after taking two programming courses. As motivation, students in all courses received credit for completing the survey.

Design. The surveys were designed to be parallel as much as possible to allow for direct comparison of students' perceptions at the beginning of the course and at the end of the course. Table 1 shows the questions used to evaluate students' perceptions related to each of the three obstacles in question. We chose not to have a "neutral" option for the linear scale questions regarding learning environment.

Results

To obtain the data we needed, the surveys had to be matched up by student identifier to find the students that took both the entry and the exit surveys. After the matching was done, we removed the student identifiers. From this set of data, we selected those students who self-reported as either men or women. A summary of the responses and response rates is shown in Table 2. The distribution of responses for each pair of questions are shown in Figs. 1–7. The visual distributions are histograms plotted horizontally with men's responses on the left and women's

Table 1: Survey questions used for assessment. Sample questions are included in the Appendix.

Obstacle	Entry Survey	Exit Survey	Type
stereotyped traits	How interested are you in majoring or minoring in Computer Science or Computer Engineering?	How interested are you in majoring or minoring in Computer Science or Computer Engineering?	linear scale
Perceived Abilities	What grade do you hope to obtain?	What grade do you think you deserve to get in this course?	multiple choice
Perceived Abilities	How confident are you in your ability to obtain that grade?	What grade do you expect to get in this course?	multiple choice
Perceived Abilities	How confident are you in your ability to be successful in this course?	Do you think you were successful in this course?	linear scale
Learning Environment	I find computer programming intimidating.	I find computer programming intimidating.	linear scale
Learning Environment	I believe that other students in computer programming courses will be welcoming of me.	I believe that other students in computer programming courses will be welcoming of me.	linear scale

responses on the right. The y axis is labeled with the responses (linear scale or multiple choice); the x axis is the percentage of men or women who selected that response.

Table 2: Summary of responses for those students who took *both* the entry and the exit surveys in the Winter 2016 term (January-April 2016).

Course	Enrollment	Total	Total	Women Respondents		Men Respondents	
		# Respondents	Rate	#	Rate	#	Rate
1A	557	467	83.8%	169	36.2%	298	63.8%
1B	648	450	69.4%	182	40.4%	268	59.6%
2	725	290	40.0%	81	27.9%	209	72.1%
Total	1930	1207	62.5%	432	35.8%	775	64.2%

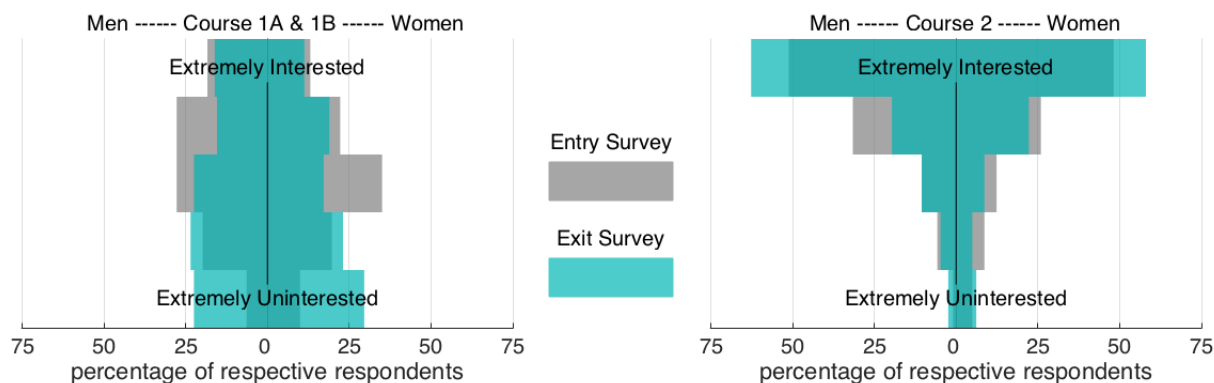


Figure 1: Distribution of responses to the question, “How interested are you in majoring or minoring in Computer Science or Computer Engineering?” *Note: This question was not asked as a linear scale question on the exit survey for Course 1B; therefore, those responses are not included here.*

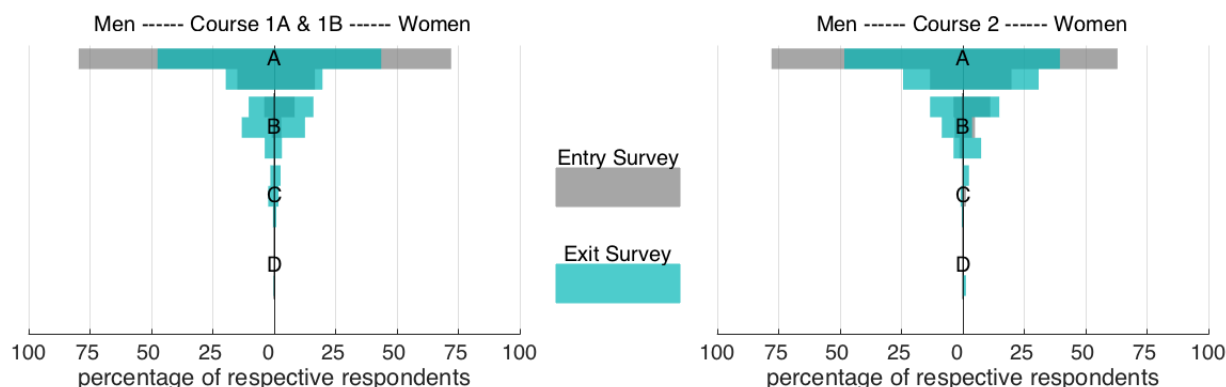


Figure 2: Distribution of responses to the questions, “What grade do you hope to obtain?” (Entry Survey) and, “What grade do you think you deserve to get in this course?” (Exit Survey)

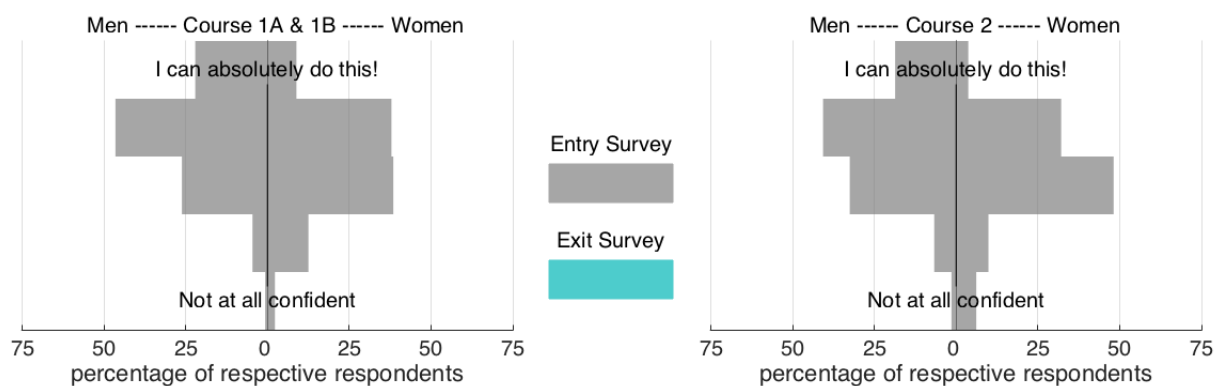


Figure 3: Distribution of responses to the question, “How confident are you in your ability to obtain that grade?” (Entry Survey, in regards to the grade they hope to obtain)

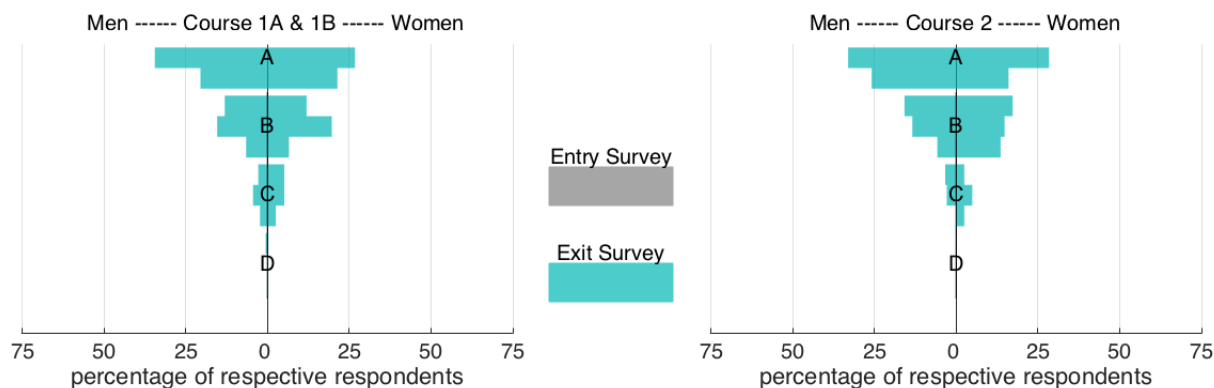


Figure 4: Distribution of responses to the question, “What grade do you expect to get in this course?” (Exit Survey)

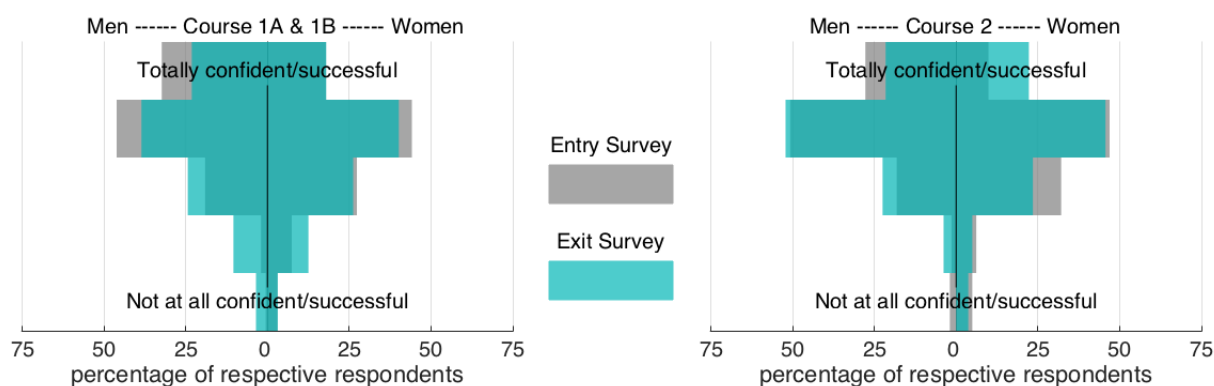


Figure 5: Distribution of responses to the questions, “How confident are you in your ability to be successful in this course?” (Entry Survey) and, “Do you think you were successful in this course?” (Exit Survey)

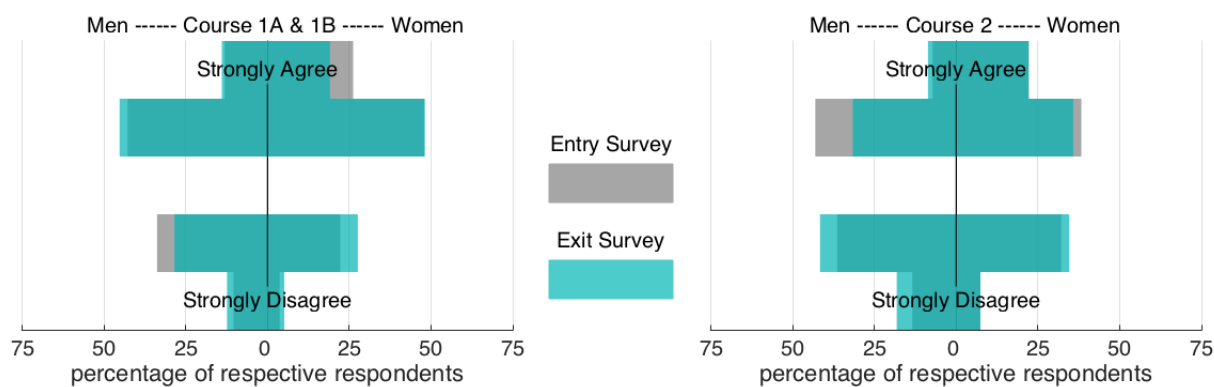


Figure 6: Distribution of responses to the statement, “I find computer programming intimidating.” Recall that we elected not to provide a neutral response option.

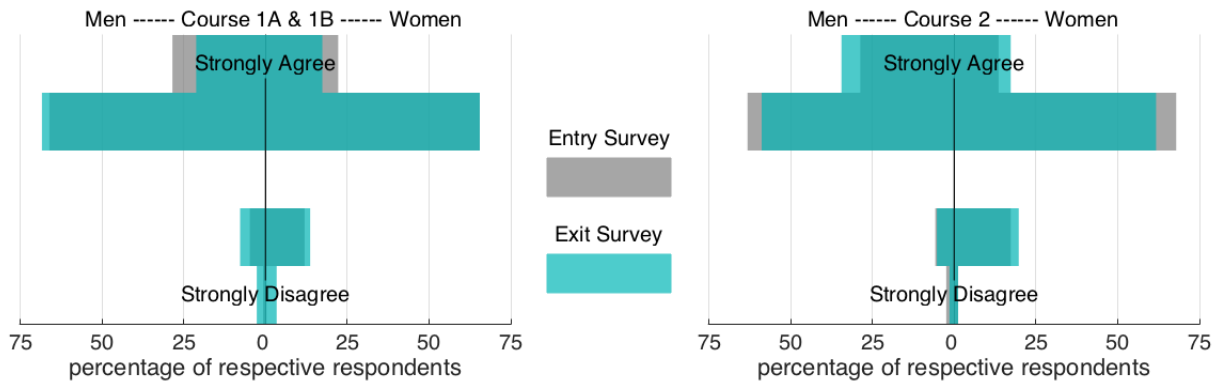


Figure 7: Distribution of responses to the statement, “I believe that other students in computer programming courses will be welcoming of me.” Recall that we elected not to provide a neutral response option.

Analysis

Overall, there is a trend that women report lower confidence and less interest in computer science and computer engineering (CS/CE) than do men. In terms of self-defined success, women show a slight positive trend, but students’ feelings on inclusion are still a concern.

Stereotyped Traits. Both men and women report being less interested in CS/CE after taking the first programming course (Course 1A or 1B), with a higher percentage of women reporting being “extremely uninterested” in CS/CE at the end of Course 1A/1B. We note here that Course 1A is required of all first-year engineering students, so it is perhaps unsurprising that significant numbers of both men and women report being uninterested in CS/CE on the entry survey. But it is disheartening that even more men and women are uninterested in CS/CE on the exit survey. Students that go on to Course 2 are generally those students who enjoy programming and had good experiences with either Course 1A or 1B. Encouragingly, both men and women report increased interest in CS/CE after the second programming course (Course 2).

Perceived Abilities. In all three courses, women tend to set the bar a little lower for themselves as opposed to their male peers, as reported by their “grade I hope to obtain” answers. Although, as most students aim for an A+/A/A-, this difference is not particularly concerning. We note that a potential target for possible intervention may be those students who hope to obtain a B+. As noted earlier regarding self-efficacy, high-performing female students may consider a B+ to be a “just barely passing” grade, perhaps thinking to themselves, “I have never programmed before... if I can just get a B+ then I will be happy.” When, in fact, a B+ shows good proficiency.

Generally, women report less initial confidence than men in their ability to obtain their desired grade and to be successful in the course (Figs. 3 & 5). However, by the end of the term, women either show less of a decrease in their evaluation of their self-defined success in the class (Courses 1A & 1B), or they show nearly the same success rate as men (Course 2). This may indicate that if a woman who has an initial interest in CS/CE can have a supportive, encouraging, and challenging experience in her first programming course, then by the time she gets through the

second programming course there is less of an overall difference in confidence between men and women.

Learning Environment. For both men and women in all three classes, there is a trend towards computer programming being less intimidating by the end of the course. However, more women than men strongly agree that computer programming is intimidating. Sadly, both men and women in the first programming classes (Courses 1A & 1B) report an overall decrease in feeling welcome in programming classes by the end of the term. The reasons for this are likely complex, and it will require more effort to what specific experiences caused students to feel unwelcome. In Course 2, men generally felt equally or more welcome by the end of the term. Women appear to bifurcate somewhat, with some more strongly agreeing that they felt welcome, but some disagreeing that they felt welcome.

Conclusions and Recommendations

The obstacles of stereotyped traits, perceived abilities, and learning environment exist for many different social groups. These introductory programming courses are some of the largest engineering classes offered at this institution; as such, they have a wide sphere of influence on the student body. An improved understanding of student experiences in these classes will provide guidance on creating and sustaining a welcoming environment for all students.

Overall, the differences in perceived abilities and learning environment between women and men were not as large as we had feared at the beginning of this study. This may indicate that our efforts to combat implicit bias were partially successful, although since we do not have pre-implicit bias activity data, we cannot be certain. While there is definite room for improvement in our classes, it is encouraging to note that the women's responses are somewhat similar to the men's responses.

Going forward, we plan to:

- Continue to administer the surveys and use results to guide future course development and other possible interventions
- Improve the surveys by asking demographic information at the end of the entry survey to avoid tainting data with preconceived notions of what the answers should be
- Analyze the revised surveys more rigorously to determine metrics that are statistically significant
- Track female student enrollment in computer science and computer engineering to see if enrollment and retention increases
- Include grades and other learning outcomes in future studies to directly assess student success
- Include a control group to observe whether these changes in student attitudes are different from normal changes in student attitudes after an introductory programming course
- Include open-ended questions to gain qualitative data

While this effort focused on gender diversity in computer science and computer engineering, we plan to also analyze our survey results for other social groups and use those results to guide future course development and other possible interventions. We encourage other institutions to do the same in order to gain a deeper understanding of the challenges our quickly-changing student cohorts face.

Acknowledgement

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Appendix: Sample Survey Questions

How interested are you in majoring or minoring in Computer Science or Computer Engineering?

	1	2	3	4	5	
Extremely Uninterested	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Extremely Interested

What grade do you hope to obtain? *

- ☐ A/A+
- ☐ A-
- ☐ B+
- ☐ B
- ☐ B-
- ☐ C+
- ☐ C
- ☐ C-
- ☐ Other: _____

How confident are you in your ability to obtain that grade? *

	1	2	3	4	5	
Not at all confident	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	I can absolutely do this!

How confident are you in your ability to be successful in this course?

	1	2	3	4	5	
Not at all confident	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	I can absolutely do this!

Do you think you were successful in this course? *

	1	2	3	4	5	
Not at all successful	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Totally successful
		Strongly Disagree	Disagree	Agree	Strongly Agree	
I find computer programming intimidating.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
I believe that other students in computer programming courses will be welcoming of me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

What grade do you think you deserve? *

- ☐ A+
- ☐ A
- ☐ A-
- ☐ B+
- ☐ B
- ☐ B-
- ☐ C+
- ☐ C
- ☐ C-
- ☐ D+
- ☐ D
- ☐ D- or lower

What grade do you expect to get in this class? *

- ☐ A+
- ☐ A
- ☐ A-
- ☐ B+
- ☐ B
- ☐ B-
- ☐ C+
- ☐ C
- ☐ C-
- ☐ D+
- ☐ D
- ☐ D- or lower