Evaluation of the Use of Growth Mindset in the CS Classroom

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ABSTRACT

Within computer science education, a growth mindset is encouraged. However, faculty development on the use of growth mindset in the classroom is rare and resources to support the use of a growth mindset are limited. A framework for a computer science growth mindset classroom, which includes faculty development, lesson plans, and vocabulary for use with students, has been developed. The objective is to determine if faculty development in growth mindset and active use of the growth mindset cues in the CS0 and CS1 classroom result in superior academic outcomes. Comparative study results are presented for two semesters of virtual classroom environments: one semester without Growth Mindset, and one semester with Growth Mindset. Female students demonstrated the most growth, as measured by academic grades, in CS0, and maintained that growth in CS1. Males demonstrated growth as well, with both males and females converging at the same high point of accomplishment at the end of CS1. Race and ethnicity gaps between students were reduced, improving academic equity.

CCS CONCEPTS

• **Social and professional topics** → **Professional topics** → **Computing education** → **Computing education programs** → **Computer science education**.

KEYWORDS

Growth mindset; Computer Science Education; Broadening Participation; Faculty Development.

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1 Introduction

A growth mindset encourages the development of intelligence, in contrast to a fixed mindset, which considers intelligence to be fixed and unable to be changed [1, 2]. A person with a growth mindset faces challenges in a positive way resulting in progressive achievements. Earlier work on the growth mindset is rooted in the belief that basic qualities are dynamic and changing. In learning environments, growth mindset can be encouraged through specific feedback and cues to students, emphasizing effort instead of accomplishment. Research has demonstrated that a growth mindset can raise the grades and engagement of underrepresented students [3, 4]. Innovations explored here support providing growth mindset training to computer science faculty and the use of growth mindset techniques and feedback methods in CS0 and CS1 computer science classrooms. Resources to support the use of a growth mindset in the computer science classroom are limited, and faculty development in the use of growth mindset in the classroom is rare. Prior work has focused on growth mindset in the K-12 classroom [5, 6], and materials support teacher-student daily classroom interaction. This research team developed faculty tools and practices that promote student development of a growth mindset approach to their CS0 and CS1 courses.

2 Background

2.1 Growth mindset in education

Prior work on growth mindset in educational settings has identified the use of growth mindset to move students away from deficit thinking and towards strengths-based thinking [7-9]. Growth mindset is asset-based and is a method which may help students overcome identity threats that may impact academic performance [10, 11]. Approaches for implementing growth mindset in the classroom often focus on K-12 environments [5, 6]. One of the most detailed outlines of interventions for implementing growth mindset in the classroom [8] was prepared for teachers of students with disabilities, but does not provide information on a specific implementation, the grade levels of students for the interventions identified, or any results. We build on this literature and show student achievement comparisons across time and across instructors to build a case for the utility of the growth mindset model developed for CS.

2.2 Growth mindset in computer science

Faculty who communicate to students that computer science is a field that can be learned may support student persistence in the field [12, 13]. Computer science educators have theorized how faculty may support students in shifting fixed mindsets to those of malleability [14-17], and the field suggests that metacognition and self-regulation, two practices of growth mindset learners, is vital to success in computer science [18]. Establishing a growth mindset is said to improve student academic outcomes [19, 20]. Studies of a "growth mindset pedagogy" exist in K-12 learning environments [21, 22] but few have studied how faculty convey messages of malleable intelligence through their teaching and assessment practices.

2.2 Research study context

The research study presented is the beginning of a longer, longitudinal examination of student support structures to encourage retention in the computer science major and persistence to degree completion. The context is a 4-year public urban research university. The university was designated as a Hispanic serving Institution (HSI) in the past 5 years, and the department where this research was conducted is more diverse than the university, with a student population that is 54% underrepresented in the profession, evenly split between Hispanic and Black students at 27% each. Many of the CS and IT majors are first-generation college students and arrive at the university with no prior experience or exposure to computer science programming.

Beginning in Fall 2019, the department began research on the use of growth mindset methods in the CS0 and CS1 classrooms. The research was initiated with a talk in Spring 2020 by Jen Rosato from the College of St. Scholastica in Minnesota, who had successfully piloted a growth mindset program. A faculty reading group was initiated, using [5], and faculty received individual copies of the book, with the intention of meeting monthly to discuss possible classroom interventions. Meetings continued during Spring 2020, but discussion moved from in-person classroom teaching to virtual classroom teaching, and initial plans to use growth mindset methods and develop university growth mindset materials were superseded by the need to establish remote, virtual classroom instruction, as the university and surrounding community was very highly impacted by the pandemic and associated restrictions.

During the summer of 2020, growth mindset discussions resumed, with the faculty working group becoming more focused, as they revised CS0 and CS1 curriculum and course materials, to ensure consistency with increasing undergraduate enrollment. Asset-based pedagogy continued to be a priority, as students were perceived as more isolated due to the pandemic, potentially making a growth mindset even more important for long-term persistence and success. Over time, the faculty have been collaborating and moving growth mindset ideas into the classroom teaching philosophies, incorporating more growth mindset language into interactions with students, and deliberately shifting course design, including lecture materials, homework, and laboratory assignments, towards growth mindset pedagogies. Earlier work [23] outlined the six principles of growth mindset, adopted for computer science. These include identifying motivations for each topic in computer science, encouraging the process of mastery, praising effort, not 'ability', identifying and encouraging initiative, such as planning, and thinking ahead, encouraging persistent and multiple attempts, providing positive, constructive feedback, and avoiding the imposter syndrome.

3 Approach

3.1 Growth mindset categories

First, the faculty distinguished between static and dynamic growth mindset. Under dynamic growth mindset, in the classroom, the timeline of the course is also necessary to keep track of. While there is a general guideline of encourage and guide students on their path to eventual success, there are timeline specific events such as evaluation of assignments, quizzes, and exams. Such events require time specific feedback: e.g., "you can catch up on what you've missed", "just always be coding" - at the beginning of the course; "you are on the right track", "moving in the right direction" - close to the middle of the semester; and "almost there", "you just need to finish it" - before the finals.

Growth mindset (GM) can also be categorized as group vs individual. While it is important to guide "all" in the right direction and make sure that faculty are spending time preparing all students to their main exams and quizzes starting in advance and then discuss the exam results and point to the weak side of overall performance in the section(s), faculty are able as well to embed growth mindset into feedback for every single student. There might be a need to talk in person or send additional emails regarding those outlining exam results in both lower and upper margins.

Another gradation which can be used while talking about GM categories is general vs specific/detailed GM. When giving feedback on a student's assignment or grading an exam, details really matter. The students should feel that faculty care and do read student explanations and understand student thoughts. This can be demonstrated by faculty addressing specific details of the work and potential mistakes or praise the good work in detail.

The faculty, as educators, had as a goal to combine all these GM techniques and implement them simultaneously, making GM an inseparable part of the courses. This integration of growth mindset becomes the way an instructor thinks and evaluates student work, within the tight timeframe of an individual class.

3.2 Research questions

The faculty designed a comparative study, based on Fall 2020 (FA20) and Spring 2021 (SP21) virtual (remote) classroom data. Both semesters were taught synchronously due to covid-19, for the full 16-week semester, using Blackboard as the learning management system (LMS). The course experience was consistent, in that the same virtual environment, CS0 or CS1 syllabus, remote office hours, and remote learning support were available. The research questions were:

RQ1: "Do explicit quotes and statements added to labs and assignments about growth mindset influence student achievement, as measured by course grades in CS0 and CS1?"

RQ2: "Do these quotes and statements influence student achievement differentially (e.g., impact women more than men)?"

FA20 instruction was conducted without growth mindset interventions. The research study was refined in late 2020 and the faculty used growth mindset interventions in SP21.

4 Growth Mindset in the Classroom

4.1 Growth Mindset Materials

Of the 5 faculty teaching 7 sections of CS0 and 4 faculty teaching 5 sections of CS1, 2 faculty from CS0 and 2 faculty from CS1 used the growth mindset interventions in the timeframe specified for the study. The participating faculty either had been part of the faculty working group, initially started in 2019, or were closely associated with the working group, participating in discussions, and sharing and contributing teaching materials to the growth mindset repository the faculty was building for CS0 and CS1.

Pedagogical change on the assignments were very specific and clear, as shown in Figure 1. The approach of displaying growth mindset inspirational quotes on bulletin board or in the classrooms are good examples of visually displaying them [8]. The faculty realized that inspirational quotes embedded in labs and assignments that are visually recognizable would promote growth mindset. Thus, the research team collected inspirational quotes that presented growth mindset ideas and added them to all the labs and assignments. Table 1 provides a selection of the inspirational quotes used as a header on all the pages for the labs and assignments as shown in Figure 1.

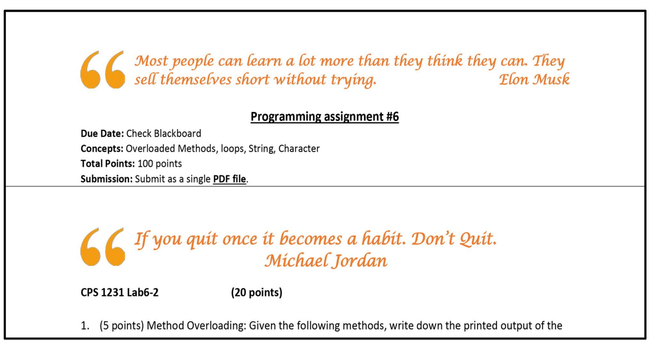

Figure 1. Examples of inspirational quotes used in CS0/1 labs

The inspirational quotes are grouped by theme. Based on the timeline and type of lab and assignments, the inspirational quotes are carefully selected. For example, quotes from the "Don't Give Up" theme are used towards the end of the semester, with quotes from the "On Failure" theme being used for complicated labs/assignments, and quotes from the "Computer Science Quotes" theme is used in the middle of the semester, and so on.

4.2 Growth Mindset in the Classroom

4.2.1 Participants. The research study was managed under an approved IRB protocol. Undergraduates enrolled in CS0 and CS1 for FA20 and SP21 participated in the research. During FA20, all CS0 and CS1 sections were taught as usual. During SP21, the faculty members who were participating in the growth mindset community of practice used their updated labs, assignments, lectures, verbal cues, and feedback to students in the virtual classroom. All students enrolled in the sections with the growth mindset faculty participated. Students in classes with faculty who were not participating in the growth mindset community of practice did not receive the growth mindset interventions. Their class was taught in the usual manner, as it had been during FA20.

Table 1. Selected inspirational quotes used in labs/assignments

Theme – Hard Work, Determination, Effort
Genius is one percent inspiration and ninety-nine percent perspiration. — *Thomas Edison*
Work hard now. Don't wait. If you work hard enough, you'll be given what you deserve. — *Shaquille O'Neal*
Theme - Success doesn't happen by accident
Success is the ability to go from one failure to another with no loss of enthusiasm. — *Winston Churchill*
Success is not an accident; success is a choice. — *Stephen Curry*
Theme - On Failure, Mistakes are how to learn
Nothing is impossible. The word itself says 'I'm possible!' — *Audrey Hepburn*
A person who never made a mistake never tried anything new. — *Albert Einstein*
Theme - Never stop learning, Don't Give Up
If you quit once it becomes a habit. Don't Quit. — *Michael Jordan*
Most of the important things in the world have been accomplished by people who have kept on trying when there seemed no hope at all. — *Dale Carnegie*
Theme - Computer Science Quotes
Programming is like a game of golf. The point is not getting the ball in the hole but how many strokes it takes. — *Harlan D. Mills*
I'm not a great programmer; I'm just a good programmer with great habits. — *Kent Beck*

4.2.2 Procedure. The faculty community of practice had discussed the types of common errors for each CS concept introduced in CS0 and CS1. Numerous areas were identified, including weak foundations in algebra and logic, confusion about variable scopes, logical operations, loops and stop conditions, array and index values, nested if-else and nested loops.

Next, the faculty discussed how they could collectively address these common problem spots and errors. The consensus was that for the GM faculty, errors, and problems which the students might encounter would be discussed at the time an assignment or lab was given, to normalize the expected error(s), and to discuss how students could respond.

Faculty discussed how praise can shape students' mindsets, the difference between process praise and person praise, and, how to shift praise to highlight the process. Examples of process praise were shared during the community of practice meetings, with discussions of where the comments could be used. The faculty goal was to avoid praising things that are typically considered stable such as talent or intelligence. The faculty wanted to encourage the development of students with a growth mindset, embracing problems as an opportunity to learn in contrast to students who assume that their intelligence is set, are more likely to seek to demonstrate their "smartness" and less likely to ask questions to overcome setbacks in their learning. Understanding this, the faculty realized, that whether a student has a growth or fixed mindset has a direct impact on how he or she faces academic challenges. A student with a growth mindset will accept challenges and persevere in order to succeed. This student will face learning and challenges with an "I have not mastered this 'yet'" attitude, implying that they will master the concept in the future.

4.2.3 Interventions. The growth mindset (GM) classes were very similar to the non-GM courses. Courses began in the usual way at the start of the semester, and the GM interventions were restricted to assignments, lectures, and verbal cues and feedback to students. Within the GM courses, each programming assignment given to students now had a GM quote as a header at the top of the page, offset by color and attributed to the speaker. Laboratory assignments also included motivating quotes in the header on each page. During lectures, one or two slides were used to initially to include a motivating quotation, which was briefly read and discussed with the class, before moving on to the standard lecture materials.

The most striking intervention was with the growth mindset faculty changing their behavior when providing verbal cues and direct feedback to students. For example, rather than stating that a solution was 'wrong', faculty would state that the student had 'not yet' solved the problem. Common shared errors were discussed, and classes discussed solutions together, reducing the potential for individual isolation and discouragement.

5 Data Gathering and Evaluation

5.1 Data Collection

In this study, the lab and assignment scores were collected for CS0 and CS1 courses for FA20 and SP21. For FA20, CS0 had a total of 7 sections with 130 students, CS1 had a total of 6 sections with 103 students. For SP21, CS0 had a total of 7 sections with 114 students, CS1 had a total of 5 sections and 98 students. In summary, a total of 233 students for FA20 and a total of 212 students for SP21.

In particular, the GM faculty that taught CS0 and CS1 in FA20 with no growth mindset interventions were a total of 3 and 5 sections, respectively, consisting of a total of 143 students (Table 2). The same GM faculty that taught CS0 and CS1 in SP21 with growth mindset interventions were a total of 3 sections each consisting of a total of 104 students. The remaining details of the number of male/female students, ethnicity, and race information is shown in Table 2.

Gender is categorized as Male and Female; Ethnicity as Not Hispanic or Latino (NHS) and Hispanic or Latino (HIS); Race as White or European American (WH), Black or African American (BA), Asian American (AS), American Indian or Alaska Native (IA), and Native Hawaiian or Other Pacific Islander (HP), which are based on the Census Bureau classification.

Two GM faculty taught CS0 for both semesters with the same material and rubrics consisting of 20 labs and 7 assignments. The same process was used with CS1 for both semesters consisting of 7 assignment and 7 labs. For CS0, GM_Faculty_A taught one section and GM_Faculty_B taught two sections for both semesters. For CS1, GM_Faculty_C taught one section for both semesters and GM_Faculty_D taught four sections in FA20 and two sections in SP21.

Table 2. Participants

		Gender		Ethnicity		Race			
		M	F	NHS	HIS	WH	BA	AS	IA/HP
FA 20 *N* = 143	CS0 = 58 3 sections	50	8	36	22	23	26	9	0
	CS1 = 85 5 sections	64	21	56	29	42	28	13	2
	N	114	29	92	51	65	54	22	2
SP 21 *N* = 104	CS0 = 46 3 sections	35	11	33	13	17	20	9	0
	CS1 = 58 3 sections	46	12	45	13	25	20	12	1
	N	81	23	78	26	42	40	21	1

5.2 Data Analysis Methods

Data was gathered after the conclusion of Fall and Spring semesters. Lab and homework assignments, and final grades were all used for the analysis. The CS0 and CS1 data score from the GM faculty's sections (Table 2) were merged and classified into two groups, FA20 (non-GM) and SP21 (GM). The data was further separated by gender, ethnicity, and race for the statistical analysis.

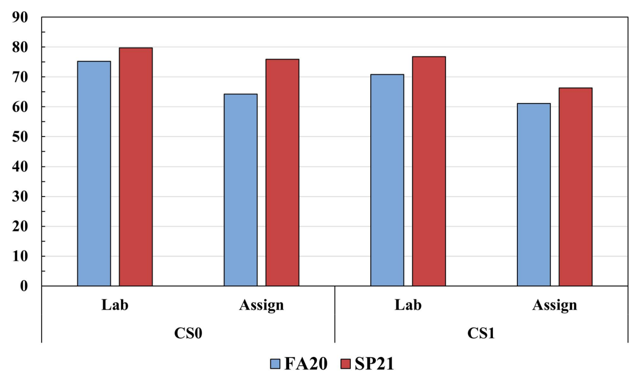

Figure 2. Lab and Assignment average scores for non-GM (FA20) and GM (SP21)

6 Results

6.1 RQ1: GM Impact on Learning Outcomes

6.1.1. Labs and Assignments. Overall, students in the growth mindset semester (SP21) performed better on both the labs and assignments with an overall average increase of 12% in CS0 and 8.5% in CS1 as shown in Figure 2. Here on after, both labs and assignments data scores for CS0 and CS1 were combined (i.e. CS0/1) and classified as FA20 (non-GM) and SP21 (GM).

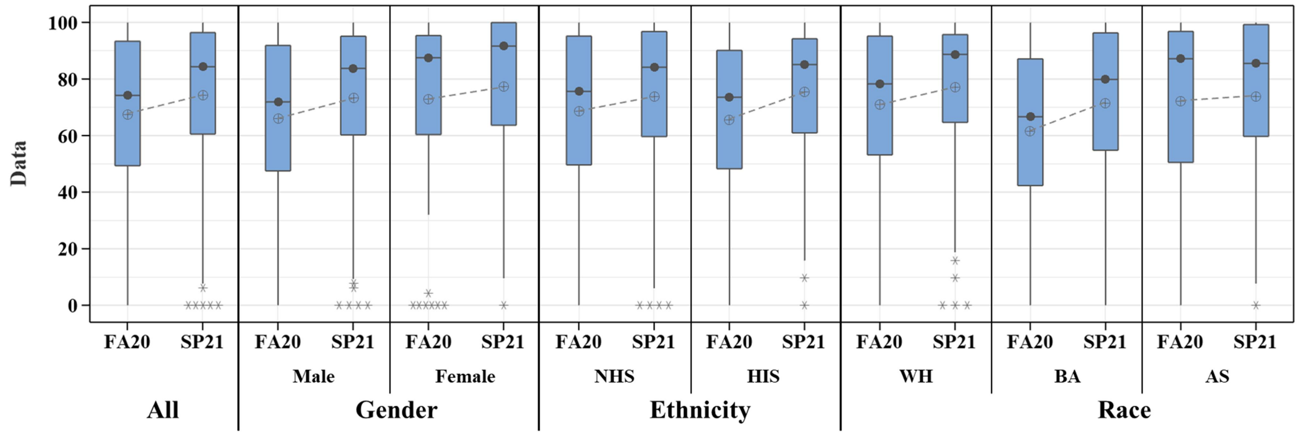

Figure 3. Gender, Ethnicity, Race: non-GM (FA20) and GM (SP21)

6.1.2. Mean Grades. From FA20 to SP21, CS0/1 students in the target classrooms shifted mean grades from 67.5 to 74.3 on a 100-point grade scale (Figure 3), with the pattern holding for both courses. These differences were compared using independent sample t-tests to understand whether the differences could be due to chance, or whether this null hypothesis should be rejected. The students who received the growth mindset intervention (μ = 74.4, sd = 27.7) compared to the students who did not receive the intervention (μ = 67.5, sd = 39.4) demonstrated significantly better grades $t(460) = -2.63$, $p = .004$.

6.2 RQ2: GM Impact by Demographics

6.2.1. Gender. When compared as sub populations, both men and women improved their average scores in the growth mindset condition. Specifically, men raised their mean score from 66.1 to 73.4 (Figure 3). The growth mindset condition led to better grades for men (μ = 73.5, sd = 27.4) than the control condition (μ = 66.1, sd = 28.7) and this difference was statistically significant $t(357) = -2.55$, $p = .006$. Women also improved in the growth mindset condition from a mean of 72.9 to 77.4, yet the lower number of women in the dataset led to lack of power to detect the difference as statistically significant for them as a subgroup $t(99) = -0.75$, $p = .229$.

6.2.2. Ethnicity: An unanticipated outcome was found with ethnicity, as the GM interventions had been designed for all students and did not target any community of students. Mean scores for Hispanic students appeared to increase at a greater rate than for non-Hispanic students, yet both subgroups increased their achievement markedly. Hispanic students who received the growth mindset intervention shifted nearly 10 points in final grades, with SP21 students earning mean score of 75.6 (sd = 25.1) and FA20 students earning lower scores (μ = 65.6, sd = 29.8) $t(119) = -2.21$, $p = .014$). Non-Hispanic students in the growth mindset condition (μ = 73.9, sd = 28.6) outperformed non-Hispanic students in the control condition (μ = 68.6, sd = 29.2) $t(330) = -1.70$, $p = .046$)

6.2.3. Race: Other subgroups were compared from Fall to Spring, with the growth mindset intervention occurring in SP21. Black students improved their average grades 10 points from control condition (μ = 61.6, sd = 29.7) to growth mindset condition (μ = 71.5 , sd = 28.1), $t(175) = -2.35$, $p = .01$. Asian students remained relatively steady with a 2-point shift, and white students improved their scores by approximately 7 points from control condition (μ = 70.9, sd = 27.5) to growth mindset condition (μ = 77.2, sd = 26.5), $t(182) = -1.65$, $p = .049$. The changes for Asian students were not statistically different.

A threat to validity of an academic achievement study could be the effect of time on grade results—meaning the specific semester itself (Spring semester, at the year mark of a global pandemic) may lead to increased achievement rather than the course implementation of a new initiative. The previous data comparison kept the instructor constant and compared across time. This analysis compares across instructors but holds the time period constant.

6.3 GM Impact by GM and non-GM faculty

The final letter grade earned in the course were converted to the 4.0 GPA scale. This was done because while the instructors who were a part of the study were sharing final numeric percentages, for the faculty who were not including growth mindset pedagogies only final letter grades were available.

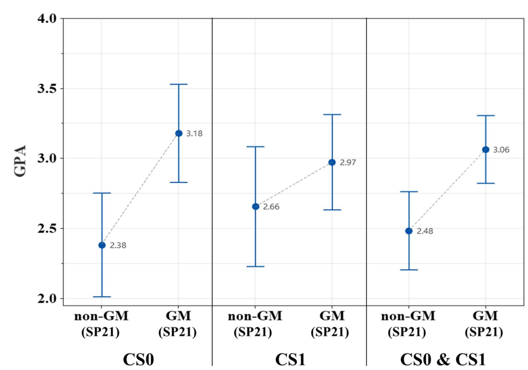

Figure 4. Average GPA (4.0 scale) for non-GM instructors and GM instructors

Figure 4 shows differences in average grades for each of the two courses. For CS0, the average GPA was 2.38 (C+) for non-GM classes and 3.18 (B) for GM classes. For CS1, the average GPA was 2.66 (C+) for non-GM classes and 2.97 (B-) for GM classes. An independent samples t-test was used to see if the groups differed statistically from one another in the Spring of 2021 only, in other words, whether students in the growth mindset courses did significantly better than the students enrolled in the same courses at the same time with no growth mindset pedagogies. Students in the GM condition ($\mu = 3.03$, sd = 1.27) outperformed their non-GM peers in SP21 ($\mu = 2.75$, sd = 1.24) by nearly a letter grade, and this difference was statistically significant $t(210) = -3.11$, $p = .001$.

6.4 Student-reported Impact

The impact of the use of the growth mindset materials on students was also assessed through a 5-question Likert scale survey, administered to the students in the growth mindset sections at the end of the semester. A total of 69 students responded to the survey, with CS0 ($n = 30$) and CS1 ($n = 39$), as seen in Figure 5. Overall students noticed the statements and most said they supported their learning, kept attitude positive.

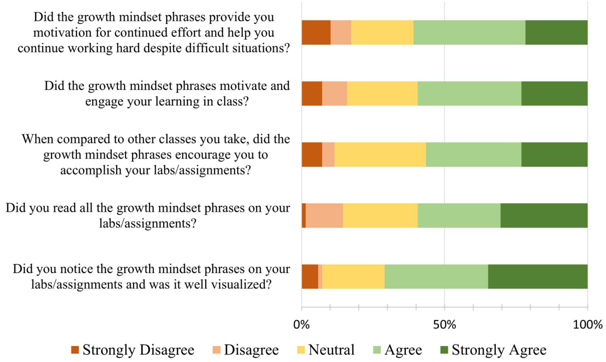

Figure 5. Student responses (*n* = 69) to the use of GM

Students in the growth mindset condition were asked to describe their experience of the growth mindset phrases that were added to assignments and labs, and sixty-nine students completed the survey. First, more than two thirds agreed they noticed the phrases and they were well visualized (71%) while slightly fewer said the phrases helped them work hard through difficult situations (61%).

Table 3. Comments from students in CS0/CS1 GM sections

Love the comments. They are very motivating.
I enjoyed seeing them on the homework and labs. I liked reading the different quotes every time.
I love it! I hope this continues because it motivates the student to face new challenges.
I like those phrases; it helps me not to give up when I have problems with the labs
When I get nervous about an assignment, I always think that I'm just learning and will grow to know it.
I think that it should be more visible and by people that are well known by students.

More than half agreed that the phrases motivated/engaged their learning in class (59%) and more than half read all of the phrases on their labs and assignments (59%). More than half stated the growth mindset phrases encouraged them to complete assignments to a greater degree than other courses (56%).

A full dataset, with comparison of the letter grades awarded, t-test results, and charts, showed that all students did better when the growth mindset statements were added to the classroom. This study was conducted with virtual classrooms, and the research team is currently working to see if this continues to hold true as face-to-face classroom interaction resumes. Table 4 summarizes the aforementioned statistical results.

Table 4. Summary of t-test Results

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$, Alternative hypothesis $H_1: \mu_1 - \mu_2 < 0$							
Criteria		Mean (FA20, SP21)	StDev (FA20, SP21)	t	df	p-value	Hypothesis
All	CS0/CS1	67.5, 74.3	39.4, 27.7	-2.63	460	0.004	Reject
Gender	Male	66.1, 73.5	28.7, 27.4	-2.55	357	0.006	Reject
	Female	72.9, 77.4	31.7, 29.1	-0.75	99	0.229	Accept
Ethnicity	Non-Hispanic (NHS)	68.6, 73.9	29.2, 28.6	-1.69	330	0.046	Reject
	Hispanic (HIS)	65.6, 75.6	29.8, 25.1	-2.20	119	0.015	Reject
Race	White (WH)	70.9, 77.2	27.5, 26.5	-1.65	182	0.049	Reject
	Black or African American (BA)	61.6, 71.5	29.7, 28.1	-2.34	175	0.010	Reject
	Asian (AS)	72.3, 74.0	32.2, 30.1	-0.25	83	0.401	Accept
GPA	Non-GM classes, GM classes	2.75, 3.03	1.24, 1.27	-1.76	220	0.004	Reject

7 Conclusion and Future work

The results demonstrate that, in a virtual environment, the implementation of growth mindset motivation quotes, verbal cues and feedback to students is easy to do and can make a detectable difference. Faculty discussed common pitfalls with the class, identifying them as expected and making sure students had strategies to detect and overcome challenges. Faculty focused on individual and overall class improvement. The sample size for this research was small, given the one-year timeframe of the study and the smaller class size of 20-25 which the department maintains for improved learning. The research team will continue to gather data to understand if a larger study, with greater numbers, shows similar results. In addition, the team will begin to make more complex statistical analyses of the data as numbers increase and intersectional groups (Latinas, black men) reach large enough numbers for statistical analyses to be meaningful. This academic study is unique in that the diverse population allows for marginalized groups to reach critical mass for statistical study. This is part of an ongoing effort towards growth mindset teaching, and it is a promising finding that faculty who have been developing the growth mindset framework in computer science teaching and learning for multiple semesters saw an increased bump in achievement with the addition of explicit quotes and statements.

The research study presented in this paper has also developed an initial set of faculty interview codes that denote fixed and growth mindset beliefs of educators in computer science. Future work will include an external evaluator who will add observations of lessons and host focus groups with students to better understand how the ideas of incremental intelligence are evident (or not evident). Triangulating these sources could provide new information regarding *how* instructional practices that emphasize effort may influence student learning.

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