Simple Steps to Lower Student Stress in a Digital Systems Course While Maintaining High Standards and Expectations

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Abstract

Student stress is an important issue that is gaining more attention with time in our universities because of the increase in competition in every aspect of the educational process, from college admission to finding a good job that satisfies students' expectations. Some studies even conclude that Engineering and Medicine students are the ones who suffer the most from academic stress. Experiencing stress directly impacts students health and wellbeing, and might cause them to make behavioral changes and sacrifices which in turn also impact their health and academic performance, especially as they undergo long-term unhealthy levels of stress throughout their years of education.

At our institution, the admission rate is usually about 10% and the students admitted often pursue double majors along with a minor, while at the same time getting some research experience, applying for internships every summer, and trying to achieve many tasks that would improve their resume to try to secure the best possible future job and life. On top of this pressure, some courses tend be harder than others and/or require more work.

This paper discusses the work realized in the Digital Systems course at our institution that has an established reputation of being the course with heaviest load among our Electrical and Computer Engineering courses. This course has been taught for the past two semesters – Fall 2018 and Spring 2019 – by a new faculty member who taught it the first semester (Fall) nearly the same way it has been taught for years, studied students' data and feedback, and redesigned the course the next semester (Spring) aiming to reduce students' perceived load and stress while maintaining the same high course standards and expectations.

Results show that by making a number of small changes to different aspects of the course, the course's likability increased and students' stress decreased from the first semester to the second. The small changes included adding a technical workshop at the beginning of the semester to better prepare students to use and debug the hardware description language they will be using throughout the course, combining every pair of homework assignments into one, carefully spreading out due dates on the schedule and never having two assignments due on one day, using a new learning management tool that enables students to submit their projects as often as they can

and get instant feedback about their assignments, using a new scheduling tool to make it easier for students to schedule appointments with the instructor, using an always-active anonymous feedback survey for students to constantly provide feedback about different aspects of the course, providing some additional resources, and removing some barriers. Furthermore, these small changes had a surprisingly positive impact on the standards of the course. Students' raw grades – i.e., grades before final raise/curve – significantly improved and the class' final projects reached higher standards.

1 Introduction

Studies have been showing that universities are becoming an additional source of stress to our students due to many reasons [1, 2, 3, 4]. Being stressed over a long term has its short- and long-term impacts on the student in terms of health, academic performance, social life, and other domains.

Chronic stress and/or anxiety impacts the student's health as it could lead to short- and long-term illnesses, cognition problems, memory deficiencies, problems with focusing, and faster aging [5, 6, 7, 8]. Studies have also shown the negative impact of stress on students' academic performance [9, 10, 11, 12, 13]. Furthermore, studies have suggested that stress unfairly impacts students in vulnerable conditions and students belonging to minority and underrepresented groups [7, 9, 14, 15, 16].

To mitigate student stress, some works address its symptoms by using stress-reduction/coping techniques during and/or outside of the classroom. Some of these techniques involve mindfulness activities, changing students perception of stress, interventions, sending students encouraging emails before exams, etc. [2, 17, 18, 19, 20, 21, 22, 23]. Other works even redesign their whole curriculum to reduce student stress [24]. It is important to note that most of stress-related research is focused on medical students and rarely addresses engineering students.

In this work, we address the direct causes of student stress in an Electrical and Computer Engineering (ECE) course at our institution – the Digital Systems course – and suggest a list of concrete simple steps to reduce it. We believe and hope that our steps could easily be replicated and applied – fully or partially – in other engineering courses since most engineering courses in different institutions have a similar structure to our course's. Course quality and amount of learning definitely come into play when making changes in our courses to reduce student stress, therefore, we also study that in this paper and make sure that the learning and course quality remain the same, or, even better, improve.

The remainder of this paper is organized as follows. Section 2 describes the stressful course to be redesigned. Section 3 details the changes that were applied to the course. Sections 4 and 5 introduce the data that was collected and the analysis methods that were used respectively. Sections 6 and 7 respectively present and discuss the results. Section 8 concludes the study.

2 Digital Systems Course Overview

Our Digital Systems course is offered over about 15 weeks throughout the semester, where students meet with their instructor twice per week for a duration of 75 minutes each and once per week with their lab TA for a 3-hour-long session. Both the instructor and teaching assistants (TA's) are also available for office hours throughout the week. Usually, about 50 students enroll for this course every Fall semester and about 40 every Spring semester. This course, up until Fall 2018, used to be known as the toughest ECE course with the most load in our institution.

The course teaches students how to design and implement combinational and sequential digital systems with special attention to digital computers. It also includes a lab session that teaches them to use of computer-aided design tools, hardware description languages (HDLs), and programmable logic chips to facilitate larger and higher performance designs. The main topics covered in the course are: Boolean algebra, Boolean arithmetic, Boolean factorization, logic blocks, Boolean adders, multipliers, and dividers, memory elements, finite state machines, pipelining and hazards, asynchronous design, CMOS design, defect tolerance, and testing. This course is not required for ECE students but is required for those double-majoring in both ECE and Computer Science (CS). It also requires student to have taken our Computer Architecture course as a prerequisite.

The course grade consists of the following elements:

- Homeworks – Short assignments that students should complete at home.
- Quizzes – Five-minute quizzes completed during class.
- Exams – Two exams; one toward the middle of the semester and another at the end.
- Labs – Lab session that occur once per week where students have to complete certain tasks to finish.
- Semester-long project – This is a project that students complete through submitting a series of checkpoint assignments throughout the semester. It involves designing and implementing a pipelined processor from scratch using an FPGA board [25], then interfacing with external components to implement and play a game on the processor.

The course uses the Sakai learning management system [26]. Piazza [27] was used for announcements and discussions (including Q&A). Grading written assignments is performed using Gradescope [28]. Grading HDL assignments was performed manually using some autograding scripts in the Fall semester then using AG350 [29] linked to Github [30] in the Spring semester.

3 Course Redesign

A new instructor taught this course during Fall 2018 the same way it has been taught for years, collected student feedback, studied the data, and made a series of simple modifications to the course during Spring 2019. These updates were mainly aimed to reduce students' stress and improve their experience during the course while trying to maintain the course's high standards.

The small, but many, modification to the course consisted of the following:

1. *Spreading out deadlines* – The course had many deliverables that are due, whether they are homeworks, project checkpoints, lab reports, quizzes, or exams, and many of them were

due on the same day. The number of deliverables was lowered (see following bullet points) and the remaining ones were spread out so that none of them was due on the same day.

2. *Merging homeworks* – The number of homeworks was cut down in half by simply merging every two homeworks together.
3. *Lowering the number of quizzes* – Quizzes were scheduled once per week. Instead, during the Spring semester, the quizzes were pop quizzes that covered the same topics but that occurred at a lower frequency (about half).
4. *More time for assignments* – Before the Spring semester, students sometimes had only a few days to complete and submit some of the assignments. In the Spring semester, every assignment was released right after its related material is covered and students were given at least one week to complete it.
5. *Replacing lab reports* – Lab reports were due about a week after every lab session and they required the use of Latex to compile them. These reports were eliminated and they were replaced by a set of short questions that the TA asks the students at the end of each lab.
6. *Adding a Verilog workshop* – Verilog was the HDL used for the course and students were wasting too much time debugging their projects. During the Spring semester, a Verilog workshop was added as a "Lab 0" (before the first lab) to better prepare students for Verilog, go over some common issues that they are most likely to face, and learn best practices for debugging in Verilog.
7. *Adding a lecture about sensors, actuators, and making* – Students struggle the most during the final part of the project when working in teams on developing a game that runs on the processor and interfaces with outside peripherals, sensors, and actuators. To help take some of the load off of them, a new lecture was introduced during the Spring semester about interfacing with sensors, actuators, and outside electronic devices, and about making in general (includes 3D printing and laser cutting).
8. *Providing clear rubrics* – Also to help remove some ambiguity surrounding the final part of the project, we introduces a unified clear rubric to students that specifies the number of points they get for every possible task they could perform. This way, no matter what game they decide to develop (that is their choice), they know how many points they can accumulate for each complete task.
9. *Additional TA office hours* – There were two TA office hours per day, from Monday to Thursday, during the Fall semester (and previous semesters). Friday TA office hours were added in the Spring semester to have two additional weekly hours.
10. *More accessible instructor office hours* – When students needed to meet one-on-one with the instructor, they had to send them an email to check if the instructor could do so. The instructor would then email them to check their availability. After they reply with their availability, the instructor emails them with the confirmed date and time for the appointment. This whole process that has many barriers was replaced during the Spring semester by using an automatic scheduler that is always linked to the instructors calendar. The automatic appointment scheduler used is Calendly [31].

11. *Instant project feedback and resubmissions* – In the Spring semester, we used AG350, an autograder tool that links to students' GitHub repositories and instantly autogrades their project checkpoints. This does not just let students get instant feedback about their progress, but also allows them to resubmit as often as they like before the deadline, which in turn incentivizes them to start early.
12. *Constant feedback collection* – The instructor introduced in the Spring semester a link that students can always access to provide their feedback anonymously about anything concerning the course. It consisted of a Qualtrics survey that has on box where they can write whatever they want and submit it. The instructor check their feedback once or twice per week and tried to address their concerns as much as possible within the course constraints.

Everything in the course that is not mentioned above remained the same. This includes but is not limited to: the instructor, the grading weights and policy, the homeworks and quizzes topics, the project requirements, the lectures material, and the exams topics and difficulty.

4 Analyzed Data

Three sources of data were studied in order to analyze the effectiveness and impacts of the course redesign:

- *Course evaluations surveys* – These are the standard course evaluations sent by the university to students toward the end of the semester.
- *End of semester surveys* – These are surveys developed by the instructor which contain course-specific questions. They were also sent to students toward the end of the semester.
- *Course grades* – These include the grades that students received on all their assignments, before and after a raise/curve is applied.

5 Evaluation Methods

Qualitative data was analyzed using the open coding methodology [32, 33]. Open coding is a method used in grounded theory to identify, classify, and analyze qualitative information. The practice involves reading through data and assigning labels, known as codes, to selected portions of text. The sections vary in length, ranging from a single line to an entire document. The process of determining codes may be repeated on the same piece of text using various sized text fragments each time. This is done multiple times until no more new information can be extracted. Researchers then look for patterns in the generated codes to create more general categories. In particular, this technique was beneficial for evaluating course feedback. It allowed for an initial objective examination of all student remarks and was conducive to a comprehensive review of themes presented in student responses.

As for quantitative data, originating from both the surveys and the grades, standard statistical analysis operations are performed to represent and analyze the data.

6 Results

6.1 Qualitative Data

Voluntary survey data was requested toward the end of the semester from a class of 50 students in the Fall, 19 of whom completed the surveys, and a class of 38 students in the Spring, 33 of whom completed the surveys. A higher proportion of students completed the survey in the Spring semester because they were incentivized through extra credit, unlike those of the Fall semester. Students enrolled in the course were generally of senior status and double majors in the electrical and computer engineering department and computer science department. The majority surveyed reported taking an average of 4 courses that semester in addition to looking for a job or internship during that time.

Categories were generated based on open coding of student feedback. Responses were first coded searching for recurring themes and sentiments. They were then recoded to establish a correlation between these patterns of jargon and perceived workload and stress. Within each category a comparison between the responses of the two groups was performed to analyze the effectiveness of the changes in the course that were made from the first to the second semester.

Responses to the following open-ended questions were reviewed:

- Give an adjective to describe the course
- Overall course appraisal
- Things I liked about the course
- Things I did not like about the course
- My suggestions for ways to improve the course (and lab) and/or decrease its load while maintaining quality

Based on the above questions' responses from both semesters, the following seven categories were discovered and extracted (the shown examples include both perceived positive and negative feedback):

Category 1: Workload

- *Description:* Students' perception of the amount of work given in the course and the time commitment to complete various assignments (projects, labs, homework).
- *Example Student Responses:*
  - "This class is exceedingly time consuming"
  - "Never have I ever had a class with so much work assigned [...]"
  - "The workload is very hard to manage."
  - "[...] workload seemed a bit unnecessarily high at times [...]"

Category 2: Emotional Response

- *Description:* Feedback that incorporated the use of emotionally charged descriptions of student experiences.
- *Example Student Responses:*
  - "This is hazing for ECE students."
  - "Life-destroying. You literally lose yourself in this class."
  - "I experienced such defeat despite devoting the greater part of my life to this course this semester."

Category 3: Overall Likability

- *Description:* Indicators of how much students enjoyed the course.
- *Example Student Responses:*
  - "I think the material and projects were very interesting [...]"
  - "[...] final project makes this class a burden that turns people away from digital systems"
  - "[...] I loved the course and would definitely recommend it to other Electrical Engineering students"

Category 4: Value of Learning

- *Description:* Students' association of their effort to what they feel they gained from the course. This includes interpreted importance of what was learned, and skills developed.
- *Example Student Responses:*
  - "[...] challenging, but incredibly rewarding."
  - "I can't think of a single rewarding, educational part of my final project."
  - "[...] the work never felt useless or impractical."
  - "Material is relevant to job interviews [...]"

Category 5: Anticipatory Stress

- *Description:* Factors contributing to student stress that were not directly a result of enrollment in the course. These responses describe preconceived notions about the course that affected perspectives regarding the reputation of the course.
- *Example Student Responses:*
  - "[...] showing students the pained course reviews of past students on the first day of class is just mean."
  - "When the TAs introduced the project to my group, they literally noted that it "will be the worst two weeks of your life" [...]"
  - "[...] we are prepared at this point in our ECE curriculum at [...] to handle it."

Category 6: Course Structure & Grading

- *Description:* Student comments related to the course schedule, grading policies, and expectations.
- *Example Student Responses:*
  - "[...] level of connection for the most part between labs, project checkpoints [...]"
  - "[...] grading seems to be arbitrary and you never know how many points you have [...]"
  - "Expectations were for the most part clear [...]"
  - "Good pace (not too fast, not too slow)"

Category 7: Instructor Quality

- *Description:* Feedback directly about the quality of the instructors (professor and teaching assistants).
- *Example Student Responses:*
  - "The professor was very fair and the TAs were very timely."
  - "[...] seems to care about the course and about the students [...]"
  - "[...] obviously have the passion to teach this course and for students to learn [...]"
  - "I am very disappointed by the lack of tutoring availability [...]"

Significant results of student responses for each semester are summarized below:

- *Fall 2018:* Overwhelmingly, respondents used the phrase "too much work" to describe the course. Students deemed the course assignments, particularly the final project, unnecessarily difficult and "anxiety inducing". Also contributing to the amount of stress experienced was the negative anticipation caused by the course's reputation for "intentionality of suffering". Moreover, feedback shows that unclear grading standards for the final project caused many students to feel that the course's expectations were unrealistic and thereby unattainable. Many students also said that they did not feel they learned anything useful from the completion of the project and their knowledge gained did not match the time and effort that was forgone. Respondents requested more professor intervention, especially when they had concerns. They also mentioned that it wasn't always easy for them to voice those concerns, which had an adverse impact on their overall enjoyment of the class.
- *Spring 2019:* Student accounts noted that although the amount of work for the course was more than any other course they had ever taken, this was expected and viewed as a worthwhile challenge. Comments included references to feeling a "sense of accomplishment" in the end, making the accumulation of stress throughout the semester a rite of passage that allowed them to grow. Some respondents asserted a desire for more ingenuity and creative freedom in the final project and a reduction in the work expected to be completed over university breaks. Many students admitted to the historical fear

associated with taking the course, but did not believe their experience aligned with the sacrifice on mental health their peers cautioned them about. The strongest positive responses from students correspond to feeling that their learning was valuable, while the strongest negative responses pertain to the overall workload of the course.

The frequencies of recurring codes between semesters in each category are presented in Figure 1. Figure 2 graphs this same data as a proportion of the number of responses received normalized by the number of students for each term.

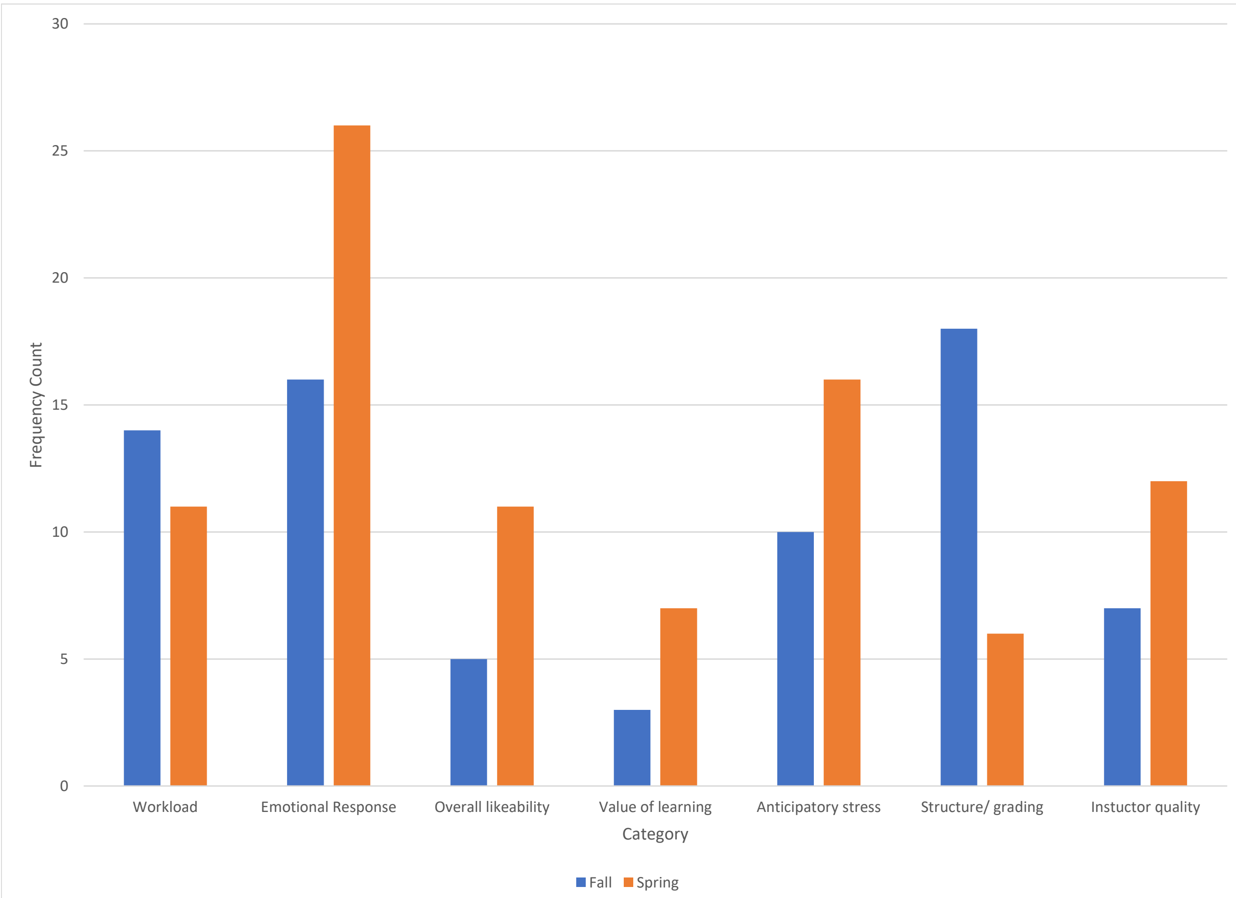

Figure 1: Frequency count of most commonly seen comments in each category.

Values in the graphs are based on cumulative answers aggregated from each of the open-ended questions. Overall, negative comments outnumbered positive comments. However, the number of positive comments grew from the Fall to Spring semester, particularly in responses on the subject of overall likability and course structure. The chosen codes show the greatest change from one group to the next and indicate a positive shift in student perceptions in the course. Categories of emotional response and anticipatory stress showed a decrease in the occurrence of perceived negative responses. This can be attributed to the students' feeling more welcomed and open to sharing their opinions, as indicated by an increase in feeling positively about the instructor quality.

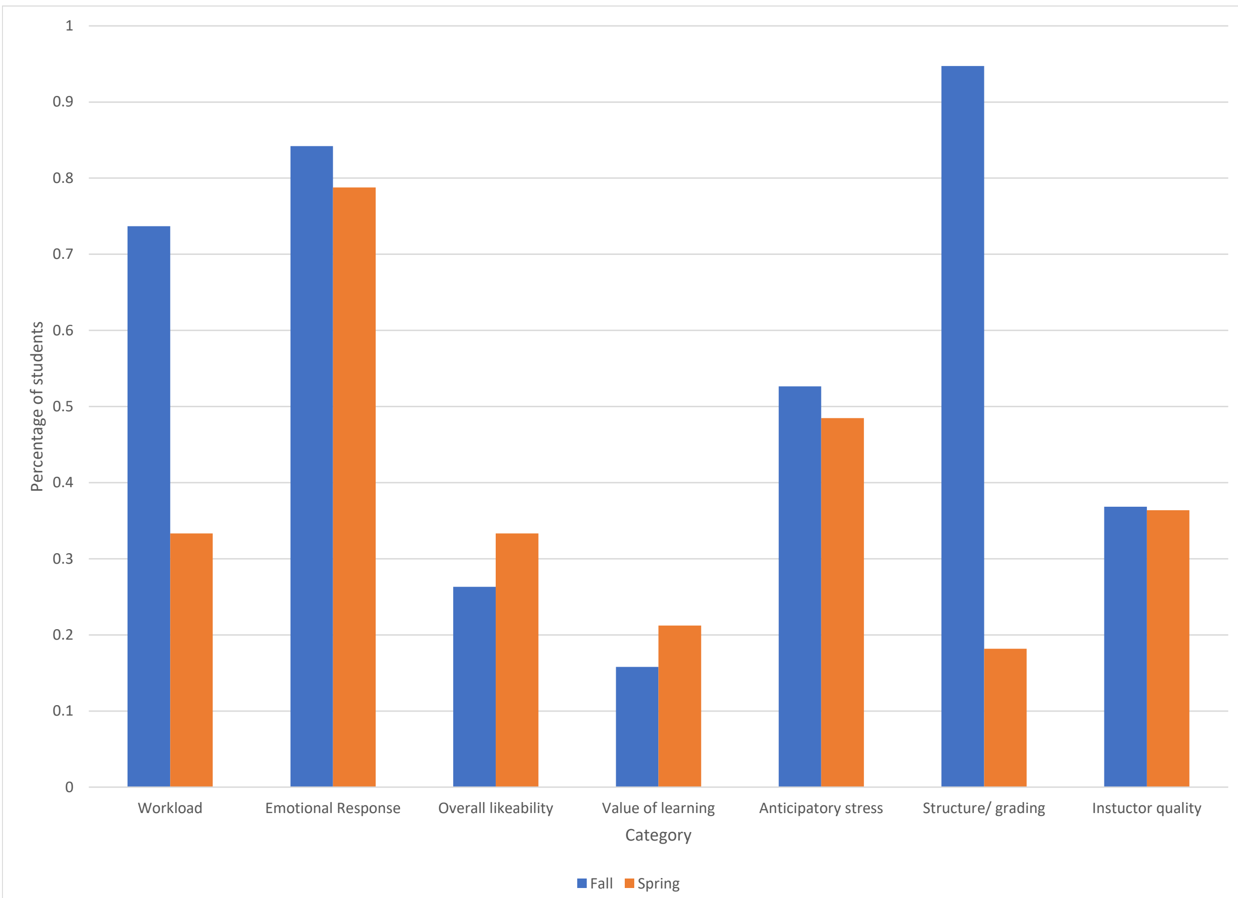

Figure 2: Proportion – normalized by the number of students in the corresponding semester – of most commonly seen comments in each category.

6.2 Quantitative Data

The main quantitative results that were collected are summarized in Table 1. These results show how each one of the shown measures, with no exceptions, improved in the Spring 2019 semester over Fall 2018. The students' perceived workload of the course dropped. Their perception of how much they learned increased, even though what was taught was the same in both semesters. Their perceptions of the instructor's quality and the course quality both increased, even though the instructor and the course content were the same in both semesters. Most significantly, the raw grades of the course increased by about seven points over 100, or about 9%.

Table 1: Quantitative Results Summary. "Average Raw Grades" designates the average class grade before any raise/curve is applied. The "Difference" column designates the absolute difference between values of both semesters. The "%Change" column designates the absolute rate of change between the two semesters.

Measure	Fall 2018	Spring 2019	Difference	%Change
Perceived Workload (max = 5)	5.00	4.84	0.16	3.2
Perceived Learning Amount (max = 5)	4.11	4.24	0.13	3.16
Perceived Instructor Quality (max = 5)	4.00	4.18	0.18	4.5
Perceived Course Quality (max = 5)	3.26	3.66	0.4	12.27
Average Raw Grades (max = 100)	76.97	83.95	6.98	9.05

6.3 Final Project Quality

Examining final projects that were submitted in both semesters, there was, on average, a noticeable improvement in the quality of the projects. The projects of Spring 2019 were more complex and more diverse than those of Fall 2018. They involved the use of more interfaces, more sensors, and more actuators, both in terms of types and quantity.

In addition, dealing with more complicated interfaces become more mainstream in the Spring semester. For example, only one team interfaced with and SD card in Fall 2018 while three teams did that in Spring 2019.

7 Discussion

When remarking on things they liked about the course, students from both semesters commented on finding the course content captivating and enjoying learning the material in lectures. Students in the Spring semester stated that they felt the course had an adequate pacing and laid out clear expectations. By contrast, only one student in the Fall gave feedback indicating course structure as something that they liked. Even though the covered material was the same, this shift in opinion is somehow expected due the the minor changes in course schedule that took effect in the Spring semester to spread out due dates.

Accordingly, when asked about things they did not like about the course, far fewer students in the Spring had negative feedback concerning the value of learning received from the course. The perception of the workload received significantly dropped in the Spring semester, with students expressing much less sentiments about the impact of the course on their emotional and mental health.

Both groups emphasized the course's reputation for high stress levels. Respondents in the Fall confirmed these expectations were correct. The Spring semester students however, commented that attempts to use the course history as a scare tactic to make them start working early were not necessary or accurate. Although students may have had similar concerns of anticipation entering the course, the changes drastically shifted the reinforcement of these views.

In a similar manner, students' view of instructor quality in both semesters was generally positive. In the Fall, students reported that the professor was well-intentioned, but they would have liked more involvement. After the addition of the always-active anonymous feedback survey and more accessible one-on-one office hours, multiple students in the Spring semester felt that the instructors cared about their learning and readily made themselves available to assist when needed.

Responses relevant to course structure and grading policies showed the most discrepancy between the two semesters. Making the small adjustments of combining homework assignments, introducing the Verilog workshop, adding a lecture about sensors and actuators, and making an explicit grading rubric for the final project led to a decrease in expressed anxiety caused by overlapping assignment due dates and unclear criterion for how the quality of their project work would be assessed.

Analyzing the data on student attitude revealed an improvement in standard outcomes and general likability. When comparing student feedback in the first semester with feedback from the second, students in the Spring semester seemed to have more pride in their work and saw significantly more value in their learning with the removed barriers. The qualitative survey outcomes were consistent with the quantitative data associated with student grades for each semester, thus demonstrating that the small changes had an overall positive impact on the course by decreasing student stress and increasing course grades, quality, satisfaction, and likability.

The main limitation of the reported results is the discrepancy in response rates between each group. Survey data from the Fall semester showed a response rate of around 38%, likely meaning that only students who had very strong feelings (positive or negative) about the course submitted answers. Whereas students in the Spring semester, who were incentivized with additional points on their final grade, had a response rate of nearly 87%. This data suggests that respondents in the Spring were more compelled to offer feedback thus making the reviewed data more representative of the larger group.

Another limitation of this work relates to the timing of the administration of the questionnaire. As noted in many responses, the survey was completed while students were concurrently working to complete the final project. This may have led feedback to be more emotionally charged than typical due to the added pressure that students experience during the final weeks of the semester.

8 Conclusion and Generalizable Findings

This paper shows how making some small changes to a technical engineering course could lead to a significant reduction in student stress, while not only maintaining quality, but also improving it. These simple steps also showed to increase the course's and instructor's likability. Of course some aspects of the course improved from the first to the second semester, but it was clear from the results how students' perception plays an important role in students' judgement. For example, students perceived that they learned more while the material covered was still the same. The main thing that changed was their stress levels, which made them like the course more.

The key generalizable findings from this work could be summarized in the following: In order to reduce students' stress while maintaining – and even improving – quality, we advise instructors to:

1. reduce barriers;
2. increase the resources available to students;
3. decrease the quantity – not necessarily content – of assignments;
4. spread out assignments' due dates without having multiple assignments due the same day;
5. provide clear rubrics for students that are fair independently of the freedom the students might have in the assignment;
6. remove any useless workload that does not serve the learning objectives;
7. substitute useful workload with alternative solutions that are simpler for the students and still lead to the same desired learning outcomes;
8. allow students to get instant feedback about their work, learn from their mistakes, and resubmit more often; and
9. have simple and automated mechanism for students to provide constant anonymous feedback and schedule appointments.

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