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Analyzing the Implementation of the Agile Methodology in a Mechanical Engineering Senior Design Course

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Contents

1 Scrum Guide

Definitions from The Scrum Guide, found at scrumguides.org

- Scrum: A set of practices that emphasize daily communication, flexible reassessment of plans, and short iterative steps of work.
- Agile: An iterative development methodology that values human communication and feedback, adopting to change, and producing working results.
- Product Owner: The person responsible for maximizing the value of the product resulting from work of the Development Team. They are the sole person responsible for managing the Product Backlog.
- The Development Team: Professionals who do the work of delivering a potentially releasable Increment of "Done" product at the end of each Sprint.
- Scrum Master: The person is responsible for promoting and supporting Scrum to the Development Team and Product Owner.
- Sprint: A period of 2-4 weeks, in which the Development team can create a usable and potentially releasable product Increment.
- Sprint Planning: Time in which the events of a Sprint are planned out.
- Sprint Goal: An objective set for the Sprint that can be met through the implementation of Product Backlog. Its purpose is to provide guidance to the Development Team on why they are building the Increment.
- Daily Scrum: A daily 15 minute event for the Development Team to plan work for the next 24 hours, inspect work accomplished in the previous 24 hours, and discuss potential impediments to work continuing.
- Sprint Review: An event held at the end of every Sprint to inspect the Increment and adapt the Product Backlog.
- Sprint Retrospective: An event held at the end of every Sprint for the Development Team to inspect itself and create a plan for improvements to be enacted during the next Sprint.
- Product Backlog: An ordered list of everything that is known to be needed in the product.

- Sprint Backlog: A set of Product Backlog items selected for the Sprint, plus a plan for delivering the product Increment and realizing the Sprint Goal.
- Increment: The sum of all Product Backlog items completed during a Sprint and the value of the increments of all previous Sprints.
- Story Points: A measure of work required during a Sprint.

2 Abstract

As major companies transition to an Agile development methodology it is crucial that mechanical engineering students learn this process before they enter the workforce. In order to prepare students, The University of Vermont's Mechanical Engineering Senior Design course has implemented an Scrum methodology into its curriculum. This study will look at its implementation and analyze student perceptions after working with Scrum on their senior design projects. Student surveys showed strong support for implementing the Agile methodology, while peer and client feedback maintained a high rating from 2018. In addition, recommendations for future implementation will also be provided.

3 Introduction

In February of 2001, 17 individuals met to find common ground on an alternative to the software development processes. What resulted was the creation of the Agile Manifesto, a framework for software development centered on four values: individuals and interactions over processes and tools, working software over comprehensive documentation, customer collaboration over contract negotiation, and responding to change over following a plan.[1] Agile is not a method, but rather a backbone and mindset that places emphasis on teamwork, incremented work, organized teams, and adaptability to changing work. Scrum is the framework that encompasses these values and has been incorporated by some of the largest development companies in the world including Google, IBM, Spotify and General Dynamics.

There have been many instances and reports of the benefits of implementing Agile into both private companies and classrooms. It improves management of the development process, improves customer relationships and increases customer satisfaction.[2] A community of Agile experts named Dr. Dobbs performed a survey in 2008 titled "Agile Adoption Rate Survey" which reported that teams that implemented an Agile methodology saw significant increases in productivity quality, and stakeholder satisfaction.[3] Through working with Agile, I have seen these benefits firsthand.

This summer was my third internship with General Dynamics Mission Systems, who have made an aggressive push to change their development framework towards Scrum. Throughout this internship, I was fully encompassed by the Agile methodology and was able to talk with a lot of Agile experts. One conversation that stood out to me was with Rob Briar, an industry expert on Scrum and its implementation within GD. During our conversation, we talked about how Agile is not taught universally at the college level, which presents a challenge for interns and new hires. This was something I pondered and could not come up with a good answer to. Why is it that engineering schools are not teaching its students the development framework that is becoming the new standard for engineering development? Coincidentally, UVM's Senior Design class (SEED) implemented Scrum into its curriculum this year, which presented a unique opportunity to research its implementation and evaluate the results.

When evaluating the implementation of a new curriculum it is important to compare it to other courses. During this study the implementation of Scrum in 2019's SEED course will be compared to the SEED course from 2018. In addition, the University of Vermont runs a Capstone course for Civil and Environmental Engineering students that does not run Scrum. SEED will also be compared to this year's Capstone class. Both previous the year SEED course and the Capstone course from this year ran waterfall. Waterfall is a linear approach to project management and is historically how new projects are developed. The approach follows the general framework of gathering and documenting requirements,

designing, testing, fixing any issues, and then delivering the finished product.[4]

4 Literature Review

Through my literature review one thing that stood out to me was the lack of research on implementing Agile into a mechanical/electrical engineering college course. The Agile Manifesto was released in 2001 and it is only within the last decade that major companies have transitioned to the framework. This means that most of the research on Agile implementation into a curriculum has been conducted recently. One such experiment was conducted at the University of Gothenburg to evaluate the effectiveness of teaching Agile with a Lego workshop. The teachers presented the best practices of Scrum using multiple Sprints of building with Lego bricks. The data collected showed an overall increase in the students' confidence with Scrum practices, but the students struggled to transfer the gained skills into their project work.[5] During research it will be important to consider not only how Agile is taught, but also how students are able to implement it into their projects.

Another researcher explored the effects of transitioning to an Agile development method for a government-contracted program. The results found that the transition to Agile was a necessity but there were numerous challenges the transition presented. While these results pertain to a government contracted project, the lessons can also be applied to a well-run project using Scrum. One such area of concern is the knowledge to which customers and clients have with Scrum, "Our study highlights the coordinated and collaborated training for both the contractors and the customers such that they have compliment knowledge, skill, and a better understanding of different roles and responsibilities."[6] During research, it will be important to look at how clients and students interact using the Agile methodology in the SEED class.

The study that was most helpful in planning research was conducted by Viljan Mahnic and is titled "Teaching Scrum through Team-Project Work: Students' Perceptions and Teacher's Observations." In this study Mahnic implemented a course at the University of Ljubljana that taught Scrum through a capstone project. The study described the course details and analyzed the perceptions of students and teachers through surveys. These surveys showed overwhelming support of the Agile methodology. Mahnic's methodology greatly influenced the research methodology to gather data from the SEED class to analyze. One of the key findings was that after the second Sprint there were significant positive attitudes attributed to Scrum. Another key finding was that satisfaction with the work on a Scrum project is strongly correlated with quality of requirements specified in the Product Backlog, clear rules for maintaining the Sprint Backlog, appropriate administrative workload, and good cooperation with the Scrum Master and Product Owner.[7]

5 Course Details

The Mechanical Engineering SEED class aims to provide students with simulated real world engineering problems and experiences. Students were split into 37 groups with 3-5 team members per group. Each group was assigned a project that was funded by a client that had an engineering problem for the students to solve. Clients ranged from professors with research proposals, to large corporations such as General Dynamics Ordnance and Tactical Systems. The Development Team self assigned one of four roles that were kept for the entire year before the first Sprint. The four roles were: Product Owner, Scrum Master, Finance Officer and Safety Coordinator. The Scrum Master and Product Owner are formal roles within Scrum.

5.1 Product Owner and Scrum Master

The Product Owner is responsible for maximizing the value of the product resulting from work of the Development Team.[8] The key responsibility of the Product Owner is to manage the Product Backlog. It is important they clearly expressed Product Backlog items and ordered items to best achieve goals and missions. This allowed the Product Owner to optimize the value of work the Development Team is performing. Another key role of the Product Owner is to be the link between the client and Development Team. The Product Owner is responsible for making sure the needs of the client are being met in the Engineering Specs and that any concerns or reservations of the Development Team are expressed.[9]

The Scrum Master is responsible for supporting the Scrum methodology within the Development Team. In service of the Product Owner, the Scrum Master is responsible for making sure goals, scope and product domain is understood by everyone on the Scrum Team. They also need to find techniques for effective Product Backlog Management. In service to the Development Team, the Scrum Master is responsible for helping the team make high-value products, removing impediments to progress, and coaching self organization. One key role of the Scrum Master is to facilitate the Sprint Review and Retrospective.

5.2 Sprint Reviews and Retrospectives

The SEED course was broken up into three week Sprints. At the end of each Sprint the Scrum Master organized a time where the development gathered to perform the Sprint Review and Retrospective. The Review and Retrospective are crucial in the Scrum process for many reasons.

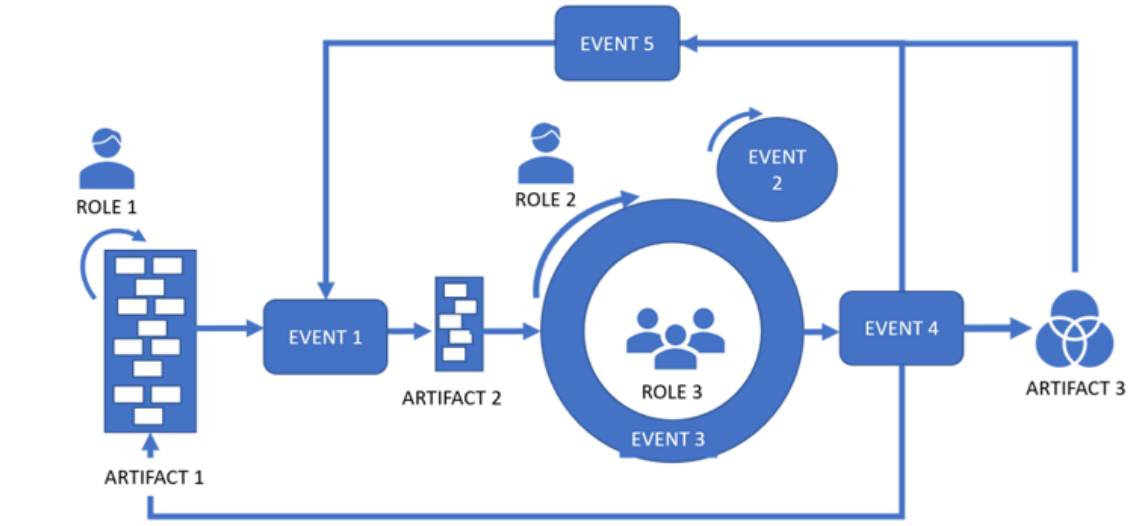
The Sprint Review is held to inspect the Increment and update the Product Backlog if major changes to the project are needed. This is a great time to communicate with the

client on the progress of the project and highlights one of the major benefits of the Agile Methodology. The client can suggest changes or highlight which parts of the Increment they would like to be worked upon in the next Sprint. This also provides a time for all involved to discuss the project as a whole and the progress to the overall Product Backlog. In this course, the first step of the Sprint Review was to talk about the Sprint Goal. The Sprint Goal is an objective that will be met within the Sprint through the implementation of the Product Backlog, and it provides guidance to the Development Team on why it is building the Increment.[10] The goal was reflected upon and team members addressed if it was completed or not. Next, the Product Owner went through which items of the Product Backlog were done and not done. Finally, the increment was presented to the client. The client would then inspect the Increment and ask questions which would be answered by team members.

The Sprint Retrospective was a meeting at the end of the Sprint that was only attended by team members. The purpose of this meeting was for the team to inspect itself and create a plan for improvements.[10] The Sprint Retrospective aims to inspect how the last Sprint went in regards to people, relationships, process and tools. One of the key aspects of the Scrum development method is the Kaizen. The goal of the Kaizen is to discover the one improvement in the Development Team's own process that can be achieved during the next Sprint. In the SEED course the Sprint Retrospective was started by first going over the Story Points planned for and Story Points completed. During Sprint Planning, teams decide which tasks to pull from their Product Backlog and put into their current Sprint Backlog. They then brake up the task into smaller sub-tasks. The sub-tasks are assigned an arbitrary value, usually ranging from 1-13 depending on the difficulty of the task. Next, the team went over what went well during the Sprint. Next the team discussed what could have been better (CHBB). The Kaizen is identified from this list of CHBB and a measurable goal is set for the Kaizen. This goal will be evaluated at the next Sprint Retrospective to see if the Kaizen was accomplished. Finally, the team members were asked to track happiness. each team member gave a rating of 1-5 from miserable to very happy on how the Sprint, team and course went. There are many purposes to this exercise. First, tracking happiness gives a measurable way to look at how the project has progressed over time. Next, it provides a time for team members to talk to each other if something is making them unhappy. Finally, it forces team members to evaluate their own happiness and find ways to improve upon it.

5.3 Implementing and Teaching the Agile Methodology

The Agile methodology was first introduced to the class as a homework assignment before the first Sprint started. The class was given the assignment to read the Scrum Guide and fill out the quiz that highlighted the various components of it.



ROLE

1. _____
2. _____
3. _____

EVENT

1. _____
2. _____
3. _____
4. _____
5. _____

ARTIFACT

1. _____
2. _____
3. _____

Figure 1: Scrum Quiz given to SEED Class

After students filled out the quiz, Professor Kenneth Burkman went through the Agile methodology in a lecture to the class. The purpose of the lecture was to reinforce the reading that students completed on Scrum. During the following three weeks students performed three exercises with their development teams to highlight various aspects of the Scrum process. One such activity, called The XP Game, had students try to maximize the amount of buisness value by completing various simple tasks. Each team was given a handful of tasks that had a value assigned if they were completed. The students were then told to create a Product Backlog and Sprint Backlog to plan for which tasks to attempt and in which way they would accomplish them. Another activity saw teams try to maximize the amount of paper airplanes produced in two minutes. There were restrictions put into place such as a

limit of one fold per team member before another team member had to make a fold. The restrictions forced teams to collaborate on each paper airplane. There were multiple Sprints for this exercise and after each Sprint each team had a Sprint Retrospective and Sprint Planning to look back on how things went and improve upon their plan to maximize the number of planes created.

Throughout the course there were various methods of reinforcing the Agile methodology. After the second Sprint, Professor Burkman met with each team to go over their Sprint Retrospective and see how they were adjusting to Scrum. Even though submitting the Sprint Retrospective and Review as written documents is not part of Scrum, it is a big part in reinforcing Scrum in the course. This gave professors the opportunity to evaluate the students events and make comments on them. In the first semester, Professor Dustin Rand had a handful of teams present how they were using the development software BaseCamp to incorporate the Agile methodology. In the second semester, Professor Burkman held a meeting for all the Scrum Masters to discuss how they were incorporating Scrum. This allowed students to talk with each other on the best ways to run Scrum within their teams. This meeting was extremely helpful for Scrum Masters because they could borrow techniques from other teams to implement within their own team.

6 Methodology

The first aspect of the study was to look at different ways to compare the current SEED class. It was determined that comparing this year's SEED class to the previous year was best for analyzing the implementation of the Agile methodology. In addition, looking at this year's waterfall run Civil Engineering Capstone class would prove beneficial in understanding how Agile compares to waterfall.

Before collecting data it was important to understand which parts of the Agile methodology pertained to the Mechanical Engineering SEED Course. The Agile Manifesto highlights 12 principles behind the methodology. This study focused on the following principles:

1. Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.

2. Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.

3. Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.

4. At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

In order to measure the satisfaction of clients the data from client feedback surveys were analyzed. These surveys were given to SEED clients from previous year's and this year's SEED clients. The mid-semester surveys were analyzed to see the level of satisfaction clients have with their development teams. One limitation of this survey is that it only incorporates half of the year. However, since all surveys are only from the first semester the effects of Scrum on early product development can be analyzed.

In addition to client feedback surveys, peer feedback surveys from different SEED classes were also be analyzed. One very important aspect of the Agile methodology is that team members reflect on the attitude and culture of the team and make adjustments to the team if necessary. This revolves around the third principle of Agile as motivated individuals work better in teams.

To compare the SEED and Capstone Courses from this year an identical survey was given to each class. The survey was conducted in the middle of the first semester and in the middle of the second semester. The purpose of the survey was to isolate differences in the groups that could be associated with the switch to an Agile methodology. The major themes of the survey were the frequency and perceived benefit of client interactions and intragroup reflections.

Project Evaluation Survey

Which class are you currently enrolled in (circle one): ME186, EE188, BME188 or CE185

Team Number: _____

Please rate the following information on a scale of 1 to 5:

1 weekly 2 every other week 3 every three weeks 4 monthly 5 once a semester

How often do you informally communicate with your client {i.e. text/slack/email}

1	2	3	4	5

How often do you have a formal meeting with your client {phone calls/ in person meeting}

1	2	3	4	5

Approximate the number of times you have formally met with your client: _____

How often do you evaluate satisfaction within your group?

1	2	3	4	5

How often do you reflect on your current design and make changes to it?

1	2	3	4	5

How often do you make decisions to impact the direction of the project?

1	2	3	4	5

Please rate the following information on a scale of 1 to 5:

1 strongly disagree 2 disagree 3 neutral 4 agree 5 strongly agree

Client meetings have resulted in meaningful changes to the project

1	2	3	4	5

Discussing satisfaction has prompted meaningful changes to the way our group operates

1	2	3	4	5

Our design has significantly changed since initial planning

1	2	3	4	5

A working solution is the most important part of the project

1	2	3	4	5

Figure 2: Survey given to SEED and Capstone Students

During each team's Sprint Retrospective, team members were asked to rate their happiness with the course, their team, and the Sprint. These ratings are meant to spark discussion between team members on how they feel different aspects of the project are going. While collecting this data, teams and team members were kept anonymous. A master key of team members and team numbers was kept separate from the data in order to protect each student's anonymity.

Track Happiness

1= miserable, 2 = unhappy, 3 = meh, 4 = happy, 5= very happy

	This Sprint	Team	Course
Team Member 1			
Team Member 2			
Team Member 3			
Team Member 4			

Figure 3: Happiness Survey given to SEED students during each Sprint Retrospective

While conducting research one theme that stuck out was that student's retention of the Agile methodology was not strong. In order to test the retention of the Agile methodology the SEED class was given the same quiz they took at the beginning of the year. This quiz was given without a word bank and tested to see what aspects of Scrum students were able to identify.

7 Results and Discussion

7.1 2019 SEED Happiness Surveys

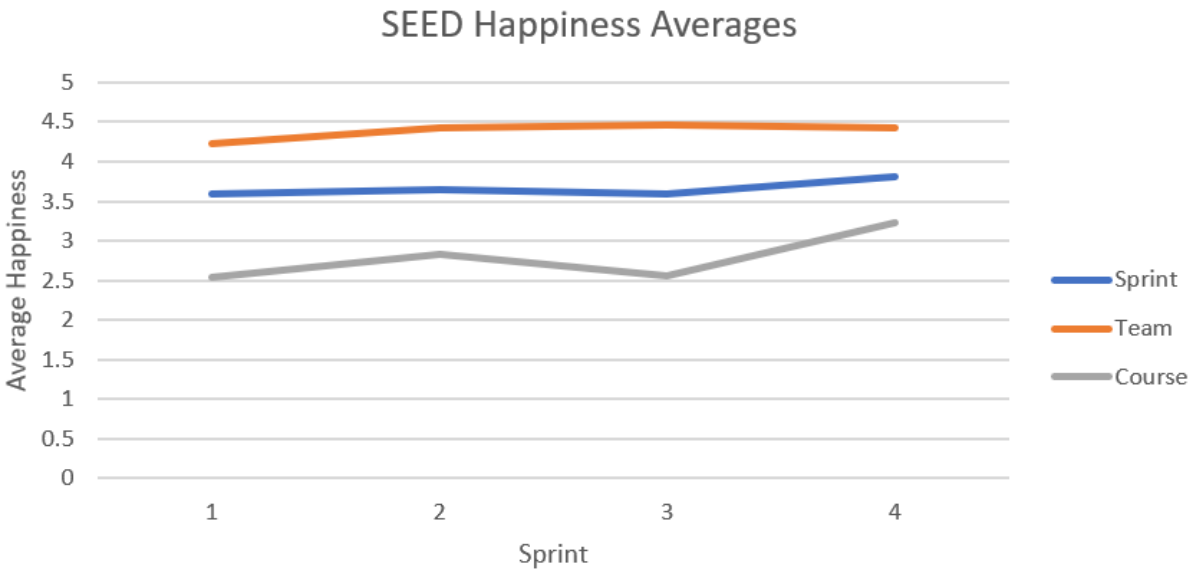


Figure 4: Results from Sprint Retrospective Happiness Surveys

The results from this survey were scored on a scale from 1-5 ranging from miserable to very happy. Individual team averages were calculated first, then these averages were averaged to give a total class average. This equalized the weight of each team since teams had an unequal number of members.

Team happiness was rated as the characteristic that team members were most happy with. The class average score for team happiness during Sprint 1 was a 4.22 which increased to 4.4 for the next three Sprints. Although a slight increase, this shows that as the project progressed past the first Sprint team members felt better about their teams. This could be an indication in the success of Sprint Retrospectives. Teams addressed the problems with their group dynamic after the first Sprint during the first Sprint Retrospective. An increase in team happiness for all future Sprints highlights the success of the first Sprint Retrospective.

Sprint happiness was the second highest rated happiness index recorded. For the first semester the happiness index for the Sprints were all roughly 3.6, which indicates a feeling between 'meh' and 'happy'. The first Sprint of second semester saw an increase to 3.81

which shows students leaned closer to a 'happy'. The second semester saw an increase in the time students had to work directly on their projects and work closer towards a final product. Ownership of the final design was more apparent in this Sprint and could be a cause for students feeling more happy about the success of the Sprint.

The lowest rated happiness index recorded was course happiness. Students for the first Sprint rated the course between a 'meh' and 'unhappy'. In conversations with students the most apparent part of the course that students had a problem with was the number of assignments during the first Sprint. Students felt like they did not have enough time to work on progressing the project, but rather felt forced into doing assignments. What is promising is that the score for the fourth Sprint increased to a 3.2. This shows that as students were able to work more on their projects they were happier with the course. Another explanation of this is that students got more used to the course as a whole. New courses offer a variety of challenges, but as students get familiar with the course they might feel more happy.

Overall the happiness indices were very promising. All three indices increased as the course progressed which shows that as students became more familiar with the Scrum process and were overall more happy. Familiarity and practice are two key factors for implementing a successful Agile methodology with students. Another promising sign was the reduction in disgruntled students as the course progressed. Disgruntled students are defined as any student who put a 'miserable' or 'unhappy' rating on the happiness survey.

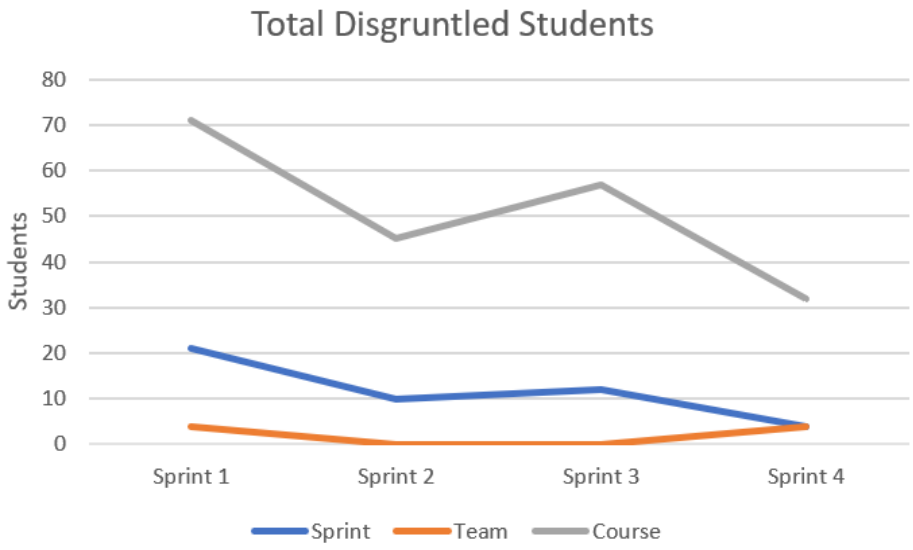


Figure 5: Amount of Disgruntled Students per Sprint

As the course progressed students unhappy with the course decreased 55%. Students unhappy with the Sprint decreased by 80%. While the number of unhappy students with their teams did not change from Sprint 1 to 4, there were 0 unhappy students with their team in Sprints 2 and 3. This represented the lowest number of disgruntled students. Class averages in happiness showed small changes over time, but they were significant due to the large number of teams and team members. This data on individual unhappiness is very significant because it shows a sharp decline in individual student unhappiness. This shows that as students had working experience with Scrum they became more happy with the course and therefore the newly implemented methodology.

7.2 2018 vs. 2019 Client and Peer Feedback Surveys

	Fall 2018	Fall 2019
The team member is meeting your expectations for performing their assigned team roles.	4.55	4.58
The team member adheres to all aspects of your teams Code of Conduct.	4.66	4.67
The team member produces quality work on time.	4.54	4.55
The team member demonstrates initiative on the project.	4.49	4.51
The team member is an active and engaged participant on the project.	4.58	4.6
I am satisfied with the overall performance of this team member.	4.6	4.58
Number of students below .9 Adjustment Factor	10/125 (8%)	12/148 (8%)

Figure 6: Results from Semester 1 mid-Semester peer feedback surveys from 2018 and 2019

Results from the mid-semester peer feedback surveys were very surprising. One key aspect of the Agile methodology is the importance of team dynamics. It was expected that Sprint Retrospectives would help teams address problems within their teams and would result in higher scores on the mid-semester peer feedback survey after Sprint 2. However the averages from each student was nearly identical from 2018, when AS was not implemented into the course. Professor Rand uses the Adjustment Factor to determine which students perform below their peer's expectations. This number compares an individual to their teammates. The higher the number the better that students peer feedback scores compared to their peers. Professor Rand used .9 as a mark for a student who was sufficiently rated lower than their peers. the percent of students from 2018 to 2019 who had an Adjustment Factor lower than .9 remained unchanged at 8%. While this result could indicate the switch to Scrum had no

impact on team dynamic, there are some potential explanations. Overall the scores for both years were extremely high across the board and very few students were marked significantly lower than their peers. Unless a student is a clear problem to the team it can be difficult to distinguish between great and good teammates. This could explain why numbers both years were very high consistently. Overall however, mid-semester peer feedback results did not show a connection between the switch to Scrum and an increase in individual performance as rated by peers.

	Fall of 2018	Fall 2019
Number of clients who answered survey	27	27
Team applies math, science, and engineering to the solution of your problem.	4.59	4.52
Team appears capable to design a system, component or process to meet your needs.	4.44	4.59
The team appears to have knowledge of current technology and contemporary issues	4.48	4.33
The team appears to use modern engineering skills and tools necessary for engineering practice?	4.48	4.52
The team understands the problem you are trying to solve.	4.63	4.74
The students appear to function effectively as one cohesive team.	4.41	4.33
Team shows up for scheduled meetings on time and prepared.	4.66	4.63
The interactions you have with the team are professional and informative.	4.74	4.7
The team communicates with you about the status of the project via weekly status reports.	4.26	4.22
The weekly status reports contain information about past and future actions, risks and mitigation plans, resource and schedule status. (If you have directed the students to alter their status reports from the above information, are you receiving the information you want?)	4.15	3.96
I am satisfied with my team's overall performance.	4.44	4.52

Figure 7: 2018 and 2019 client feedback surveys from the end of semester 1.

Results from the 2019 end of semester client surveys followed a similar trend to the surveys from 2018. Agile strives to increase effective communication between the client and Development Team. In the SEED course the Sprint Review was a mandatory time were teams met with their client to review the latest iteration. An initial hypothesis for this survey was that with increased communication with clients, the ratings would be higher. This was not the case however, as the client data was nearly identical in 2019 as it was is 2018. Another hypothesis that turned out to be false was that with an increase in client communication there would be more clients who filled out the survey. This once again turned out to be false. Client survey results were high both years, so a positive to take away from this is that a switch to Scrum did not hurt relationships with clients.

There are many potential reasons for survey results being nearly identical. One reason could be that the switch to Agile had no impact on the relationship between a client and Development Team. However, there are other reasons that seem more likely. One reason is that results from 2018 were already very high, so it would be statistically very difficult to increase these numbers. Since the 2018 numbers were so high, maintaining the same averages should be viewed as a successful implementation. This is because results show that implementing Agile did not have a negative effect on peer and client feedback surveys. In the first year of implementing a new development methodology this is an extremely promising sign.

Statistical Analysis was performed on both the Client and Peer feedback surveys. An analysis of variance (ANOVA) was performed on each question from the Client and Peer feedback surveys. An ANOVA: Single Factor test was used on each question comparing the results from 2018 and 2019. A standard alpha value of 0.05 was used to perform these tests. The Null Hypothesis was that results from the question did not change from 2018 to 2019. The F-value and F-critical value were analyzed as well as the p-value. If the F-value was greater than the F-critical value there is evidence to reject the Null Hypothesis and say that the samples had significantly different means. In addition, if the p-value is less than the alpha level, there is evidence to reject the Null Hypothesis. The following table shows the results from the statistical analysis for both the Client and Peer feedback surveys from 2018 and 2019:

	F	F crit	P-value
Client Feedback Question 1	0.2	4.027	0.657
Client Feedback Question 2	0.803	4.027	0.374
Client Feedback Question 3	0.678	4.027	0.414
Client Feedback Question 4	0.049	4.027	0.825
Client Feedback Question 5	0.496	4.027	0.485
Client Feedback Question 6	0.112	4.027	0.740
Client Feedback Question 7	0.067	4.027	0.796
Client Feedback Question 8	0.065	4.027	0.800
Client Feedback Question 9	0.025	4.027	0.874
Client Feedback Question 10	0.596	4.027	0.443
Client Feedback Question 11	0.123	4.027	0.728
Peer Feedback Question 1	0.001	3.876	0.978
Peer Feedback Question 2	0.418	3.876	0.518
Peer Feedback Question 3	0.086	3.876	0.770
Peer Feedback Question 4	0.001	3.876	0.976
Peer Feedback Question 5	0.110	3.876	0.741
Peer Feedback Question 6	0.271	3.876	0.603
Peer Feedback Question 7	0.241	3.876	0.624

Figure 8: Results from ANOVA: Single Factor test for Client and Peer feedback surveys with an alpha value of 0.05

Statistical analysis did not reject the Null Hypothesis for any of the Client or Peer feedback survey questions. The F-value was always lower than the F-critical value and the p-value was always greater than the alpha value of 0.05. Both of these statistical measures show the Null Hypothesis was upheld. Therefore, it cannot be stated with certainty that results from 2019 varied from 2018.

7.3 Scrum Quiz

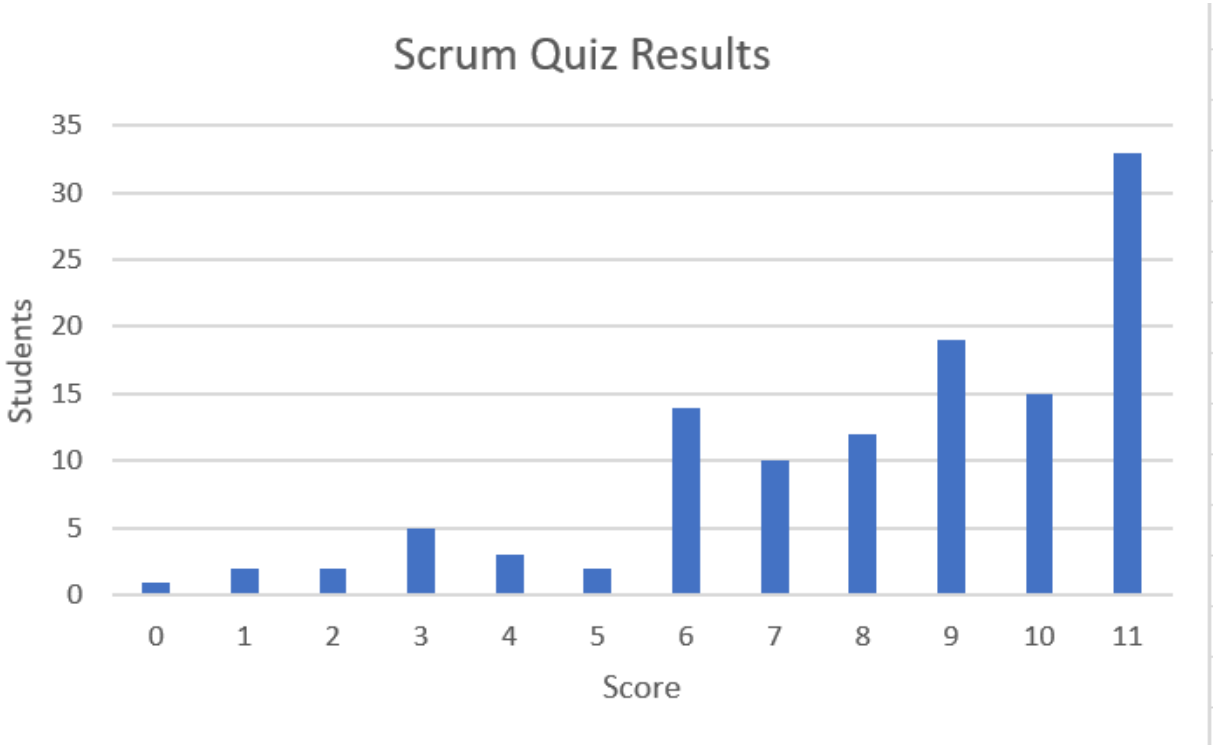


Figure 9: Results from Scrum Quiz administered in the second semester of SEED.

The results from the Scrum quiz showed promise in the retention of Scrum knowledge. Nearly 60% of students scored at least a 9 on the quiz. This quiz tested basic understanding of the Scrum process. However, there were not as many perfect scores as expected. One professor believed 90% of the class would score perfect, while another believed 60% would. This highlights Mahnic's findings that students struggled to maintain the knowledge learned during the first portion of the class in regards to Scrum.

7.4 SEED vs. Capstone Survey

In this section the results from the SEED vs. Capstone data will be analyzed question by question. These results compared the switch to Scrum in the SEED class to the waterfall run Capstone class. Both surveys were conducted at the same point in the semester.

Statistical analysis was also performed on each survey question. An ANOVA: Single Factor test was performed on each question comparing the results from SEED and Capstone,

first in Semester 1 then in Semester 2. A standard alpha value of 0.05 was used to perform these tests. The Null Hypothesis was that results from the question did not significantly change between SEED and Capstone. The F-value and F-critical value were analyzed as well as the p-value.

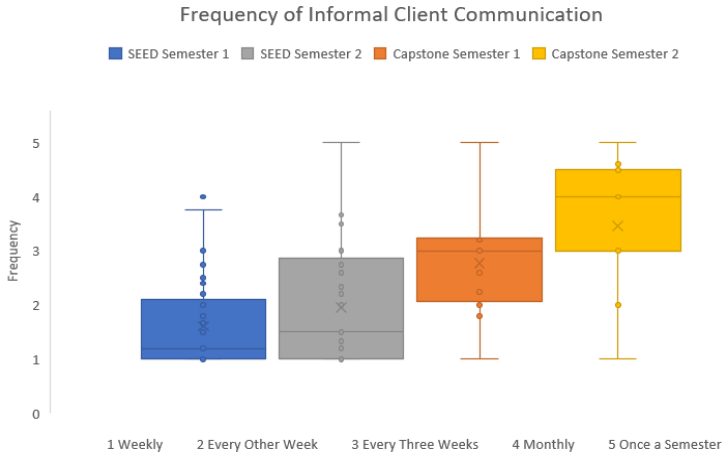


Figure 10: Question 1: How often do you informally communicate with your client (i.e. text/slack/email)

The results from the first survey question showed that SEED teams met with their clients more often than Capstone clients. The ANOVA test showed with certainty that the null hypothesis for Question 1 was rejected and therefore there was meaningful difference in the results between SEED and Capstone[i]. With an interquartile range between 1 and 2, SEED teams met with their clients between once a week and once every other week. As stated previously, Agile strives to maximize the effectiveness of formal client interactions. This is an encouraging sign in the switch to Scrum because informal interactions are crucial for cohesive and efficient product development. If a team is able to talk with their client without needing to set up a formal meeting, work can be done quicker and teams can get answers to questions sooner. An interesting result from this survey is that client meetings actually declined in the second semester. This would make sense because the need for formal meetings is most important when starting a project and the Development Team knows little about it. This contrasts an initial hypothesis that stated that in the second semester there would be more client meetings because students found the meetings beneficial.

[i]Question 1 Statistical Analysis: Semester 1; F=52.53, F crit = 3.89, p = 1.49E-11. Semester 2; F = 66.43, F crit = 3.9, p = 1.17E-13

Capstone students met with their clients on a much less frequent basis, with the an interquartile range between every other week to every three weeks. Similarly, in the second semester Capstone students also had a decrease in informal client communications.

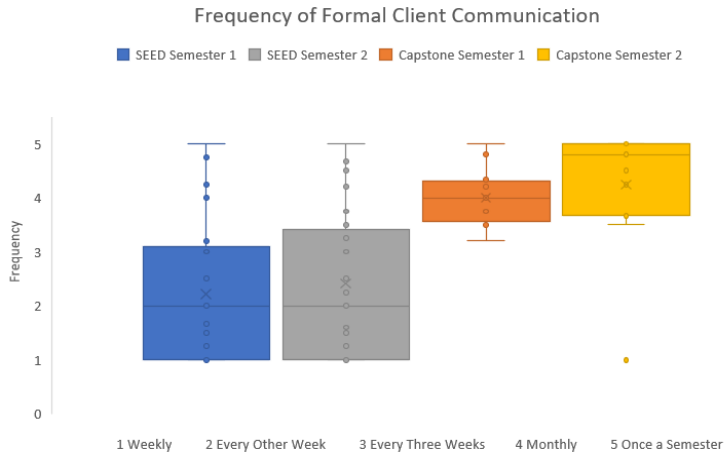


Figure 11: Question 2: How often do you have a formal meeting with your client (phone calls/ in person meeting)

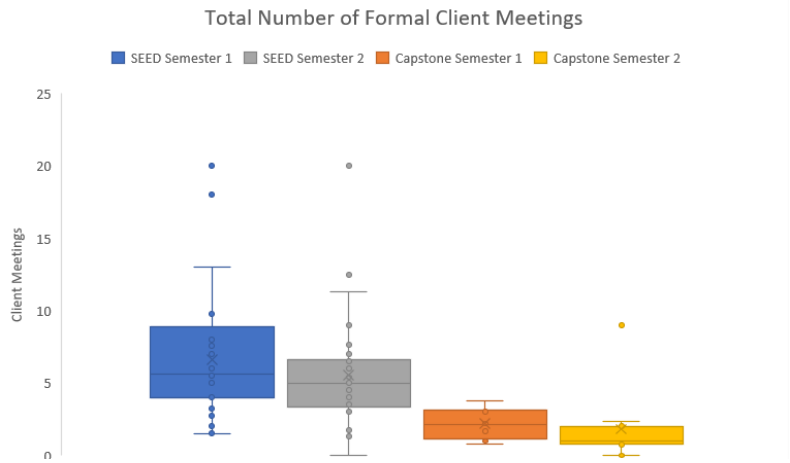


Figure 12: Question 3: Approximate the number of times you have formally met with your client

Results from the frequency of formal meetings also showed an increase in the frequency of formal interactions with a client. The ANOVA test showed with certainty that the null

hypothesis for Question 2 was rejected and therefore there was meaningful difference in the results between SEED and Capstone[ii]. Interestingly, the interquartile range was a lot bigger compared to informal meetings. That suggests a large variation in how often teams formally met with their clients. Even though the interquartile range was large it was almost entirely under the 'every three weeks' line. This line is important because it marks how often teams should be having a Sprint Review. This shows that for the most part teams were, at a minimum, meeting with their clients for Sprint Reviews. SEED students met with their clients twice as often as Capstone students, who met with their clients formally on a monthly basis or only once a semester. Similar to informal meetings, formal meetings decreased in the second semester, but only slightly.

Results from the total number of meetings during the semester followed the same trend as questions about frequency of meetings. The ANOVA test showed with certainty that the null hypothesis for Question 3 was rejected and therefore there was meaningful difference in the results between SEED and Capstone[iii]. SEED students met with their clients more often and total meetings decreased second semester. One interesting result is that total meetings were nearly three times higher in SEED compared to Capstone, but the frequency was less than twice as much. This was due to a lot of outliers in the SEED course who met with their client more often than weekly. Some teams met with their clients as much as 20 times over the course of the semester.

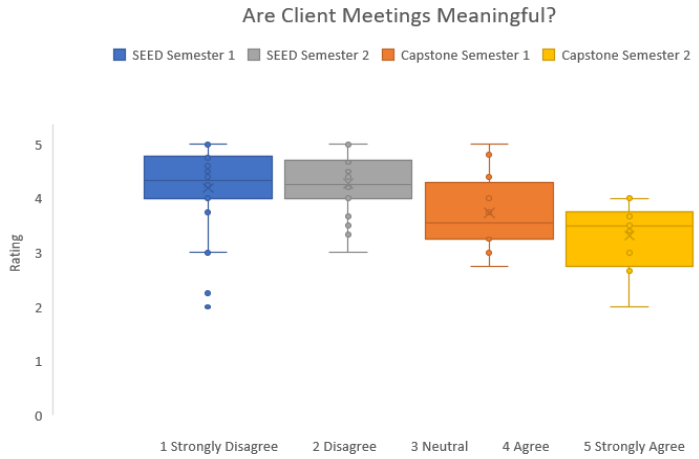


Figure 13: Question 7: Client meetings have resulted in meaningful changes to the project

[ii]Question 2 Statistical Analysis: Semester 1; F=84.03, F crit = 3.89, p = 1.75E-16. Semester 2; F = 67.07, F crit = 3.9, p = 9.34E-14

[iii]Question 3 Statistical Analysis: Semester 1; F=47.59, F crit = 3.89, p = 1.04E-10. Semester 2; F = 41.12, F crit = 3.9, p = 1.66E-9

Results from asking if client meetings are meaningful showed that SEED students fell between 'agree' and 'strongly agree' that client meetings have resulted in meaningful changes to their project. The ANOVA test showed with certainty that the null hypothesis for Question 7 was rejected and therefore there was meaningful difference in the results between SEED and Capstone[iv].This is very encouraging in analyzing the switch to Scrum. Not only did students meet with their clients more, these students felt that the meetings were more meaningful to their project compared to the Capstone course. The Capstone students fell between 'agree' and 'neutral' when it came to rating the meaningfulness of client meetings.

This trend highlights the importance of a development methodology that highlights client interactions. As the frequency of client meetings increased, the perceived value of those meetings increased. Having a set time and structure where students can meet with their clients resulted in more meaningful engagements. For a lot of students this is the first time they have interacted with actual clients. It is encouraging that students understand the importance of client interactions.

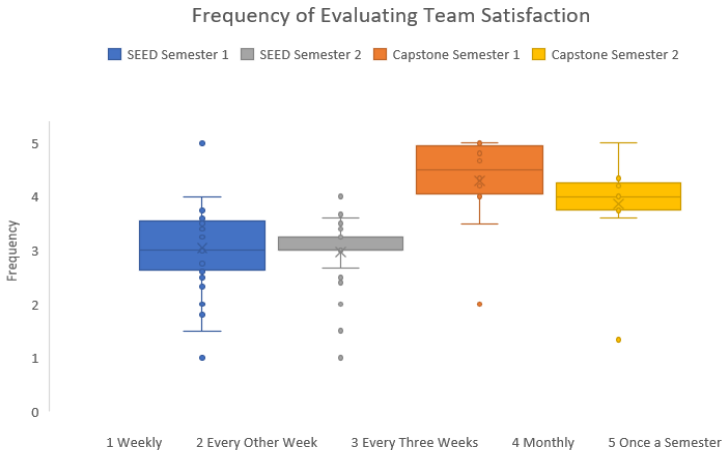


Figure 14: Question 4: How often do you evaluate satisfaction within your group?

[iv]Question 7 Statistical Analysis: Semester 1; F=7.17, F crit = 3.89, p = 0.00816. Semester 2; F = 31.59, F crit = 3.9, p = 8.69E-8

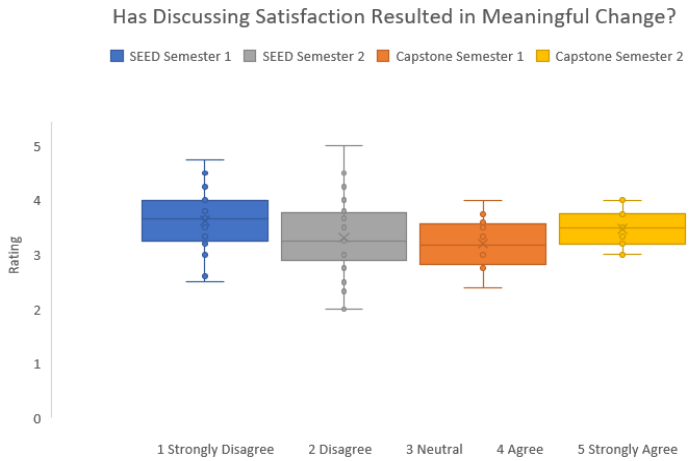


Figure 15: Question 8: Discussing satisfaction has prompted meaningful changes to the way our group operates

SEED students measured satisfaction within their group every three weeks both semesters. This correlates to the Sprint Retrospective timetable, which took place every three weeks. The small interquartile range indicates that most teams were around the 'every three weeks' mark for evaluating team satisfaction. Since the question did not explicitly state 'Sprint Retrospective', it shows that students understood the purpose of a Sprint Retrospective and put them into practice. This is crucial in implementing Scrum into a course because students learned an aspect and had ownership on implementing it into their project. The ANOVA test showed with certainty that the null hypothesis for Question 4 was rejected and therefore there was meaningful difference in the results between SEED and Capstone[v].

Another encouraging sign for this implementation is that students in SEED felt that discussing satisfaction resulted in more meaningful changes to their team. The ANOVA test varied between semesters in regards to rejecting the Null Hypothesis. In the first semester the Null Hypothesis was rejected, while in the second semester it could not be said with certainty that the Null Hypothesis was rejected [vi]. Compared to every three weeks, Capstone students evaluated satisfaction once a monthly or only once a semester basis. When looking at satisfaction, SEED students were on the high end of neutral-agree,' while Capstone students were on the lower end of 'neutral-agree.' This shows that not only did SEED students evaluate satisfaction more often, but they generally felt like it was more meaningful.

[v]Question 4 Statistical Analysis: Semester 1; F=48.37, F crit = 3.89, p = 7.61E-11. Semester 2; F = 21.99, F crit = 3.9, p = 6E-6

[vi]Question 8 Statistical Analysis: Semester 1; F=5.52, F crit = 3.89, p = 0.0199. Semester 2; F = 0.611, F crit = 3.9, p = 0.4355

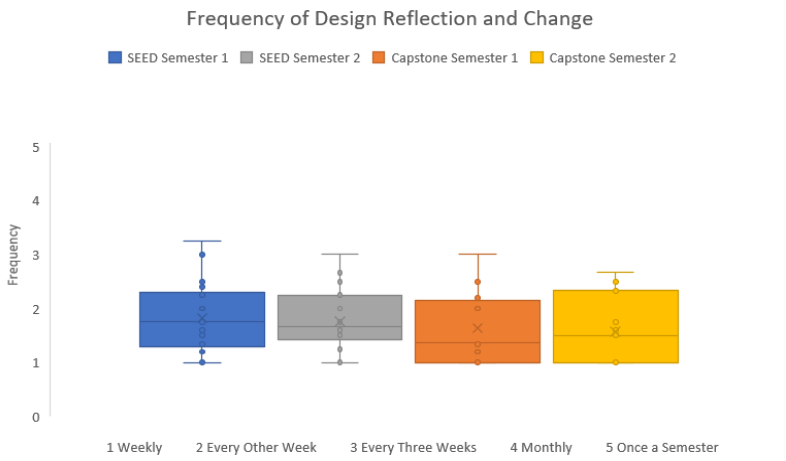


Figure 16: Question 5: How often do you reflect on your current design and make changes to it?

Results from this question indicate that SEED students reflected on their design and made changes to it roughly every two weeks. It is encouraging that this number is below every three weeks because that would reflect only changing the design during Sprint Reviews. SEED students did slightly increase the number of times they changed designs in the second semester. This is slightly concerning because one would think designs would change more often in the initial stages of a product's development. The ANOVA test showed with certainty that the null hypothesis for Question 5 was not rejected and therefore there was no meaningful difference in the results between SEED and Capstone[vii].

[vii]Question 5 Statistical Analysis: Semester 1; F=0.576, F crit = 3.89, p = 0.449. Semester 2; F = 1.703, F crit = 3.9, p = 0.1938

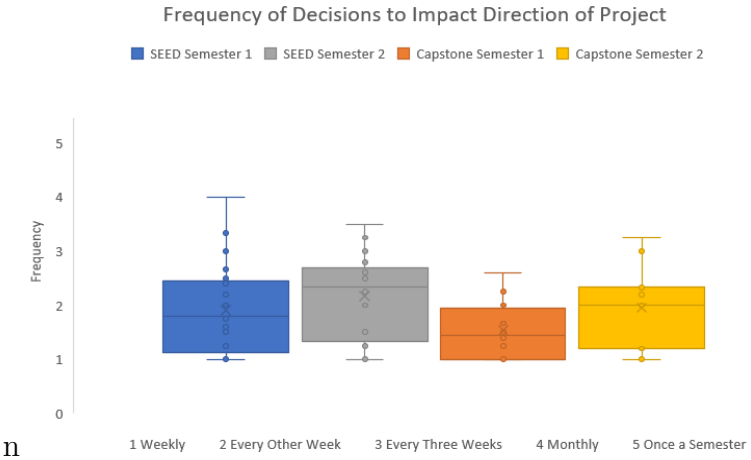


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Figure 17: Question 6: How often do you make decisions to impact the direction of the project?

Results from this question show that SEED students also make decisions to impact the direction of the project roughly every two weeks. Unlike the previous question, actual decisions to change the direction of the project occurred less frequently in the second semester. This would make sense because as a project gets closer to finished, it gets harder to change its direction. The ANOVA test showed with certainty that the null hypothesis for Question 6 was not rejected and therefore there was no meaningful difference in the results between SEED and Capstone[viii].

[viii] Question 6 Statistical Analysis: Semester 1; F=2.642, F crit = 3.89, p = 0.105. Semester 2; F = 1.424, F crit = 3.9, p = 0.234

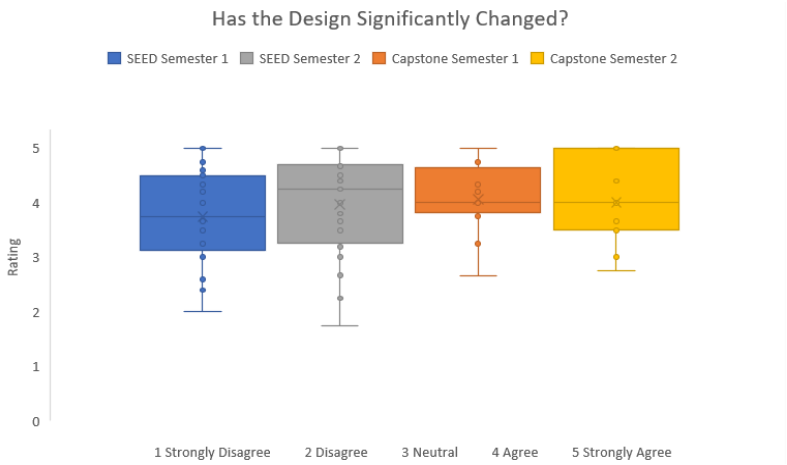

Figure 18: Question 9: Our design has significantly changed since initial planning

Results form this question show that both SEED and Capstone students feel strongly that their projects have changed significantly. The ANOVA test showed with certainty that the null hypothesis for Question 9 was not rejected and therefore there was no meaningful difference in the results between SEED and Capstone[ix]. This is surprising because part of the implementation of Scrum is that designs can change dramatically. However, this is not always the case because sometimes clients have a good understanding of what their final product should be. This contrasts traditional waterfall methodologies that are more linear in their development. However, SEED students did agree that their projects have significantly changed. One potential cause of this is how students interpreted the word 'significant.' Two students could have very different definitions of what a significant change looks like.

[ix]Question 9 Statistical Analysis: Semester 1; F=3.691, F crit = 3.89, p = .0564. Semester 2; F = 0.481, F crit = 3.9, p = 0.489

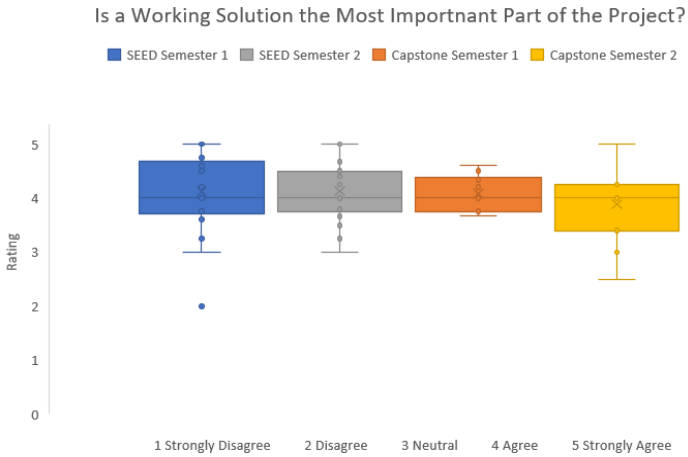

Figure 19: A working solution is the most important part of the project

Results from this question highlight the part of the Scrum process that working solutions are the most important part of a project. Overall, both SEED and Capstone students did agree that a working solution was the most important part of the project. In the first semester, the ANOVA test showed with certainty that the null hypothesis for Question 10 was not rejected and therefore there was no meaningful difference in the results between SEED and Capstone. However, in the second semester the Null Hypothesis was rejected because the p-value was slgihtly lower than the alpha value[x]. One of the more appealing aspects of the Agile methodology from a business perspective is that working solutions are the most important part of the project. It is a lot easier to sell a working solution than something theoretical. Therefore, it is a good sign that SEED students understand the importance of designing working solutions.

Overall the SEED vs Capstone survey yielded a lot of interesting results. While there are numerous factors that contribute the differences in these classes, development methodology is a major difference. The disparity in the frequency of client meetings and the perceived value of these meetings was the most significant difference, found in this survey, between the two classes.

[x]Question 10 Statistical Analysis: Semester 1; F=1.13E-6, F crit = 3.89, p = 0.999. Semester 2; F = 3.903, F crit = 3.902, p = 0.0499

8 Recommendations

While the implementation of an Agile methodology should be considered a success, there are some changes that could be made that would improve upon the experience and learning of the students. The first change that would improve upon comprehension of roles would be role workshops at the beginning of the first semester. After students have their role assigned there should be a workshop with all the Product Owners, Scrum Masters, Safety Coordinators and Financial Managers individually to go over their roles and what they are expected to do in the role. This meeting would look very similar to the meeting that Professor Burkman ran for Scrum Masters in the second semester. If students had a better understanding of their roles at the beginning of the project they would be better equipped to handle the challenges associated with their roles. Another change that would improve the Scrum roles would be to push back assigning roles until after the first Sprint. This would allow students to work together and get an understanding for the team dynamic before making a choice on roles that impacts the entire year.

Another change that might increase the course happiness index for Sprint 1 would be to push back Sprint 1 three weeks. This year, Sprint 1 was filled with assignments and it felt like teams were not able to do the early stages of prototype development. While talking to students this was one of the most expressed issues with the way Scrum was introduced in the class. The first chance students had to work with the methodology was revolved around assignments and not the Increment. It is very difficult to plan Story Points for assignments. However, these assignments, such as the prior art review and reverse engineering, are incredibly important. If Sprint 1 was pushed back until these assignments are due, it would give students a better first taste of Scrum. At the end of Sprint 0 there could be a Review and Retrospective to introduce students to that format as well. Agile was designed for effective and efficient prototyping, not class assignments and this small change could help students with the transition to the methodology.

Another change to the course to improve how students implement Story Points and Sprint Backlogs would be a random assignment that checks for these things. At the end of each Sprint one third of the teams would be randomly selected and graded on their Sprint Backlogs, Story Points, and Product Backlogs. Grades would not be released until the end of the semester so that each team would need to keep up to date with their backlogs because they would not know if theirs was graded yet. At the end of each Sprint a professor would release a document with some common mistakes in the backlogs and Story Points so teams could learn from the mistakes of each other. If implemented, this assignment would force teams to not only implement Story Points, Sprint Backlogs and Product Backlogs, but it would make them maintain them each Sprint.

9 Further Studies

During the 2020-2021 school year the same survey could be given to SEED and Capstone students to see how another year of teaching Agile would impact the results. The Scrum quiz should also be included on both semesters SEED survey for a better understanding of Scrum knowledge retention.

There are a few changes the SEED class should make to help collect meaningful data through the surveys. Peer feedback surveys should directly ask students how they view Agile. Direct questions on the Agile methodology are just as important as the indirect ones. Possible questions could be:

- How successful has your group implemented Scrum into the project?
- Do you enjoy using an Agile methodology?
- Which parts of the Agile methodology do you think are unnecessary and which parts are crucial to your teams success?

Also directly ask the Clients a few questions on their interactions with Agile would be beneficial. As mentioned in the literature review, one of the key indicators of successfully Agile implementation is when the Clients have a deep understanding of the process, in addition to the Development Team. Some possible questions could be:

- Do you feel like you have a good understanding of the Scrum framework?
- Has your team explained the Scrum framework to you?
- Do you think the Scrum framework has had a positive impact on the development of your product?

10 Conclusion

The implementation of Scrum within the University of Vermont's Mechanical Engineering Senior Design course should be viewed largely as a success. Some of the reported benefits, such as improvements to the development process and increased client relationships were seen throughout the course. It is no coincidence that major companies are making the switch to Scrum. Therefore it is growing increasingly important to teach engineering students Scrum and its benefits. The data collected showed that students learned about the Scrum process, were able to implement it within their projects and retained the knowledge throughout the course.

Overall, the data found during this study showed positive results when determining the impact of the implementation of an Agile methodology in a Mechanical Engineering Senior design class. Survey results between SEED and Capstone showed apparent benefits to running the methodology. SEED students met with their clients more often and valued these meetings higher than Capstone students. When comparing survey results between different years of SEED there was little change to the high results.

One of the difficulties of this study is attributing Scrum solely with the results found. There are a lot of factors including new clients, new students, new assignments, and different ways the classes were run. One of the major differences was that in 2019 Professor Rand only had lab once a week. This gave teams 2 time slots during the week where all members were free. However, survey data does suggest that clients maintained a strong connection to their teams and were more than pleased with their work. Peer feedback was also overwhelmingly positive during the SEED course. Overall the implementation of Scrum should be considered a success. Students showed a retention for the material and implemented the methodology in unique ways within their projects and schedules.

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