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Assessing Scrum Project Management and Teamwork in Electrical and Computer Engineering Courses

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1. Introduction and Motivation

Teamwork and project management are essential skills for engineering students, as recognized in the new ABET *Criterion 3. Student Outcomes*, in particular criterion "5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives" [page 42, 1]. Our team of instructors exposes students to project management techniques at multiple levels within our undergraduate ECE program. By learning project management early and practicing it often, students improve their teamwork efficacy in projects, courses, and in their future careers. Scrum is a cyclical project management technique commonly used in high-tech industries. Scrum provides a framework that facilitates teamwork and project management through an adaptable, incremental process. We have tailored our variant of Scrum for students working on engineering projects in a higher-education environment. We intend to better understand student learning of project management and teamwork so that we can improve our curriculum.

It is common practice in undergraduate engineering programs for students to participate in multiple projects during their studies. The ABET requirement for a "curriculum culminating in a major design experience" [1] for accredited BS programs often means a senior capstone activity that involves a substantial project-based component. While projects may differ in their scope, complexity, and size, a key factor for improving success is some form of project management. Frequently though, students use an *ad hoc* project management approach, as they lack experience in formal techniques. Regardless if the project is simple or sophisticated, students need to reduce the given problem into logical tasks, divide responsibilities among team members, and develop a feasible schedule to solve those tasks.

Once students begin their capstone project, they are expected to apply more formal methods of project management. In traditional approaches, project management is often done using a "waterfall" framework, which is a sequential process that requires outlining a set of work phases that cascade over the duration of the project. This is typically a static, front-loaded process that needs a major investment of time for task definition, schedule planning, and resource allocation. In addition, it also relies heavily on documenting and locking-in requirements at a very early stage. While this process is employed for many types of projects, it can be inflexible when dealing with specifications that change often or when progress goals are not met and schedules must change dynamically to compensate.

2. Introduction to Scrum Project Management

Scrum is an alternative approach to project management that originated with the software industry and has spread to other fields, such as engineering, urban planning, and law [2]. Instead of focusing on long-term project forecasting, Scrum employs a cyclical feedback process in

which the current progress of a project is used to update project planning incrementally and produce products on an iterative basis. Development cycles, which are called "sprints," are usually a few weeks long. This allows the project team to assess and react frequently, which enables it to adapt rapidly to changes in customer requirements, available resources, and new knowledge gained by the team. While Scrum and other Agile methods have been widely used in the software industry, their use in software engineering programs is still limited [3]. Even less has been reported on their use and effectiveness in other engineering disciplines [4]-[9]. Our team's initial findings on using Scrum in electrical and computer engineering program were reported in [10].

A Scrum team consists of three types of members: the product owner, the Scrum Master, and multiple team members. The Scrum team members engage in four types of specialized meetings: sprint planning meetings, stand-ups, sprint reviews, and retrospectives. During sprint planning, the team commits to addressing a subset of user stories, which are akin to specifications, and are defined by the product owner in consultation with the client. The team members decide how to implement those user stories during a sprint. A sprint is a set time period, typically two or three weeks, during which the team fulfills the user stories. Teams meet daily during very brief stand-up meetings to assess progress. At the end of the sprint, the team should have developed a minimum viable product that can be presented to the product owner. The sprint ends with a sprint review meeting, during which the team evaluates the user stories that the team committed to completing, followed by a retrospective meeting during which the team scrutinizes, and seeks to improve, its Scrum management practices. Throughout the sprint the Scrum Master keeps the team focused on the user stories and within the bounds of the Scrum process. The sprint process repeats until the backlog of user stories is empty.

Within the context of engineering education, Scrum provides several advantages over traditional project management techniques [4,10]:
- Rapid prototyping
- Quick feedback
- Incremental development
- Discovery of core values which are important to the customer and are not obvious at the start of the project
- Decentralized project management – more students have the chance to experience it
- Transparency in teamwork – frequent meetings expose any weaknesses in individual team member contributions
- Project status understanding – frequent meetings provide all team members with a granular understanding of the project's status

Existing literature on using Scrum in engineering education deals almost exclusively with upper-division or graduate engineering courses [4]. While this may be an obvious place to utilize

Scrum, it should actually be taught across the engineering curriculum. For example, it has been shown that technical writing is a skill that ought to be taught and reinforced across multiple engineering courses and years [11,12]. For any project management technique to be really useful, we should start teaching it early and reintroduce it often. For these reasons, we have been implementing Scrum methodology across several years of our ECE undergraduate program.

2.1. Scrum in Freshman ECE Courses

To increase freshman students' motivation and their retention, many ECE programs, including our own, utilize projects to demonstrate to students the applicability and significance of what they are learning. However, many students face a major shock when switching to university courses after high school or community college. As a consequence, we have been careful not to overburden students with yet another learning goal. Therefore, we do not insist on "proper" project management (PM) for our first-year courses.

Rather, PM tools are used primarily to encourage activity planning and to enable collaboration among teammates. One major tool we ask students to use is the kanban board, which provides a visual representation of a project's workflow and progress [19]. Combining Scrum and kanban provides a dynamic and graphical view of a project's current status. This makes it more apparent where actual and potential obstacles may lie, and it also highlights the responsibilities assigned to individual team members. Kanban boards and frequent stand-up meetings provide positive peer pressure to ensure steady progression of the project and continued team development. In our first-year courses ECE 101 Exploring Electrical Engineering and ECE 102 Engineering Computation, we introduce students to Trello, which is a web-based project management application that can be used as an online kanban board. Details of our introductory ECE 101 and 102 courses may be found elsewhere [13],[14]. In ECE 101, students learn some basic tools and work on designing a Rube-Goldberg machine (similar to [5]). In ECE 102, the project involves a data acquisition (DAQ) unit, which is programmed through MATLAB [14]. In both courses, projects are done in two phases. The first phase is used to invoke some preliminary research or similar activity, while the second one involves design, construction and testing. We introduced Trello as a PM tool in Fall 2015 and have used it since. Details of its implementation are discussed next.

2.2. What is Trello?

In order to provide proper context for the later sections, we first provide a basic description of what goes on in Trello software, how it is used to create kanban boards, and how students are meant to use it for project management. Each team is assigned a Trello board, which contains labeled columns[1] (a.k.a. "lists") containing multiple cards. A full-blown Trello board with all

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[1] Trello documentation calls these columns "lists" but we will use term "column" by itself to describe their content as this seems more descriptive.

columns and a few cards is shown in Figure 1. This is a template that is initially shared with students. Students are supposed to develop cards for the **Backlog** column based on customer input (in Scrum, these are called "user stories"). Cards are then moved to the **Ready** column once they are given sufficient details and are ready to be assigned to a team member. Once that happens, they are moved to the **In-progress** column. After all tasks on a given card are completed, they are moved to the **Review** column, where another team member can verify that indeed everything is done so that the card can be moved to the **Done** column. This procedure constitutes a Scrum framework to which two columns are added: **Comments** are used for leaving feedback from teaching staff or from "customers." The **Journal** column is to keep track of meetings and decisions made.
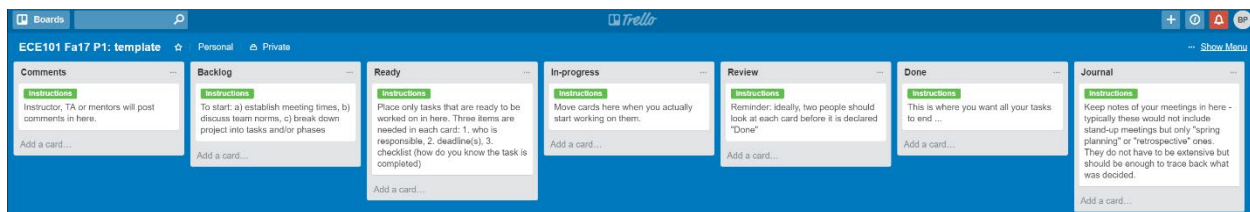

Figure 1. Trello board template that is shared with students.

2.3. Trello Board Organization

Trello boards are organized to follow the Scrum approach to project planning and are hierarchical with columns containing cards, which contain details of tasks. Columns include:

1. **Comments**: A place for instructor, teaching assistant, undergraduate (UG) helper, mentor or "customer" to leave comments for the team. This is where feedback on PM, i.e., results of the scoring rubric, are placed.
2. **Backlog**: All the features of the eventual product are listed here. In Scrum, this would be a list of user stories, but initially students need to list all the things they are considering for implementation.
3. **Ready**: Students need to prioritize features (user stories) from the backlog and turn them into tasks that can be accomplished during the next week or two. In Scrum, these could become part of the next sprint. These also need to be prioritized and given three essential components: who, when, and how – as discussed next.
4. **In progress**: Cards are moved here only after they are given top priority and have three components:
   a. Who is responsible for this task?
   b. By what date/time does the task need to be completed? (due date)
   c. How do we know the task is complete? This is usually done as checklist that shows progress in completing the task. The final outcome of the task, e.g., drawing, sketch, email, price, report, etc., should also be listed.
5. **Review**: Once a task is completed, it is moved here so that one or more other team members can review it. The person who moves the card to Review should also assign the reviewer to that card. If everything is OK then the card is moved to "Done".

6. ***Done***: This serves mostly as an archive and is useful when reflecting on the current state of the project or when planning the next stage of the project. In Scrum, these would be called "sprint retrospective" and "sprint planning" stages, respectively.
7. ***Journal***: This is used to keep track of dates of meetings and decisions made. It helps the team and instructor(s) track their activity. There should be at least one in-person team meeting outside of the classroom (lecture or lab time). It can be done using online tools, e.g., Hangouts, Skype or similar.

Depending on the details of a project, more columns can be added. However, having too many columns can make information more obscure so this should be used with care.

2.4. Trello Cards

Once the overall picture of all the requirements and tasks is developed in the ***Backlog*** column, cards need to be given specific content before being moved forward. A representative card is shown in Figure 2, demonstrating three major elements: ***Who*** (person responsible), ***when*** (deadline), and ***what*** (checklists). A place for comments is also indicated because comments can clarify some actions or provide feedback. A responsible person is designated by clicking on their profile icon. Students are expected to follow this arrangement except on rare occasions when tasks are very simple so that no checklist is required. Students are introduced to the basics of Trello in ECE 101 and then use it on more demanding projects in follow-on courses.
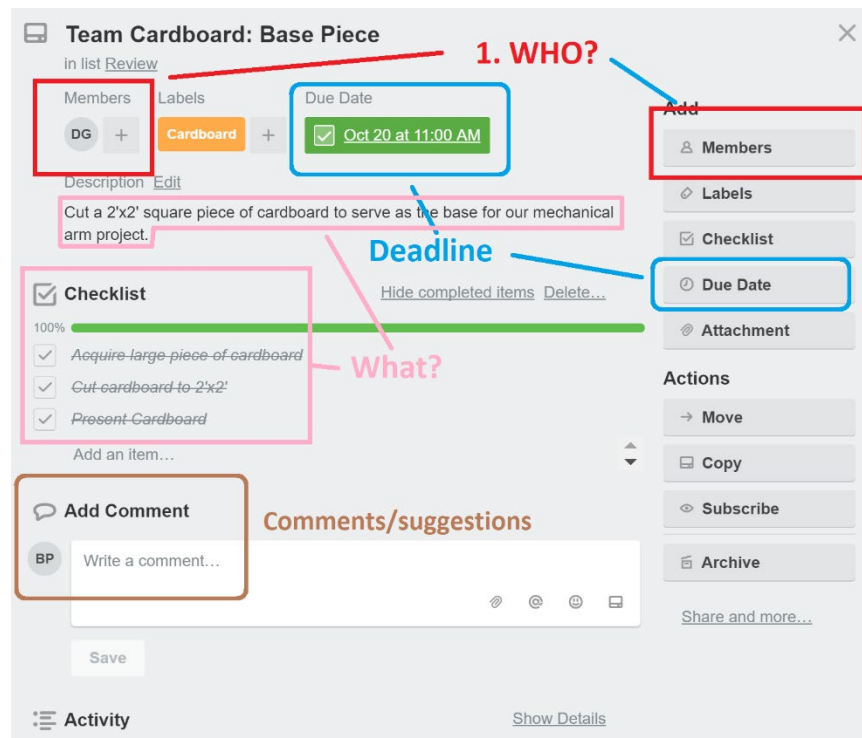

Figure 2. Example of Trello card with all major elements indicated.

3. Project Management Assessment

Student PM work could be assessed by direct observation of teams and their interaction, but to do this systematically we would need, for example, one Scrum Master on each team who could then provide first-hand assessment and feedback to students. We currently do not have the infrastructure to do this, so we provide feedback by means of a rubric, which is used for periodic evaluation of Trello boards.

PM is completely new to freshman students in ECE 101. Therefore, our assessment is initially purely formative. In the 2nd and 3rd freshman courses (ECE 102 and 103), we use a combination of formative and summative assessment. In other words, student grades increasingly depend on how well they execute their PM. We gradually increase our expectations so that most of the characteristics in the rubric improve to a better-than-adequate level, i.e., numerical scores are greater than three on a five point scale. Next, we discuss student self-assessment followed by project management assessment using a rubric.

3.1. Student Evaluations of Project Management

We have surveyed students to determine their views on how helpful these new project management techniques are and how they assess their own abilities in this area. We asked students two questions:

1. "How helpful were these activities in learning material in ECE 101: Utilizing Trello for projects", on a scale Waste of time, Not helpful, Neutral, Somewhat helpful, and Very helpful.
2. "I am confident that I can define and implement a project management plan", on a scale Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree.

As results in Figure 3 show, students found Trello useful. But, a significant fraction of around 20% thought that it did not help their learning, or worse. While we would like to decrease the latter percentage, some pushback should be expected given that for many students this is their first exposure to college and engineering coursework.

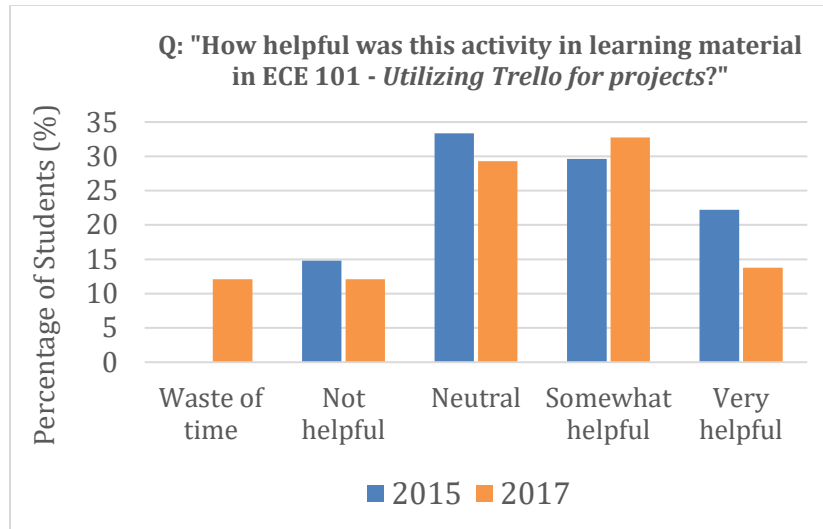**Q: "How helpful was this activity in learning material in ECE 101 - *Utilizing Trello for projects*?"**

Figure 3. Student evaluation of usefulness to their learning: using Trello for projects. Collected in ECE 101 in Fall'15 and Fall'17, N=27 and N=58, respectively.

Interestingly, as shown in Figure 4, students are much more confident in their project management skills with roughly three-quarters of students agreeing or strongly agreeing with the statement that "I am confident that I can define and implement a project management plan." This needs to be triangulated using direct assessment, as discussed next.

"I am confident that I can define and implement a project management plan"

Figure 4. Student self-efficacy regarding their ability to define and implement a project management plan. Done in ECE 101, Fall'17. N = 58.

3.2. Project Management Assessment Using Trello

We could use various Scrum "artifacts", e.g., schedules, user stories, and kanban boards, to assess team project management, but we will focus on kanban boards and use a rubric for evaluating the Trello boards. Our initial observations of first-year students show that they need

close guidance and supervision, such as through the use of templates and weekly kanban reviews. These interventions have resulted in marked improvement of student project management performance.

We have developed a detailed assessment rubric, shown in Table I, which is based on our expectation that Scrum and Trello are to be primarily used for planning purposes. It gives students clear information on what the expectations are. It has three major criteria: 1. *Trello board organization*, 2. *Content & quality of Trello cards*, and 3. *Degree of activity*. **Target Characteristics** describe specific qualities of student work, e.g., very clear and concise cards, as well as student behaviors, e.g., everyone participates. Only the exemplary or excellent characteristics are listed. The evaluator's task is to determine how far the student has advanced on the scale from excellent (5) to adequate (3) to 1 (not yet).

Table I. Trello scoring rubric

Trello scoring rubric			
Scoring range for each element: 5 (Excellent) – 3 (Adequate) - 1 (Not yet) Scoring points are prorated to reflect relative weights of different elements: In this instance, all weights are one (1)			
Element (max. pts.)	**Target Characteristics**	**Comments**	**Score**
1. Trello board organization (5 pts)	• Cards are in appropriate lists and are moved along • Follows suggested organization of lists (backlog, ready, in-progress, review, done, journal) • Lists are prioritized • Adds some valuable or original information to the lists or cards (e.g. color coding, list of resources)		
2. Content & quality of Trello cards (5 pts)	• Very clear and concise cards • Clear description of tasks • Cards contain suggested components: person responsible, due date and checklist.		

3. Degree of activity (5 pts)	• Everyone participates several times a week by performing activities, e.g.,
	  o creating new cards or commenting on them
	  o checking off tasks
	  o moving or prioritizing cards
	  o uploading documentation
	  o doing administrative chores such as archiving cards, adding/deleting users, and similar
	 • Board is updated several times a week
	 • No overdue cards present		

Currently, all three criteria are weighted equally. Note that the rubric is analytic, but at this time we do not provide a detailed breakdown of what constitutes, for example, adequate degree of activity. Instead, desired or target characteristics are listed and students are expected to work towards accomplishing these targets. How much progress they have made is indicated by their numerical score, and we expect to see improvements over time.

3.3. Providing Feedback

To make sure that students are making good progress and following best practices in using Trello, their boards are periodically evaluated, either weekly or bi-weekly. For the feedback to be useful, it needs to be timely and specific. The rubric- given in Table I is used to assign a score, but each item should have comments on how students could improve their performance. An example of feedback is given below and would be placed in the **Comments** column by an instructor, TA, or UG helper:

"Here are some suggestions on how to improve your Trello board:

1. Content and quality of cards: some cards are OK but many are missing responsible person, deadline and checklist(s). Sometimes checklists can be avoided if there is only one action item needed, but that is usually not the case. Change task color to green by checking it off (there is checkbox next to its due date) once it is completed. (3/5)
2. Organization: You are using the same lists from the original template and that is good but you are not moving cards along. Try to make cards a bit more interesting / colorful. (4/5)
3. Activity: Not everyone is contributing. I would expect each team member to contribute to Trello board at least twice a week (in a substantive way). This relates back to how well you distributed your tasks - if everyone has several tasks assigned then they must also be active. (score: 3/5)"

An example of a card with such feedback is provided in Figure 5. Note that a deadline and team members are added to the card. Also, a checklist is given to indicate that each member has read the evaluation.
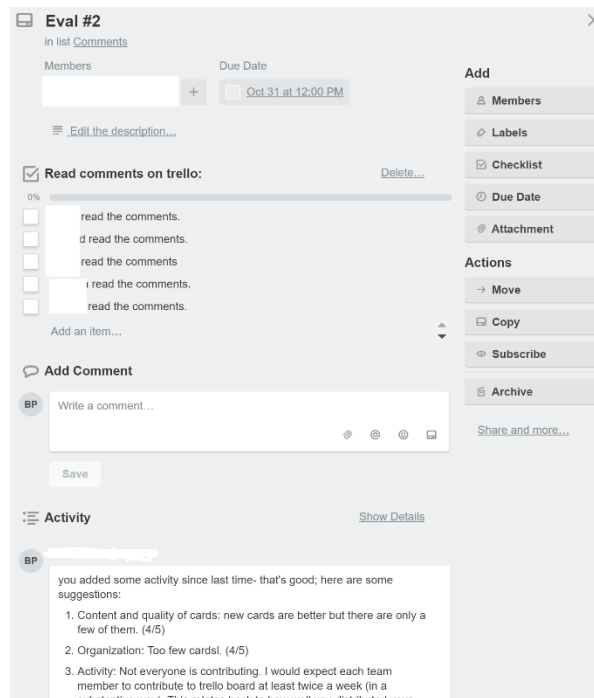

Figure 5. Example of feedback provided in a Trello card placed in the *Comments* list.

The evaluator can also take a screenshot of Trello board and store it for comparison with the next evaluation. This is useful not only as an archive of student work but can also be used as visual representation of student progress and learning.

We are currently in the process of collecting assessment data utilizing this rubric and will analyze it at the end of the 2017-18 academic year.

4. Teamwork in Freshman Courses

To assess the effectiveness of student teamwork, we use the CATME Peer Evaluation survey, CATME is a 360° team survey tool that allows for assessment of issues pertaining to team satisfaction, tasks, mission and goal, and conflict through self and peer evaluation [15-17]. The tool measures team member contributions within five areas using a behaviorally-anchored rating scale:

1. Contributing to the team's work
2. Interacting with teammates
3. Keeping the team on track
4. Expecting quality
5. Having related knowledge, skills and abilities

These areas align with our objectives for teaching project management within undergraduate ECE courses. Furthermore, by administering a CATME assessment mid-way through the term, malfunctioning teams are identified so that the instructor can intervene.

The CATME system was used to assess teamwork in ECE 101 and 102 where we included only the default questions. Here we report on the five questions listed above and in Table II, as well as three questions related to satisfaction with the team, as given in Table III. Additional and more detailed questions about project planning become more relevant as students progress through sophomore and upper-division courses, and especially for the Capstone design sequence, as discussed in the next section. Note that questions in Table II are peer-evaluations including self-evaluations, i.e., they relate to assessment of individual team members. Questions in Table III relate to satisfaction with overall team performance. Both sets of assessment data are for ECE 101 and 102 collected during the 2016-17 academic year. Column "Mean" gives mean values and "SD" standard deviation values. In general, we set the threshold at 4.00 so that teams are exceeding our expectations if Mean ≥ 4 and meeting our expectations if $3 <$ Mean < 4. Overall results indicate that students are satisfied with their teammates' contributions to the team (Table II) and they like how their teams functioned (Table III). Interestingly, Q3 "Keeping the team on track" scores are consistently the lowest, which seems to indicate that teams have problems with keeping up with their schedules, which may be unrealistic or poorly executed.

Table II. Peer-assessment of contributions to the team using CATME for ECE 101 (N= 32 out of 37, 8 teams, Fall'16) and ECE 102 (N= 41 out of 54, 17 teams, Winter'17).

		ECE101		ECE102	
		Mean	SD	Mean	SD
Q1	Contributing to the team's work	3.93	0.94	3.92	1.12
Q2	Interacting with teammates	4.02	0.9	4.02	0.96
Q3	Keeping the team on track	3.88	1.06	3.83	1.07
Q4	Expecting quality	3.96	1.03	3.87	1.04
Q5	Having related knowledge, skills and abilities	3.99	0.94	3.92	1.03

Table III. Assessment of satisfaction with teamwork using CATME for ECE 101 (N= 32 out of 37, 8 teams, Fall'16) and ECE 102 (N= 41 out of 54, 17 teams, Winter'17).

		ECE 101		ECE 102	
		Mean	SD	Mean	SD
QS1	I am satisfied with my present teammates	4.22	0.79	4.10	1.02
QS2	I am pleased with the way my teammates and I work together	4.00	0.95	4.12	0.84
QS3	I am very satisfied with working in this team	3.97	1.00	3.95	1.07
QS	**Overall team satisfaction (entire class)**	**4.06**	**0.92**	**4.06**	**0.98**

Note that ECE 101 and 102 teams are subject to fluctuations as some students are uncertain if they want to pursue an engineering career and stop participating mid-way through the course. Out of eight teams in ECE 101, there were three that exhibited significant problems with individual student's contributions but the teams produced final projects nonetheless. There were no teams that completely failed. There were 17 teams in ECE 102, out of which two exhibited problems with individual student's contributions, two had students effectively drop the class, and only one team really failed as there was only one out three students contributing.

Comparing the results in Table III with Table IV in the next section, which gives the same data for seniors doing capstone design, we observe somewhat lower satisfaction with teamwork among freshmen. Similarly, there is a wider spread of opinions among freshmen, as indicated by larger SD values. This is expected given that many freshmen have limited teamwork experience. However, we need to work on the middle two years and assess student development of teamwork skills. Overall, we are currently satisfied with how our freshman students handle teamwork.

5. Experiences with Capstone Teams

We have been using Scrum management practices for our senior capstone projects for the past three years. The ECE capstone experience may be divided into two distinct parts. In the Fall term, students take on a term-long project, dubbed the "practicum experience," under the

direction of a faculty mentor. The practicum is a vehicle for introducing the students to project management techniques, as well as other professional practices, prior to the students engaging in the second part of the capstone experience during Winter and Spring terms [18]. During this second part, students work under the direction of an industry sponsor on a project defined by the sponsor. During both parts of the capstone experience, the faculty mentor periodically administers surveys to measure the students' teamwork and managerial practices.

5.1. Capstone Practicum

For the practicum experience, students are assigned a controls-based, term-long engineering project, for which they must use a programmable logic controller (PLC) to realize a feedback control solution to an engineering problem. Teams of students are provided a set of engineering specifications that they must prioritize and implement by the end of the term. This is a challenging engineering project that builds upon student experiences from several other courses, specifically controls, electronics, power engineering, and electrical machines.

However, the project is but a vehicle for introducing students to the Scrum project management process. During the practicum experience, students, a TA and a faculty member assume the Scrum roles. Students serve as team members and Scrum Master, while the TA and faculty member play the role of product owner. Students use the engineering specifications to develop user stories for their kanban *Backlog*. The students implement kanban boards using Trello, just as they do in ECE 101 and 102. Through the iterative cadence of Scrum, students incrementally realize the specifications, delivering some form of a minimum viable product at the end of each sprint.

Over the ten week period of the practicum experience, students iterate through four or five sprints, which allows them to refine their project management competencies. We observe that students need to run through three to five sprints prior to "getting it," a time period which the ten-week practicum experience provides. The application of Scrum during the practicum experience serves as a "dress rehearsal" for their capstone design project.

5.2. Capstone Design Project and Team Assessment

After developing their Scrum management skills through the practicum experience, students are assigned a capstone project. All ECE capstone projects at our University are focused on engineering problems defined by an industry sponsor, whom we refer to as the client. Students are not required to use Scrum as their project management method, but for those that do, a faculty member assumes the role of the product owner, who represents the industry client. One of the senior students serves as the Scrum Master, providing managerial leadership during stand-up, planning, and retrospective meetings. The remaining seniors serve as team members. Team members work with the product owner to generate a backlog of user stories. Team members then work together to prioritize, refine, and commit to executing the user stories.

We use the CATME tool to perform assessment of teamwork for both the practicum experience and the capstone projects. As noted previously, CATME provides several assessable points, a few of which are presented in Table IV and Figure 6. Table IV shows details for two of the assessment categories, *Team* and *Goal Specification*, as well as average student scores, for an assessment administered after one of the sprints. Very similar results were obtained in 2015 [10] but the standard deviation is larger in this set of data. Only one category had a mean score less than four, which we set up as the border between "meeting" and "exceeding" our expectations. Figure 6 shows the change in average scores for four assessment categories across four successive sprints, showing a general upward trend in improvement.

From these and other data not presented in this manuscript, we can infer that the students are engaging each other effectively within their teams, establishing goals, formulating strategies and planning, managing team conflict, and enjoying their work. Based on these data and our observations, we offer the following insights of our capstone Scrum teams:

- Students need to run through three to five sprints prior to "getting it," a time period which the ten-week practicum experience provides.
- Project teams appear to apply a steady amount of effort to their capstone project rather than rushing to complete the project prior to the end of spring term, as seems typical of our traditional, non-Scrum, capstone teams.
- Team conflicts have been rare, and the CATME tool signals moments for intervention. The frequent stand-up meetings and reflective retrospective meeting, plus deeper involvement from the product owner, may account for this phenomenon.
- Student performance has been exceptional, both from the perspective of our industry sponsors and product owner/faculty members.

Table IV. Mean scores and standard deviation for two assessment categories (QS and GS) from the CATME survey administered after the 4th and final sprint of the term for the Fall'16 Capstone practicum.

|	*ECE 411, Fall 2016, 5 teams, 22 respondents*	*Mn*	*SD*	*Expect.*
QS1	I am satisfied with my present teammates	4.45	0.84	exceeds
QS1	I am pleased with the way my teammates and I work together	4.27	1.01	exceeds
QS3	I am very satisfied with working in this team	4.41	0.83	exceeds
QS	**Team, Class**	**4.38**	**0.85**	**exceeds**
GS1	Set goals for the team	4.09	0.79	exceeds
GS2	Ensure that everyone on our team clearly understands our goals	4.00	1.04	exceeds
GS3	Link our goals with the project specifications provided by the client	4.09	0.79	exceeds
GS4	Prioritize our goals	4.09	0.67	exceeds
GS5	Set specific timelines for each of our goals	3.95	0.88	meets
GS	**Goal Specification, Class**	**4.06**	**0.76**	**exceeds**
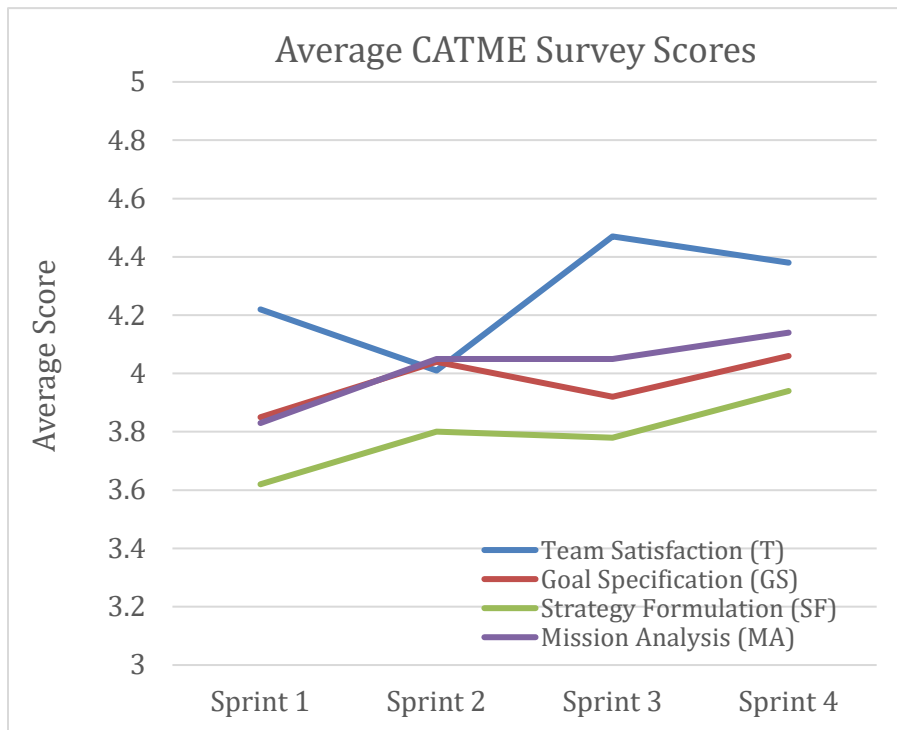
Figure 6. Average scores for four assessment categories from CATME surveys administered after each of the four sprints in the Fall'16 Capstone practicum.

6. Conclusions

We are now in our third year of implementing Scrum in ECE freshman courses with projects and senior capstone design courses. We believe that in order to become proficient practitioners of Scrum, students need to learn about it early and use it often. To accomplish this, we will expand its use into a sophomore-level Cornerstone design course starting in Fall 2018. Our initial experiences with freshmen are encouraging, but application of project management and Scrum this early requires careful scaffolding. The use of Trello for implementing on-line kanban boards provides some of that scaffolding. To better assess student project management skills and to provide them with timely feedback, we have developed a rubric based on Trello boards. This assessment is primarily formative. We are currently collecting data based on it and will adjust the rubric as needed.

We expect that students will implement Scrum on their own in other project-based coursework outside of these required instances. If so, then that would indicate students find the management framework provided by Scrum to be a useful tool. Anecdotally, we have already observed this with the capstone projects; students are not required to utilize Scrum to manage their capstone teams, but the majority of teams who were exposed to Scrum during the practicum use Scrum for

their capstone project. As freshmen students matriculate into their sophomore and junior years, we expect to see them using Scrum in their other project-based courses.

In order to complete projects successfully, students also have to be good at teamwork, which we assess using the CATME tool. As expected, more problems tend to surface in freshman courses than in senior Capstone design ones, and CATME has also been valuable in identifying malfunctioning teams early. Early data also indicates student development as they work through several sprints in their capstone practicum. In our experience, modern tools paired with careful planning of student activities help develop effective student teams and successful implementation of Scrum-based project management.

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