Applying Scrum Project Management in ECE Curriculum

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***Abstract*—Scrum is a cyclical project management technique whereby members of a development team work together to define product development strategies in pursuit of a common objective in an adaptable and incremental manner. We have found that Scrum is a promising approach for exposing students to project management of undergraduate engineering projects. But, the technique is not used often in undergraduate education, and it is virtually unknown outside of software engineering circles. We are experimenting with using Scrum in projects across several years of undergraduate engineering education. Our goal is to gradually expose students to project management in order to make their project experiences and learning more efficient and effective. We report on successful initial implementations in freshman courses and senior capstone design courses. Obstacles include expanding practice across all four years, accommodating a diverse student population, and overcoming a lack of experience in assessing Scrum project management.**

Keywords—engineering curriculum, engineering management, electrical engineering, freshman, design projects, capstone projects, Scrum.

I. Introduction

Undergraduate electrical and computer engineering students are engaged in multiple projects during their studies. Projects can differ in terms of technical area, duration, scope, depth, size of teams, etc., but some form of project management is common to all of them. It is expected that the complexity and scope of projects will increase as students progress in their studies, but students in even the simplest team projects will apply reductionism: they will break up the problem into tasks, assign tasks to group members, and develop a basic timeline to solve those tasks. Some electrical and computer engineering (ECE) programs use project-based learning as the main component of their curriculum but the majority of programs still use project-based learning in only a select few courses. Given ABET's requirement for a "curriculum culminating in a major design experience" [1] all accredited BS programs in the US will have some form of capstone project that is usually project-based.

By the time they begin their capstone project, students should be able to apply more formal methods of project management. Traditionally, project management is done within the so-called "waterfall" framework, a sequential process involving a cascade of phases, often represented using Gantt charts. One disadvantage of this approach is that it is fairly static and most planning for time and resources is done up front. It relies heavily on documentation and a set of requirements and specifications.

An alternative approach to project management is Scrum, which has spread from the software industry into other fields, e.g. engineering, urban planning, and law [2]. Scrum does away with the long-term project forecasting of the waterfall method. Instead, it employs a cyclical feedback process that uses the progress of a project to increment project planning and produce products on an iterative basis. Development cycles ("sprints") are usually only a few weeks long, which allows frequent and rapid adaptation to changes in customer requirements, available resources, and new knowledge gained by the team. Agile and/or Scrum methods have been widely used in software industry but relatively little has penetrated software engineering programs [3]. Even less has been reported on their use and effectiveness in other engineering disciplines. Our literature search for papers on "engineering education" and "scrum" or "agile" yielded only a handful of relevant papers [4]-[9]. Within the engineering education context, Scrum provides some advantages over traditional project management techniques [4]:

- Rapid prototyping
- Quick feedback
- Incremental development
- Discovery of core values which are important to customer and are not obvious at the start of the project
- Decentralized project management function so that more students experience it

To this list we add the following:

- Transparency in teamwork – frequent meetings expose any weaknesses in contributions by team members
- Project status understanding – frequent meetings provide all team members with a granular understanding of the status of the project

Existing literature on using Scrum in engineering education deals almost exclusively with upper-division or graduate engineering courses, e.g. [4]. This is an obvious place to try out how well Scrum works, but like any other professional skill it should be taught across the curriculum and in the context of engineering projects. For example, it has been shown that technical writing needs to be taught in the context of engineering and across curriculum [10]. For Scrum, or any other project management to be really useful across curriculum, we should start teaching it early and often. For these reasons, we plan to experiment and implement Scrum across several years of the ECE undergraduate programs, as outlined below.

II. Scrum in Lower Division ECE Courses

In order to increase freshman students' motivation and retention, many programs, including our electrical and computer engineering programs, utilize projects that directly demonstrate to students the applicability and significance of what they are learning. However, many students suffer a large shock when switching to university courses after high school or community college. As such, we have to be careful to not add yet another learning goal to an already crowded field. Therefore, in our freshman courses, we do not insist on proper project management (PM).

Rather, PM tools are used primarily to encourage planning of activities and to enable collaboration. One such tool is the Kanban board, which provides a visual representation of project progress [16]. This visualization is an important tool for managing the flow of knowledge. From an educational perspective, the combination of Scrum and Kanban has the advantage of dynamic and graphical representation of the current status of the project. Its format makes it obvious where the biggest obstacles are and it highlights individual team member's responsibilities. Kanban boards and frequent "stand-up" meetings provide positive peer pressure to ensure progression of the project and continued development of the team itself. In our freshman ECE 101 Exploring Electrical Engineering and ECE 102 Engineering Computation we introduce students to the online version of these tools via the web-based project management application Trello (trello.com, which offers free accounts). Trello provides a means for creating on-line Kanban boards. While we would like to preserve the "touch and feel" of whiteboards with sticky notes typical of Kanban boards, we do not have appropriate place to hold upwards of 20 boards.

Details of our introductory ECE 101 and 102 courses may be found elsewhere [11],[12]. Both courses feature one major project. In ECE 101, it is a Rube-Goldberg machine (similar to [5]). In ECE 102, the project involves a data acquisition (DAQ) unit, which is programmed through MATLAB [12]. Projects are done in two phases, where the first one is used to handle some preliminary research or similar activity while the last 5-6 weeks of the quarter are used for design, construction and testing. In the Fall of 2015 we introduced Trello as PM tool in ECE 101. Table I gives student responses to question on "how helpful was Trello" as a tool for their learning. Students were not overly excited: 14 out of 27 found it very or somewhat helpful, 9 were neutral and 4 found it not helpful.

During Winter 2016 we evaluated ECE 102 student work on Trello-based Kanban boards using a simple rubric, shown in Table II. Maximum score for each criterion is one for a maximum total score of 3. Fig. 1 gives a histogram of scores for individual students based on this rubric. Students' scores were reduced if they did not contribute significantly to their Trello Kanban board and zero was given if no board was created. Around ⅓ of the class is below expectations (total score <2.25) and we need to improve their performance.

Table I. ECE 101 Student evaluation of how helpful Trello was in their learning (27 respondents).

	Very helpful	Somewhat helpful	Neutral	Not helpful	Waste of time
Using Trello	6	8	9	4	0

Table II. Rubric for assessing student use of Trello Kanban boards.

Criterion	***Exceeds expect. (1)***	***Meets expect. (0.75)***	***Does not meet expect. (0.25)***
Organization	Very well organized	Decent organization	Disorganized layout
Quality of Trello cards	Very clear and concise story cards	Decent task descriptions on story cards	Unclear or rambling tasks on story cards
Degree of activity	Everyone on the team actively participates	Most, but not all, people interact consistently	Mostly the work of one person
Total score	3	2.25	0.75

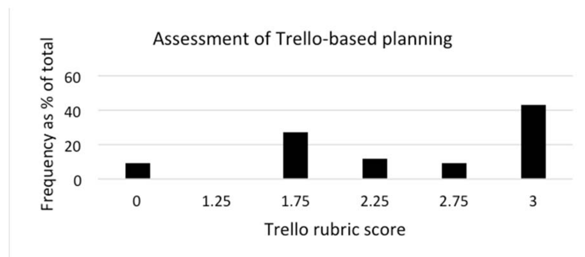

Fig. 1. Histogram of student scores using rubric in Table II for ECE 102 course.

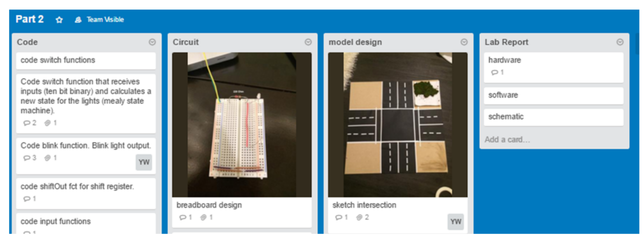

Fig. 2. Example of student designed cards in Trello illustrating incorrect use of Kanban board approach.

Our current PM assessment is under development and we need to, for example, improve rubrics and add other metrics. However, we can offer some initial observations:

- As expected, student performance varies widely. For example, Fig. 2 shows that students can organize their workflow in unexpected ways. Instead of organizing their work in stages, e.g. Backlog, Ready, In progress, Review and Done, they organized the lists by tasks (see column labels in Fig. 2): Code, Circuit, model design and Lab Report. This makes it impossible to gauge progress of their work and negates one of the main advantages of using Kanban boards. We will need to provide more scaffolding and oversee teamwork and project management more closely.

- More direct oversight of groups is needed and we are experimenting with assigning upper-class students to run Scrum-like meetings during the lecture time or labs. These meetings are currently done 2-3 times a week.
- Watching instructional videos on use of Trello is insufficient and we have now started providing templates for students to work with. Students have to be monitored for entering checklists, deadlines and assignments.

A. *Teamwork assessment*

The CATME peer-evaluation system [13],[14] was used to assess teamwork in ECE 101 and 102. Only the basic functioning and team cohesiveness questions were included but these may be expanded in the future to include Mission Analysis, Goal Specification, and Strategy Formulation and Planning. These additional questions become more relevant as students progress through sophomore and upper-division courses, and especially for Capstone design sequence (see section III). Table III gives assessment results for ECE 101 and 102 collected during 2015-16 academic year. Column "Mn" gives mean and "SD" standard deviation values. Column "Expect." is our assessment of teams' performance based on mean values. Teams are exceeding our expectations if Mn > 4 and meeting our expectations if 3 < Mn < 4.

TABLE III. CATME PEER-ASSESSMENT RESULTS FOR TWO FRESHMAN COURSES. SCORING RANGES FROM 1 TO 5.

	ECE 101, Fall 2015, 9 teams, 32 respondents	***Mn***	***SD***	***Expect.***
Q1	I am satisfied with my present teammates	4.03	1.26	exceeds
Q1	I am pleased with the way my teammates and I work together	4.15	0.97	exceeds
Q3	I am very satisfied with working in this team	4	1.27	exceeds
Q	**Team, Class**	**4.06**	**1.18**	**exceeds**
	ECE 102, Winter 2016, 12 teams, 32 respondents			
Q1	I am satisfied with my present teammates	3.97	1.10	meets
Q1	I am pleased with the way my teammates and I work together	4	1.12	exceeds
Q3	I am very satisfied with working in this team	4	1.03	exceeds
Q	**Team, Class**	**3.99**	**1.08**	**meets**

ECE 101 teams are subject to fluctuations as students may decide well into the term that they are not really interested in ECE programs and effectively withdraw from the class without doing so officially. ECE 102 teams are more stable and out of 12 teams there were 2 that exhibited significant problems. Comparing results in Table III with Table IV, which gives the same data for seniors doing capstone design, we observe 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 very limited teamwork experience. However, we need to fill in the blanks for the in-between years. Overall, we are satisfied with how our freshman students handle teamwork but there is a lot of room for improvement.

B. *Sophomore Cornerstone course*

To fill in the gap between freshman and junior courses, our department will be implementing a two-quarter long, project-based cornerstone course during sophomore year. It will serve, among other goals, to solidify students' understanding and use of project management skills, started within ECE 101 and 102, in order to expose students to more formal approaches to design. Scrum will be our technique of choice for project management. We anticipate continued use of upperclass students to help with project management segment. These helpers will be trained in Scrum during their capstone projects, as explained below, along with some additional training.

III. EXPERIENCES WITH CAPSTONE TEAMS

We have been using Scrum management practices for our capstone projects for the past two years. The ECE capstone year may be divided into two distinct parts. In Fall term of their senior year, students take on a term-long project, dubbed the "practicum experience." The practicum is used to develop project management techniques, and other professional practices, prior to the students engaging in the second part of the capstone experience during Winter and Spring terms [15].

A. *Senior Practicum Experience*

For the practicum experience, students are assigned a controls-based engineering project, for which they must use a PLC to realize a feedback control solution to an engineering problem. The project though is but a vehicle for introducing students to a more formal Scrum process. During the practicum experience, students, a TA and a faculty member assume one or more of the following Scrum roles: product owner, scrum master and team members. The scrum 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. The team members decide how to implement those user stories during a time period called a sprint. A sprint is a set time period, 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 items chosen from the backlog, followed by a retrospective meeting during which the team scrutinizes its management practices. Throughout the sprint the scrum master keeps the team focused. This process repeats until the backlog is empty. Over the ten week period of the practicum experience, students iterate through multiple sprints, refining 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.

B. *Senior Capstone Project*

After honing their scrum management skills through the practicum experience, students are assigned a capstone project. All ECE capstone projects at Portland State University are focused on engineering problems defined by an industry sponsor, whom we refer to as the client. A faculty member assumes the role of the product owner, who represents the client and generates the backlog of prioritized user stories. A graduate student serves as the scrum master, providing managerial leadership during stand-up, planning and retrospective meetings. The seniors serve as team members, prioritizing, refining and committing to user stories.

TABLE IV. CATME PEER-ASSESSMENT OF CAPSTONE TEAMS. SCORING RANGES FROM 1 TO 5.

	ECE 411, Fall 2015, 4 teams, 17 respondents	***Mn***	***SD***	***Expect.***
Q1	I am satisfied with my present teammates	4.53	0.50	exceeds
Q1	I am pleased with the way my teammates and I work together	4.47	0.50	exceeds
Q3	I am very satisfied with working in this team	4.65	0.48	exceeds
Q	**Team, Class**	**4.55**	**0.5**	**exceeds**
GS1	Set goals for the team	4.06	0.64	exceeds
GS2	Ensure that everyone on our team clearly understands our goals	3.94	0.64	meets
GS3	Link our goals with the project specifications provided by the client	4.35	0.48	exceeds
GS4	Prioritize our goals	4.00	0.59	exceeds
GS5	Set specific timelines for each of our goals	3.82	0.78	meets
GS	**Goal Specification, Class**	**4.03**	**0.86**	**meets**

C. Capstone Team Assessment

We use the CATME tool to perform assessment of teamwork for the practicum and capstone projects. CATME is a 360° team survey tool that allows for assessment of issues pertaining to Team Satisfaction, Tasks, Mission & Goal and Conflict. CATME provides many assessable points, and a few are presented in Table IV. From these example tables and other data not presented here, we can infer that the students are engaging each other effectively as a team, establishing goals, formulating strategies and planning, managing team conflict, and enjoying their work. Based on this 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 not been an issue to date. The frequent stand-up meetings and reflective retrospective meeting, plus deeper involvement from the product owner, may account for this phenomena.
- Student performance has been exceptional, both from the perspective of our industry sponsors and product owner/faculty members.

IV. CONCLUSIONS

We agree with some recent reports that Scrum methodologies present interesting opportunities to enrich student learning in senior capstone courses. However, we believe that in order to become proficient, practitioners of Scrum should learn about it early and use it often. Our initial experiments with freshmen are encouraging, but application of Scrum this early requires more scaffolding. The use of Trello for implementing on-line Kanban boards provides some of that scaffolding.

We intend to expand student preparation and make it more sophisticated in the sophomore year through a project-centric cornerstone course. In their junior year students should be proficient enough with Scrum to apply the process in their course-level projects, e.g. in power systems design, without a lot of supervision and scaffolding. This would then make them ready to undertake more complex, longer term, and real-life projects in their capstone courses. Our initial experiments with capstone teams have been very positive and we will be expanding them further in the years ahead.

REFERENCES

[1] ABET EAC Criteria 2015-16, http://www.abet.org/wp-content/uploads/2015/05/E001-15-16-EAC-Criteria-03-10-15.pdf . Last accessed 4/23/2016.

[2] The Scrum Guide, http://www.scrumguides.org/scrum-guide.html . Last accessed 6/19/2016.

[3] M. R. Marques, A. Quispe, and S. F. Ochoa, "A systematic mapping study on practical approaches to teaching software engineering," in 2014 IEEE Frontiers in Education Conference (FIE) Proceedings, 2014, pp. 1–8.

[4] M. Edin Grimheden, "Can agile methods enhance mechatronics design education?," Mechatronics, vol. 23, no. 8, pp. 967–73, Dec. 2013.

[5] D. Reith, C. Bachmeier, and I. Gross, "Be an Engineer right from the start: An introductory project with Rube Goldberg machine and SCRUM," in 2015 IEEE Global Engineering Education Conference (EDUCON), 18-20 March 2015, 2015, pp. 249–54.

[6] E. Valentin, J. Carvalho, R. Barreto, "Rapid Improvement of Students' Soft-skills Based on an Agile-process Approach," in 2015 IEEE Frontiers in Education Conference, October 21-24, El Paso, TX, USA

[7] R. de Souza, S. Zorzo, D. da Silva, "Evaluating capstone project through flexible and collaborative use of Scrum framework," in 2015 IEEE Frontiers in Education Conference, October 21-24, El Paso, TX, USA

[8] L. Collingbourne, W. Seah, "Teaching Project Management using a Real-World Group Project," in 2015 IEEE Frontiers in Education Conference, October 21-24, El Paso, TX, USA

[9] D. Rover, C. Ullerich, R. Scheel, J. Wegter, and C. Whipple, "Advantages of agile methodologies for software and product development in a capstone design project," in 2014 IEEE Frontiers in Education Conference (FIE) Proceedings, 2014, pp. 1–9.

[10] S. Conrad, W. A. Kitch, T. J. Pfeiffer, T. R. Smith, and J. V. Tocco, "Students Writing for Professional Practice: A Model for Collaboration Among Faculty, Practitioners, and Writing Specialists," in 2015 ASEE Annual Conference and Exhibition, Seattle, WA, 2015.

[11] P. Wong, M. Holtzman, B. Pejcinovic, and M. Chrzanowska-Jeske, "Redesign of Freshman Electrical Engineering Courses for Improved Motivation and Early Introduction of Design," in 2011 ASEE Annual Conference and Exhibition, Vancouver, Canada, 2011, pp. 22.1224.1 – 22.1224.13.

[12] P. Wong and B. Pejcinovic, "Teaching MATLAB and C Programming in First Year Electrical Engineering Courses Using a Data Acquisition Device," in 2015 ASEE Annual Conference and Exhibition, Seattle, WA, 2015, pp. 26.1480.1 – 26.1480.11.

[13] M. L. Loughry, M. W. Ohland, and D. D. Moore, “Development of a Theory-Based Assessment of Team Member Effectiveness,” Educational and Psychological Measurement, vol. 67, no. 3, pp. 505–524, Jun. 2007.

[14] T. Kijewski-Correa, M. Ohland, L. McWilliams, K. Meyers, and S. Silliman, “Comparison Of Two Peer Evaluation Instruments For Project Teams,” in 2008 Annual Conference & Exposition, 2008, pp. 13.315.1–13.315.19.

[15] M. Faust, A. Greenberg, and B. Pejcinovic, “Redesign of senior capstone program in electrical and computer engineering and its assessment,” in 2012 Frontiers in Education Conference Proceedings, 2012, pp. 1–6.

[16] H. Kniberg and M. Skarin, *Kanban and Scrum - making the most of both*. lulu.com, 2010.