Sprint+PDCA Approach to Improving Project Management Skills and Mindset in Capstone Design

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In recognition of student's normal resistance to take time to schedule their capstone design projects unless forced by specific assignments, short duration sprint schedules are used to lessen student resistance and build on the growing success of agile project management as a useful tool in industry. Paired with the Plan-Do-Check-Act process improvement cycle, a preliminary *Sprint+PDCA* implementation in a capstone design course showed positive impacts when compared to a prior year without the treatment, and in surveys and observations of student and team development during the treatment year. Although this work is preliminary and could benefit from more rigorous means of assessing skills and mindset, we believe the results support our hypothesis that the *Sprint+PDCA* approach takes advantage of industry methods for rapid learning to create favorable conditions for the development of project management skills and mindset. Although we make observations about project management mindset, our experiences highlight the need for a better means of assessing mindset to be developed and tested over a longer time period.

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Introduction

An intended outcome of many capstone design courses is for students to transition from a student mindset (follow a specific set of instructions with a specific due date) to a professional mindset (develop plans to accomplish appropriate goals). In our experience, students often do the minimum for scheduling, commenting that 'busy work' gets in the way of their ability to finish the project. Supporting our observations, Lawanto, Cromwell and Febrian, researching student's self-regulation in managing projects, found that an "area of significant concern lies in students' infrequent efforts to define, update and adhere to a project schedule.[1] "

Agile project management with sprint scheduling pushes a design team to produce something for external feedback as soon as possible, enabling quick changes or pivots in the project trajectory as new information becomes known. Sprints have expanded beyond their origins in software development to many other fields as evidenced by the title of the March 2016 book *Sprint: How to Solve Big Problems and Test New Ideas in Just Five Days*. Importantly for education, sprints are designed for rapid learning and therefore warrant consideration for student projects. In an ASEE paper from 2011[2], Reichlmayr proposes adaptations for implementing relevant aspects of agile project management in an Android App development course. Much earlier, in a 1998 ASEE paper[3] Schreuders and Johnson showed increased student motivation from their form of sprints - multiple short duration student projects in place of a single long duration 'marathon' project.

From this background and our own experiences, we hypothesized that 2-week sprint durations and the review meetings after each sprint would allow students to quickly experience the frustrations of what doesn't work, providing motivation to make the next sprint schedule better. In this research we study capstone design team use of multiple short sprints to simultaneously create product (quick and unrefined prototypes) and process (quick attempts at scheduling tasks to create a prototype) deliverables that can be evaluated for continuous improvement. We define a project management mindset as a recognition of the value of project scheduling, evidenced by student use of some form of project management tool for sufficiently complex projects when not required by an assignment.

To increase the chances of creating a behavioral and mindset change, we pair the use of sprints with the historic Plan-Do-Check-Act (PDCA or alternately PDSA when check is replaced with study) process which has its origins in process improvement in industry. The PDCA process was popularized by W. Edwards Deming and has been used to drive continuous improvement in settings ranging from developing the post-WWII Japanese economy to enriching the

curriculum of engineering programs[4]. Our *Sprint+PDCA* approach encourages learning before doing (plan), adds structured reflection (check or study), and heightens awareness of the process improvement (act) aspects of sprint scheduling.

A review of engineering education literature identified some papers related to developing project management skills[5], but none that used sprints or PDCA or addressed development of a project management mindset. Our work builds on Pazos and Magpili's work[6] that showed scaffolding can have a significant impact on professional skill development (in their case teamwork) for engineering students.

Research Study Details

This study occurs in a year-long Senior Capstone Design course with 70 - 90 students working in five-person teams on projects that encompass an entire product development cycle (from working with a customer to define the problem, through building, testing, delivering and providing technical support for a working prototype). Industry professionals help mentor the teams and provide direction at critical points in the design process. The perspectives of these mentors are included as one of the sources of evidence in this research study. Smartsheets was used as the common scheduling software throughout the main part of this study. Development and maintenance of the schedule is meant to be a rotated student responsibility, though in practice for some teams a single member took on a primary scheduling role.

In this research we specifically seek to determine whether a *Sprint+PDCA* approach allows students to:

1. Overcome their natural resistance to scheduling
2. Develop project management skills
3. Develop a project management mindset

We hypothesize that students given achievable scheduling tasks in a short sprint to the next milestone will gain confidence in their ability to schedule during each iteration, and through reflection on small successes and encouragement from mentors will gain an appreciation for the value of scheduling. The study has two parts. Part 1 is a comparative experiment with teams from one year (2015-16) as the control population and teams from the following year as the treatment population, with a follow up comparison conducted in a third year. Part 2 looks more closely at development of the students and teams in the treatment group (2016-17). Note that in both control and treatment groups, the students also used a PDCA approach for individual professional skill development. About 15% of the students in the control selected something related to scheduling or project management for their individual professional skill development, but their development project was only discussed individually with the instructor and was not shared with the team.

Part 1 – Comparative study

The control teams were given a Smartsheets schedule template that included a line item for all design process tollgate items. For example, line items for "Design Process Phase 1: Problem Definition, Design Specifications and Standards, and Team Development" are: Needs Statement and Customer Requirements, Research and Benchmarking, Target Design Specifications, and Plans for Team Effectiveness. They had more details for required deliverables and due dates than the treatment group, but the overall requirement and encouragement to maintain a project schedule was more informal than for the treatment group. Instead of a schedule template, treatment teams were given a 'blank slate' Smartsheet file that simply contained each phase of the design process, but none of the line items. For example, their Smartsheet for Phase 1 only included the title of the phase and a milestone completion date for the entire phase. Treatment teams were assigned multiple sprint scheduling iterations during the problem definition, conceptual design, and prototype design phases of the design process, but were given liberty to develop and maintain their own version of a sprint schedule to increase their sense of ownership and encourage them to see it more as an aid to their progress, rather than as a separate assignment. One downside of this flexibility for comparative purposes is that it gave rise to a wide variety of formats and uses of sprint schedules in the treatment group. This is further evaluated in part 2 of the study.

One comparative result of interest is that only 33% (5 of 15) of control group teams stayed on schedule throughout the design process, compared to 64% (9 of 14) treatment group teams. Further, external project mentors confirmed improved team progress during the treatment year, with our lead mentor stating: "Team progress has been better this year compared to last. Steps taken to accelerate scheduling have been successful."

A second comparative result is related to the "winter break performance lag" that occurs for many design teams starting the week before fall semester finals and continuing through a slow start the first few weeks after the 4-week winter break. Only 20% (3 of 15) of control group teams minimized this lag though warned about it in advance, compared to 64% (9 of 14) of treatment teams. We believe the short-term responsibilities in the sprints and more frequent check-ins helped teams stay on task through the disruption caused by the break, but this explanation requires further study.

An observation from the comparative study is that only 13% (2 of 15) of control group teams continued

using any written type of team / project schedule after the requirement was removed (after initial prototype delivery), indicating most control group teams did not develop a project management mindset. The two teams that continued using a schedule included non-traditional students with significant industry work experience, a factor that was found to impact a team's attitude towards scheduling independent of the treatment.

Because of student feedback and a change in university software licensing agreements, Smartsheets was dropped as the required scheduling software for the 2017-18 projects. These teams completed readings and learning activities related to agile project management and received some guidance on constructing and maintaining a schedule but were given freedom to select the format and software for their schedule. It was expected that most would follow a form of short duration sprint scheduling, but that was not the case. Their main scheduling motivation was the need to demonstrate prototype manufacturing 'schedule feasibility' along with technical and cost feasibility to get budget approval to buy parts. Towards the end of their prototype manufacturing stage as part of the regular cycle of TA meetings with the teams, team members were asked to reflect on their schedules up to that point, and then to develop a sprint schedule for the next week of the prototyping phase. A pre-post survey was used to spur reflection on scheduling and get some evidence of their perspective on sprint scheduling. Of the students surveyed, 29% cited communication and accountability issues in their team in the pre-survey. After utilizing a sprint schedule, 84% of the students reported that the sprint schedule aided communication between team members and accountability of team members related to deliverables. A confounding observation is that students who reported using the schedule more than twice during the week gave only a slightly higher average rating (8.2 vs. 7.8) on the statement "On a scale of 1-10, was it a good use or poor use of team time to create bi-weekly sprint schedules" than the students who used the schedule less. This highlights the challenge in assessing student perspectives on scheduling, especially with survey data.

Part 2 – Impact on skill development and mindset

To dive more deeply into the treatment group, before, during and after surveys were used to characterize the perceived impact of the *Sprint+PDCA* approach on student's project management skills and mindset. The survey data was supplemented by review meetings, evaluations of student work, and observations of team performance. Review meetings included using design process tollgates to judge team progress and observing use of and attitudes toward project management tools, with the overarching purpose of encouraging the engineering students to behave as engineering professionals. These meetings are a confounding factor for the comparative study, because although review meetings were consistent for both groups, it is likely that the treatment group reviews included more focus on schedules than the control group reviews.

In the survey, students were asked to assign a numerical value between 1 and 10 (1 being the lowest score and 10 being the highest) in response to each question. The "Before" results are an average of the responses from pre-test surveys that 16 students filled out before their sprint schedule iteration. The "After" results are an average of responses to a survey that 32 students completed after they had some experience with the *Sprint+PDCA* process. For the first question, "I feel prepared to make a project sprint schedule," the before result average of 6.9 compared to the after result of 9.6 shows that students perceived an increase in their skills related to sprint scheduling. This result was expected, but the high value for the "After" result shows that the sprint scheduling tasks seem very achievable to students. This high value is consistent with results reported in the required reflection report completed by all students at the end of the fall semester, in which students responded to the question: For those who took primary responsibility for one of the Sprint Schedules this term, rate how prepared you feel for scheduling of future projects.

Prepared - I have a basic understanding and would be able to put together a starter schedule	75% (32 of 43)
Semi-prepared. Can get started but would need some assistance.	23% (10 of 43)
Unprepared. Not sure where to start	2% (1 of 43)

Another result from the required reflection report (shown in the table below) was that 82% of the students thought it would probably or definitely be worth spending time to make and use a project schedule.

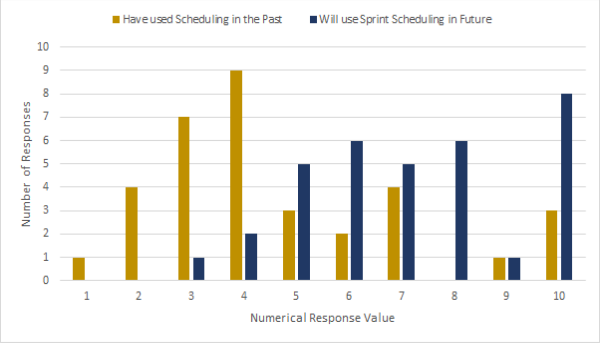
At this stage of the project, do you believe spending time to make and use a project schedule can help your team make more effective use of your time and resources?

Yes, the time invested would pay off and we plan to pay attention to our schedule	48% (30 of 62)
Probably, if we give it more attention than in the past	34% (21 of 62)
Maybe, but I am not sure	13% (8 of 62)
No, unless forced to	5% (3 of 62)

The comments received from students in the survey and reflection reports showed a strong approval of sprint scheduling, with some students making comments such

as: “in a setting where design work is your job… that it would be very effective.” Other teams reported that the sprint scheduling “kicked them in gear” or that “sprint schedules feel like a great tool to see where the team currently is and where we need to speed up or work harder.” The negative comments received were generally recommending improvements on how the tools and expectations were introduced, rather than dissatisfaction with the tools themselves.

To further explore the development of project management mindset for the treatment group, later in the process students were asked to respond on a scale from 1 – 10 to the survey questions “Have you used scheduling in the past as an engineering tool?” and “How likely are you to use scheduling as an engineering tool in the future?” Results plotted against each other in the graph below show that although most students had little experience using scheduling in the past, 60% responded with a 7 out of 10 or higher likelihood that they would use it in the future.



Other relevant observations of the treatment group made during team review meetings are included below.

- After overcoming an initial resistance due to the software learning curve, the TA found that most teams began reporting that Smartsheets and sprint scheduling were valuable tools that help them stay focused by transforming more abstract long term goals (like prototype completion by March 1) into smaller, shorter term, more attainable objectives.
- Teams that adopted the regular use of sprint scheduling began progressing towards their objectives at a much more consistent and steady rate. The review meetings they had were more fruitful, the questions they asked were more directed towards tangible goals, and their overall pace outstripped other teams. When asked, the students themselves seemed to attribute the above successes to their use of the tools provided.
- As the academic year progressed, an increasing number of teams were observed scheduling a team meeting early in the week to discuss both short and long-term goals and the steps to be taken that would accomplish those goals. Most of these teams also scheduled an end of the week follow-up meeting to act as a “debrief” of sorts, and discussed if the goals were met or how to take steps to reach them.
- Some teams did adopt and apply a project management approach beyond the minimum requirements, and these teams were more successful. Direct assessment of student work showed a significant difference in schedule quality and detail for these teams. Also, members of these teams showed more evidence of a project management mindset than members of other teams.

Conclusions, and Future Work

Although this work is preliminary and will benefit from more rigorous means of assessing skills and mindset, the results and observations are promising. The impact on team performance and skill development for scheduling was consistently positive across surveys and observations, and we believe the results support our hypothesis that the *Sprint+PDCA* approach creates favorable conditions for the development of project management skills and mindset. The goal that *Sprint+PDCA*’s focus on setting realistic short-term goals would encourage a consistent pace throughout the design process and help most teams lessen the procrastination effect was met. In this regard some teams excelled beyond expectations - one professor remarked that a team he was working with seemed to “run like a professional design team in the way they set goals, managed time, and provided regular updates.” The results concerning *Sprint+PDCA’s* impact on the project management mindset of the students are not sufficient to make any conclusions, but give some background for ongoing studies. A better means of assessing mindset will need to be developed and tested over a longer time period to generate defensible conclusions.

In the future, in addition to improving assessment methods we hope to do a longitudinal study to track whether a stronger project management mindset at graduation correlates with a faster trajectory to promotion within a range of organizations and industries.

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