Integrating project management early in the engineering curriculum: a spreadsheet-based approach

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ABSTRACT: The use of self-directed teams in design project-based courses is common in engineering schools around the world. Despite the technical proficiency of students, project targets are often not met due to poor management and communication between team members, as well as between teams and the course instructor. In this article, the authors present a spreadsheet-based approach to facilitate the management of design projects in order to ameliorate project outcomes. Using *Excel* for the approach provides advantages firstly for institutions because no investment in another software is required, and secondly for students since they are not burdened to learn a new software package. An assessment investigated the impact of this new approach on students' design performance along with its ease of use. The results provided in the article suggest that the overall implementation was very effective.

INTRODUCTION

The use of team projects in teaching engineering design is pervasive across all engineering disciplines and throughout the curriculum. The success of any design team – both in learning design concepts and performing well – requires that students have a good grasp of technical and management aspects of the design process. Poor management or lack of communication within a team and between teams and their faculty advisor/ instructor may result in a mediocre project, no matter how technically proficient team members are. The importance of team management and common methods to achieve a successful design experience are widely discussed in the literature [1-5]. Common methods for project management include team calendars, Work Breakdown Structures (WBS), Gantt/milestone charts and Project Evaluation and Review Technique (PERT) diagrams.

In this article, the authors focus on how these *textbook* methods can be effectively implemented using a common spreadsheet application, in this case MS *Excel*®. The authors' experiences with the proposed implementation strategy are also presented. An assessment of the implementation indicates this approach to be effective in terms of students' perception on the importance of project management in design projects, the effectiveness and timing of project management concepts introduced, and the impact of project management techniques utilised on their design performance.

Although commercial project management software (eg MS *Project*®) are available, their adoption in a classroom environment presents several challenges [6]. These include the design faculty may not know or feel inclined to learn how to use the software; funds may not be available to purchase the software or use of existing funds would drain already meagre resources and divert their use from other areas in the design curriculum; requiring an additional software tool may present an unwelcome burden for engineering students, who are already required to learn and use a significant number of software tools – word processing, spreadsheets, programming, illustration, image manipulation, Web site design, computer-aided design (CAD), etc; and teaching students a new software tool requires diversion of time away from existing course materials.

The use of *Excel* to create *automated project management tools*, therefore, is a natural choice, as *Excel* is available at virtually every college campus. In addition, students already have a basic level of proficiency in its use, allowing for easy implementation. The authors also demonstrate how students can use *Excel* to create Project Management Workbooks (PMWs) to incorporate *textbook* project management methods into their design experience. The authors also discuss how the use of the PMWs, in conjunction with a weekly coordination meeting, can readily address some of the problems often encountered in team projects like student laggards, project delay and lack of communication.

PROJECT MANAGEMENT WORKBOOKS

Project management involves two primary tasks: planning and scheduling, as well as directing. Planning and scheduling involves activities for understanding the project scope (tasks, time and budget) and organising. These activities define objectives, list tasks, estimate work and duration, determine interdependent tasks, schedule tasks and schedule resources. Directing, on the other hand, involves implementing approved tasks to achieve project objectives. Specific directing activities might be assigning tasks, reviewing criteria for task completion, controlling, reporting and reviewing progress, re-planning, reviewing completed work, resolving issues and closing the project.

Project Management Workbooks (PMWs) implement three common *planning and scheduling tools*: Work Breakdown Structures (WBS), design structure matrices and activity networks, and Gantt/Milestone charts. A description of each tool follows.

PMW: Work Breakdown Structures

The Work Breakdown Structure (WBS) divides the entire project into a series of tasks (no order is implied) and sub-tasks, with the level of decomposition dependent upon the complexity of the project. A generic WBS implemented in *Excel* for a design project is illustrated in Figure 1. To the right of each sub-task description is its estimated duration. This information is used to schedule the tasks appropriately and to ensure that the project is completed on time. Note that this is a dynamic document, which is altered to reflect current events in the project. New primary or lower level tasks are added or removed by inserting or deleting rows, respectively. Students need to only type in the *Start Date* for each task, with the *End Date* automatically calculated by *Excel*.

PMW Design Structure Matrix and Activity Network

PMWs also allow student teams to generate a design structure matrix that facilitates the determination of the order of the tasks (see Figure 2) and activity network diagrams. Network diagrams show all the project tasks, along with their precedence structure, taking into account interdependencies among the tasks [7].

From the activity networks, students can determine the critical project path, as well as the float times for parallel paths. These values are automatically updated each time a task's duration is changed. A screenshot of the activity network for the previously presented WBS is given in Figure 3.

projectmangement_v42.xls

	A	B	C	D	E
1			DATES AND DURATION		
2	**Electrical Bicycle Project**		Duration (days)	Planned Dates	
3				Start	End
4		0.1 Begin Project	1	12/01/03	12/02/03
5	1.0 Determine Customer Need	1.1 Interview users to establish requirements	4	12/01/03	12/05/03
6		1.2 Search the literature for any regulatory requirements	5	12/01/03	12/06/03
7		1.3 Find competitive products and research their reviews	5	12/01/03	12/06/03
8		1.4 Create a hierarchical list of customer needs	4	12/04/03	12/08/03
9		1.5 Revise Problem Statement	3	12/06/03	12/09/03
10	2.0 Generate Concepts	2.1 Functionally decompose the project	5	12/07/03	12/12/03
11		2.2 Research the literature on similar subtask solutions	7	12/09/03	12/16/03
12		2.3 Generate concepts	5	12/15/03	12/20/03
13		2.4 Select promising concept(s)	4	12/20/03	12/24/03
14	3.0 Begin Detailed Design	3.1 Perform detailed analyses of concepts	9	12/25/03	01/03/04
15		3.2 Peform simulations	9	12/25/03	01/03/04
16		3.3 Material selection/availability	9	12/25/03	01/03/04
17		3.4 Component selection/availability	9	12/25/03	01/03/04
18		3.5 CAD Drawings	17	01/04/04	01/21/04
19	4.0 Build Prototype	4.1 Purchase materials and off the shelf components	6	01/04/04	01/10/04
20		4.2 Machine/manufacture components	18	01/18/04	02/05/04
21		4.3 Assemble Prototype	8	02/04/04	02/12/04
22	5.0 Test Prototype	5.1 Develop testing protocol	6	12/07/03	12/13/03
23		5.2 Perform tests	7	02/12/04	02/19/04
24	6.0 Documentation and Reporting	6.1 Preparation of first progress report	4	12/09/03	12/13/03
25		6.2 Preparation of second progress report	4	12/21/03	12/25/03
26		6.3 Preparation of final report	5	02/16/04	02/21/04
27		6.4 Preparation of final presentation (Poster)	2	02/21/04	02/23/04
28		7.0 End Project	1	02/28/04	02/29/04

Figure 1. Sample Work Breakdown Structure implemented in *Excel*.

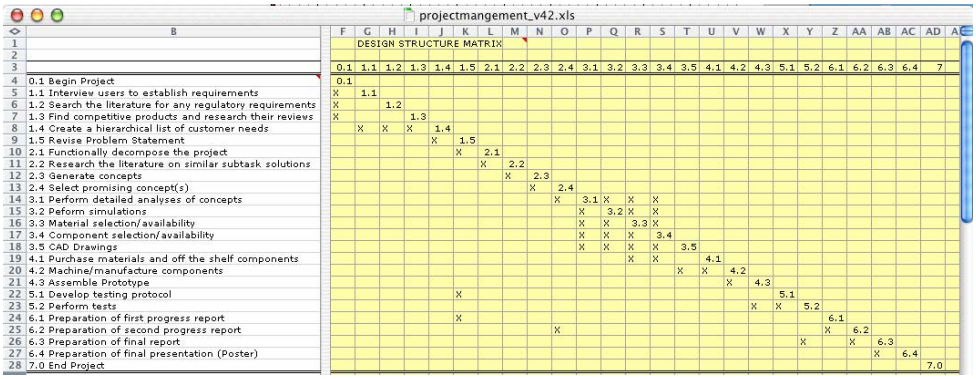

Figure 2. Screenshot of a sample design structure matrix.

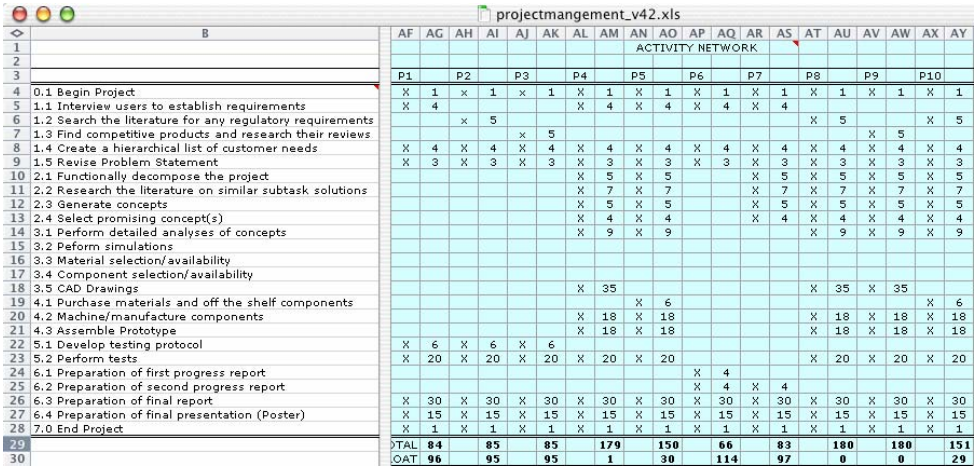

Figure 3. Screenshot of sample activity network diagram.

PMW: the Gantt Chart

The Gantt chart is the most widely used method in industry for project scheduling and progress monitoring. Its advantages include: a direct correlation of tasks with the duration of time; a straightforward integration of sub-tasks that have separate scheduling charts; flexible time units that range from daily to annual; and a visual representation for a quick assessment of a project's progress. The PMW Gantt chart is generated automatically, based on the task *start* and *end dates* from the WBS. The Gantt chart for the WBS in Figure 1 is presented in Figure 4. In addition to automatic generation, the number of scheduled days left for each task (the units can easily be changed to weeks or months), as well as a colour-dividing line signifying where the project is supposed to be based on the current date, are automatically determined and updated.

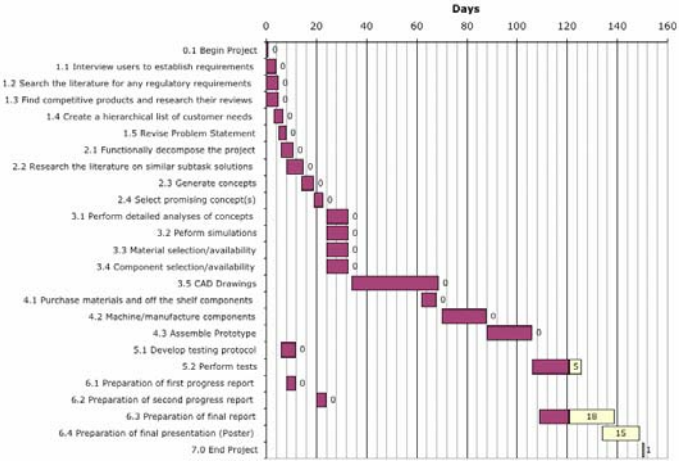

Figure 4: An *Excel* generated Gantt chart.

DIRECTING USING PMWS: WEEKLY COORDINATION MEETING

Directing a project keeps it on track, allowing for adjustments to account for unforeseen events that might occur. The project team should meet at least once a week to discuss coordination issues. This meeting could be part of regular technical meetings or a separate meeting and be scheduled for the same time each week. This ensures that team members are always present for meetings. The meeting outcomes should include: an assessment of progress from the previous week; the assignment of tasks for the coming week; and a re-evaluation of the WBS, adding or removing tasks or updating start dates and task durations. A coordination leader should be selected. Their role is to lead team discussions during the coordination meeting and to ensure the meeting stays focused and concludes within a predefined time. This should be a rotating position from week to week. The coordination leader is also responsible for taking notes at the meeting.

Teams often have a few members who do not contribute their fair share to the project, yet benefit from the communal group reward (such as the group's grade). Assigning individual and mini-group tasks each week serves to ensure that all work that should be done in the following week is completed, no team member carries an unnecessarily heavy work burden, and *all* team members contribute fairly to the project.

Further, during the administrative meeting, design teams must assess the extent of task completion from the previous week. Weekly task outcomes will determine if the current project direction is still appropriate or if alternate paths have to be followed or solutions sought. In addition, it provides a written record of who has not completed their tasks from week to week and, therefore, not fully contributed to the project.

Finally, the administrative leader should send an e-mail shortly after the meeting to all team members and the project advisor(s)/course instructor, with the PMW attached. The e-mail should include the following:

- A list of present and absent team members;
- A summary of the current state of the project, indicating successes, challenges and failures;
- An indication of the tasks, in some detail, that were completed the week before and by whom. If a particular team member did not complete their task, then that should be noted and an explanation given. Often, a task may not be completed due to an underestimation of the task's duration, or an inability to find a needed resource. Work not completed should be reassigned to the following week;
- Each team member's assigned tasks for the coming week; these tasks can be assigned to an individual or a subset of the team depending on the task type.

The e-mail memo, in combination with the project management workbook, will ensure that all team members and the project advisor(s)/course instructor are aware of the current status of the project from week to week. Each team member will know exactly what tasks they are expected to complete that week, as well as what tasks their teammates are working on. The information in the memo and workbook will allow the project advisor(s) to provide immediate feedback on the project, addressing any design challenges that the group may be facing (for example, laggard team members or a project falling behind schedule) before they become critical.

ASSESSMENT

An assessment was carried out in the fall semester of 2003, on the use of PMWs to manage an industry-sponsored design project in a first-year engineering design course, *Introduction to Engineering Design*. The major items investigated are given in Table 1 with related statements that were rated by students using a 1-5 Likert scale (1-*strongly disagree*, 2-*disagree*, 3-*neutral*, 4-*agree*, 5-*strongly agree*). Tallied ratings showed that students at least *agree* with the fact that project management is important (average rating > 4 = *agree*); they almost *agreed* with the fact that introduced project management techniques were effective and timely (average rating 3.85<4 = *agree*); they also *agreed* that the project management techniques introduced made a difference in their design success (average rating > 4 = *agree*). It should be noted that the ratings for Questions 2a and 2b were expected to be low, as a good understanding of project management should reduce the ambiguity in the project and its steps. The distributions of questions 1a, 2a and 2b – selected to directly assess the effectiveness of the project management intervention – are shown in Figure 5, which shows that the vast majority of students either *agreed* or *strongly agreed* with the corresponding statements.

Open-ended questions were also used as a second form of assessment. Results from two of the questions provided by the student teams are presented in Table 2. In the compilation, minor grammar/spelling mistakes were corrected, and duplication in content was omitted. Question 1 addressed the usage level of the project management methods. From the responses, it can be surmised that all techniques introduced

were practiced. In fact, one student stated that *Good time management will help me through all my work, all through life so will the group skills that I learned*. This statement is so powerful in that it captures the true intent of this curriculum intervention. Question 2 sought to understand the ease of use of the project management applications using *Excel*.

Table 1: Assessment results.

Assessment Items	Average
1. *The importance of PM in design projects*	
a. I consider project management to be a critical part of design process.	4.2
b. A design project cannot result in a successful product unless it is managed well.	4.1
c. I will use the project management techniques I learned throughout this class for other projects in the future.	4.2
2. *The effectiveness and timing of the PM concepts introduced*	
a. Project steps were too ambiguous to follow.	2.5
b. We did not have explicit project steps; we did whatever seemed to be pressing.	2.6
c. We used our time very well.	3.9
d. My team had a leader who organized us, and the work to be done very well.	3.6
e. We have planned/decided our design project steps.	4.1
f. Timing of the topics related to project management was well planned. We had enough time to learn and to apply.	3.8
3. *The impact of project management techniques used on team design performance*.	
a. I believe project management techniques we learned made a difference in our design performance outcome (project grade).	4.2
b. I believe project management techniques we learned made a difference in our being more efficient with our time throughout the project.	4.0

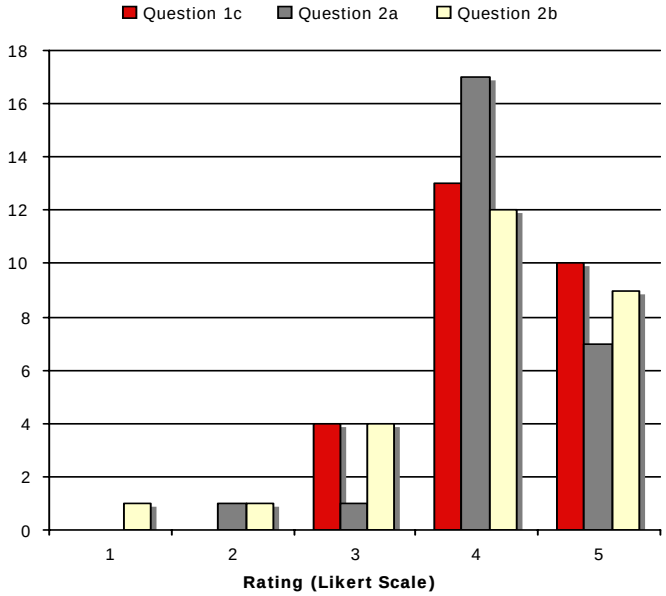

Figure 5: Distribution of student assessment ratings.

CONCLUSION

The authors present an effective spreadsheet-based method for integrating project management techniques into design project-based courses in the engineering curriculum. An assessment investigated the introduced project management tools' impact on students design performance, and the tools' ease of use. The results suggest that overall the implementation was very effective. Instructions on how to create the PMWs can be found in ref. [5]. Templates are available at www.cede.psu.edu/~ogot

Table 2: Assessment results – open ended questions.

Question 1: What techniques, tools did you use while managing your activities? Please list the most important ones and explain how they helped.
• *Main tool used was the* Excel *workbook. It let us know whether we were on track, what had been done, and what was left.* • *Used good time management and communication skills.* • *Let everyone freely and openly suggest ideas and think about them.* • *Were good at discussion and using reason to come to conclusions.* • *Most important tool was simply a list of the tasks.* • *It did help to initially get an idea how long each task would take.* • *Had meetings and voted to decide on things.* • *Wrote outlines that helped as well.* • *Good time management will help through all my work, all through life so will the group skills that I learned.* • *Communicated through e-mail.* • *Task list, team calendar.* • *Teamwork, problem solving, organization helped to complete our projects in the most efficient way possible.* • *Work breakdown structure matrix, this was very helpful in the sense that it outlined everything that was meant to be done at certain dates.* • *Gantt chart was helpful because it provided a visual representation of how our work has progressed.* • *The list of jobs and start/end dates kept us on track.* • *The progress reports were a very good idea b/c they forced us to keep up the pace.*
Question 2: Please comment on the ease of applying project management techniques using Excel *(difficult, confusing, easy, etc).*
• *Easy. It kept us on track.* • *It was not a hard technique, although sometimes it seems unnecessary.* • Excel *was a fair choice, I don't know of anything that would have been better to use.* • *Not hard at all.* • *It was easy to apply project management techniques using* Excel. • *Very easy to use and understand.*

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