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EFFECTIVE DESIGN PROJECT MANAGEMENT WITH A SPREADSHEET BASED APPROACH

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1 Introduction

The use of team projects as a way to teach 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. Accordingly, poor management or lack of communication within a team and between teams and their faculty advisor/instructor will typically 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 has been discussed [1-5]. Common methods for project management include team calendars, work breakdown structures (WBS), Gantt/milestone charts and Program Evaluation and Review Technique (PERT) diagrams.

This article does not introduce new management methods, but instead focuses on how these "textbook" methods can be effectively implemented using a common spreadsheet application, in this case Microsoft Excel (Excel). Our experience with the proposed implementation strategy is also presented. Assessment of implementation indicates that our approach is effective in terms of students' perception on: (1) the importance of project management in design projects, (2) the effectiveness and timing of project management concepts introduced, and (3) the impact of project management techniques used on their design performance.

2 Literature Review

Managing the design process, while is essential to successful project completion, is not very easy. The seemingly unstructured nature of designing activity, especially during its conceptual development stages, has been well reported. Several researchers have discussed this for various design domains such as Nagl et al. [6] for chemical engineering, Thorpe and Mead [7] for construction engineering, and developed countermeasures. For example, Nagl et al. [6] have developed a management system that covers products, activities, and resources, and their mutual relationships for the chemical engineering domain. Thorpe and Mead [7] studied project specific web sites (PSWS) for their effectiveness in providing a centralized coordination. However, they report that unless everyone involved in the project uses the PSWSs, they cannot be effective. Chang [8] modeled the engineering project related work as information processing to reduce uncertainty and ambiguity related to tasks, and proposed tracking both completed work and related communication time due to the fact that both external and internal communication is critical for project success.

Commercial project management applications such as Microsoft Project support management functions such as planning, monitoring, and controlling [9]. These applications define the milestones to be accomplished and provide the foundation for resource scheduling and cost

estimation and control. They are widely used in practice despite their limitations: project plans are often too coarse grained, document flow is not considered, project plans are not integrated with the actual work performed by engineers, and there is no way to define domain-specific types of project plans [9]. Workflow management systems [10] (e.g., FlowMark, COSA) manage the workflow among work participants, according to a defined procedure consisting of a number of tasks [11]. To this end, tasks and documents are passed from participant to participant in a predetermined order. However, workflow management systems are mostly restricted in supporting the very dynamic design process because many workflow systems assume a statically defined workflow that cannot be changed during execution.

More recently developed product management systems support storing, manipulating, and retrieving information during the design process. These systems are labeled according to the context in which they are employed such as engineering data management systems, or product data management systems [12]. Documents such as flow diagrams, cost estimations, etc. are stored in a database, which records the evolution of documents. In addition, product management systems may support the management of activities in a limited way, or they include workflow components. Overall, however, because their primary focus is management of products management of human resources is hardly considered.

As discussed above, although commercial software is readily available to perform project management tasks, their adoption in a classroom environment presents several challenges. These include: (1) design faculty may not know or feel inclined to learn how to use the software, (2) funds may not be available to purchase the software or use of existing funds would drain already meager resources and divert their use from other areas in the design curriculum, and (3) requiring an additional software tool may present an unwelcome burden for students, who are already required to learn and use a significant number of software tools – word processing, spreadsheets, programming, illustration, image manipulation, website design, CAD, etc., and (4) teaching students a new software tool will require diversion of time away from existing course material.

The use of Excel to create *automated project management tools*, therefore, is a natural choice as Excel is available on virtually every college campus. In addition, students already have a basic level of proficiency in its use allowing easy implementation. The remainder of this article demonstrates how students can use Excel to create Project Management Workbooks (PMWs) to incorporate the "textbook" project management methods to their design experience. Then, it goes on to 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: student laggards, project scallop, and lack of communication.

The approach has been implemented in three courses (freshman design, junior reverse engineering, and senior capstone). In this paper, we report our experience with the approach in a freshman design course and present an assessment of its effectiveness in relation to students' perception on: (1) the importance of project management in design projects, (2) the effectiveness and timing of project management concepts introduced, and (3) the impact of project management techniques used on their design performance.

3 Project Management Workbooks

Project management involves two primary tasks: (1) planning and scheduling, and (2) directing. Planning and scheduling involves activities for understanding the project scope (tasks, time and budget) and organizing. These activities are to 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 project. Sections 3.1 and 3.2 will discuss how planning and scheduling, and directing can be implemented using PMWs.

3.1 Planning and Scheduling Tools

Various tools are available to assist in planning a project to ensure its completion in the allotted time. The three sequential stages for project planning (with the commonly used tools shown in brackets) are:

1. Listing all the tasks that need to be done, and estimating how long each one will take to complete (*Work Breakdown Structure*).
2. Deciding which tasks can be done in parallel and which ones must be done sequentially (*Design Structure Matrix/Activity Networks*).
3. Setting approximate start and end dates for all tasks (*Gantt/Milestone Charts*).

3.1.1 PMW: Work Breakdown Structures

Before a student team can plan or manage a project, they need to have an idea of the project scope. They need to know what tasks need to be performed and make estimates on how long it would take to complete them. The Work Breakdown Structure (WBS) divides the entire project into a series of tasks (no order is implied), and further breaks down the tasks into sub-tasks. The level of decomposition - for example, subsub-tasks, subsubsub-tasks - will depend on the complexity of the project. The WBS presents the tasks in an organized form that allows team members to readily see and understand how the tasks fit into the overall project.

The Project Management Workbooks implements the WBS list format. 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 will be used to schedule the tasks appropriately and ensure that the project is completed on time. Note that this is a dynamic document that is altered to reflect current events in the project. New primary or lower level tasks are added by inserting a new row and existing ones removed by deleting the row. Students need only type in the *Start Date* for each task, with the end date automatically calculated by Excel.

3.1.2 PMW Design Structure Matrix and Activity Network

The PMWs also allow the student teams to generate design structure matrices (facilitates the determination of task order – *see* Figure 2) and activity network diagrams. Network diagrams show all project tasks along with their precedence structure, taking into account interdependencies amongst tasks. From the activity networks the 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 duration is changed. A screen shot 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.

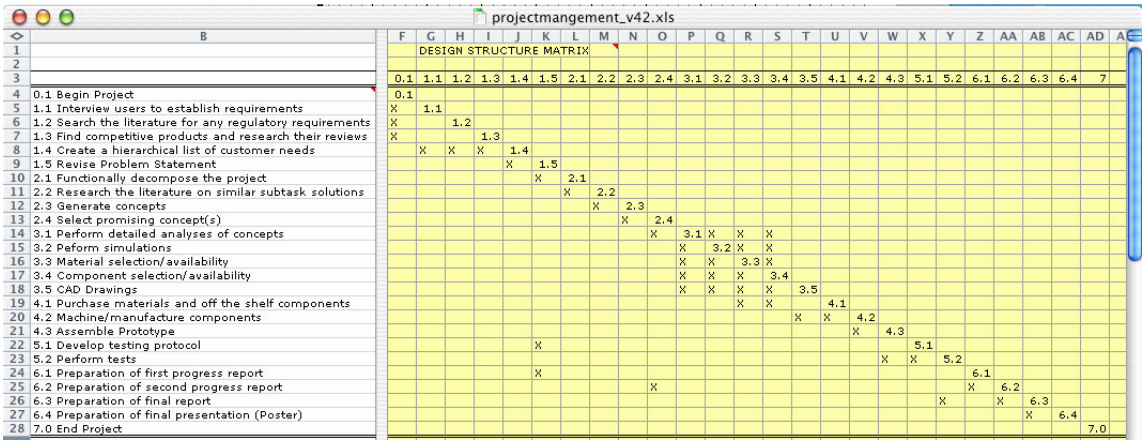


Figure 2. Screenshot of Sample Design Structure Matrix

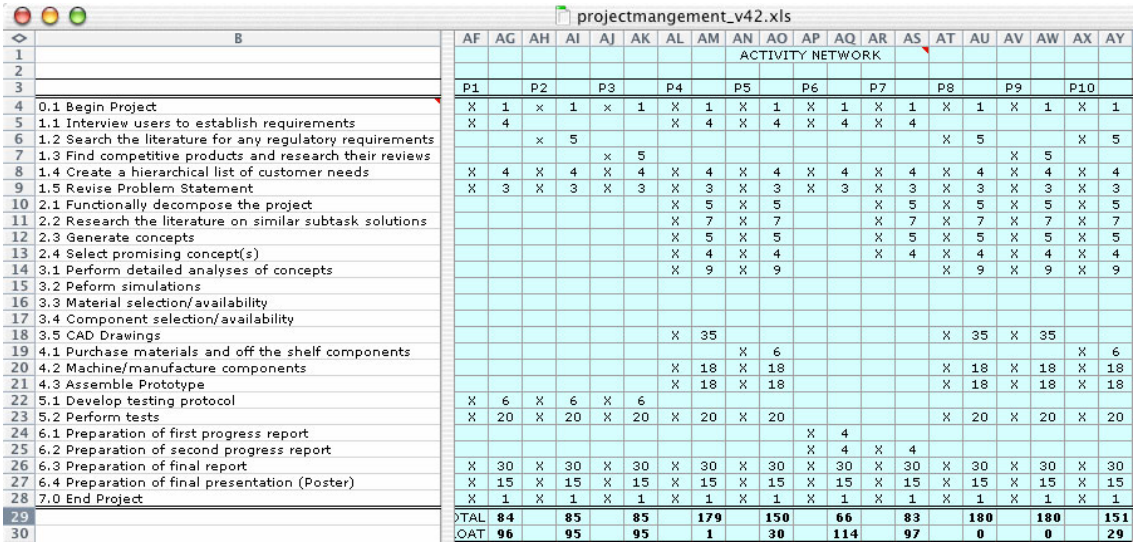


Figure 3. Screenshot of Sample Activity Network Diagram

3.1.3 PMW: The Gantt Chart

The Gantt Chart is the most widely used method in industry for project scheduling and progress monitoring. Its advantages include:

1. Direct correlation of tasks with duration of time.
2. Straightforward integration of sub-tasks having separate scheduling charts.
3. Flexible time units ranging from daily to annual.
4. Visual representation for quick assessment of project progress.

The PMW Gantt Chart is generated automatically, based on the task *start* and *end dates* from the Work Breakdown Structure. 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 color dividing line signifying where the project is supposed to be in the current date are automatically determined.

3.1.4 PMW: Team Contact Information

The team contact worksheet lists all the team members with appropriate contact information: email, phone number and mobile phone number. This will allow team members to readily contact each other as the need arises during the course of the project. A sample contact page is shown in Figure 5.

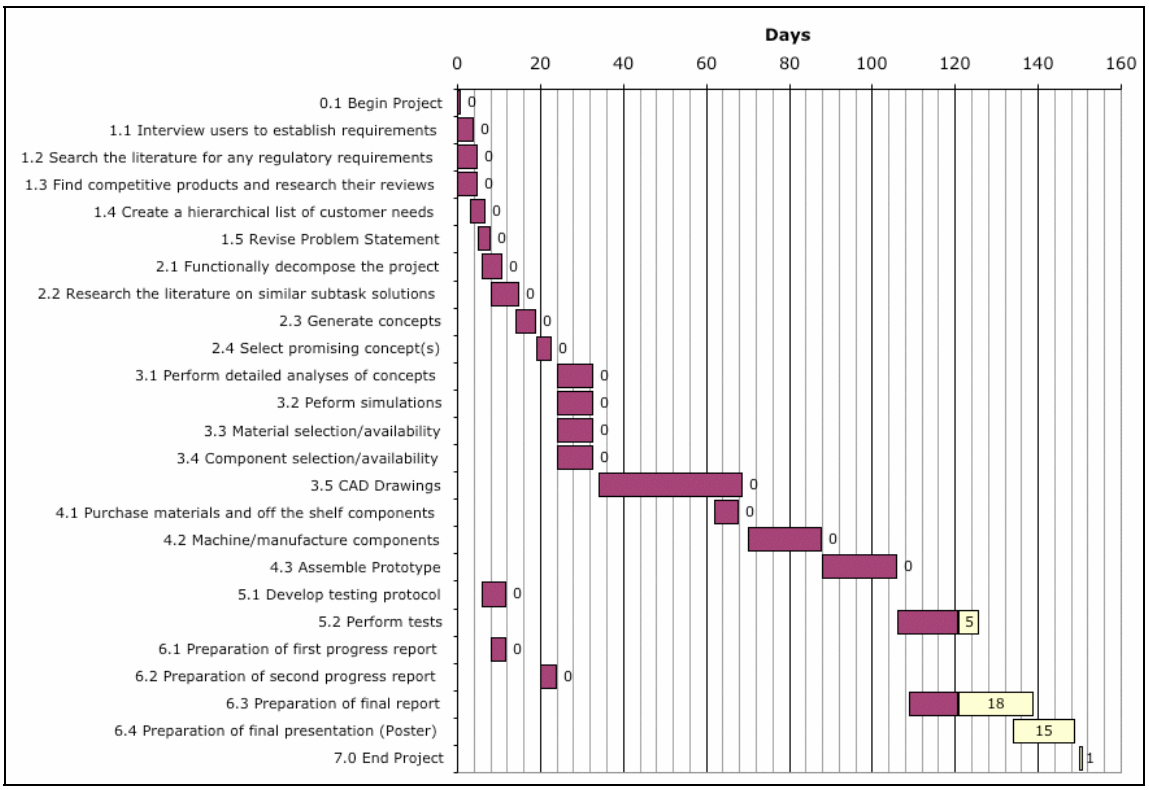


Figure 4. Excel Generated Gantt Chart

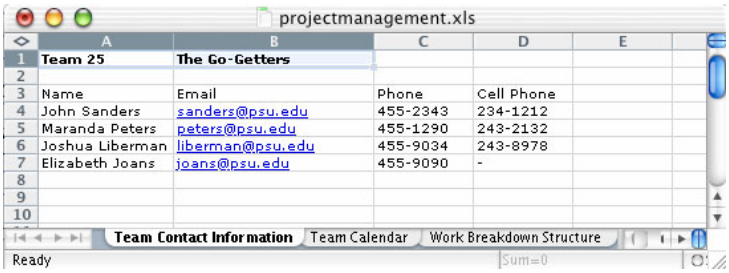


Figure 5. Contact page in the Excel Project Management Workbook

3.1.5 PMW: Team Calendar

The team calendar should span the start through end dates of the project. The calendar should be populated with all events that are relevant to the project. These could include meetings, deadlines, availability of team members and so on. Color - text or cell shading - can be used to highlight or categorize particular events. A sample team calendar is illustrated in Figure 6.

3.2 Directing Tools

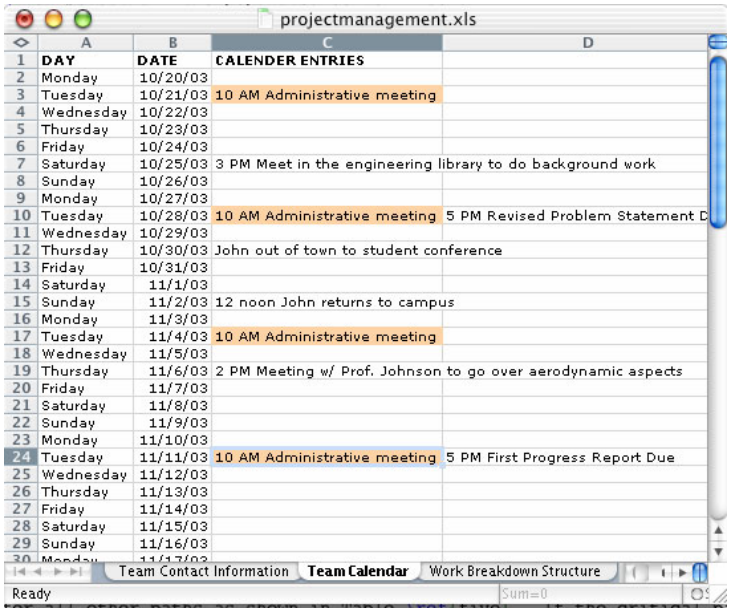
Directing a project serves to keep it on track, making adjustments to account for unforeseen events that might occur during project duration. This section will illustrate how the PMW combined with email communication can be effectively used for directing. Directing design projects should include following elements:

- Weekly coordination meeting
- Selection of a coordination leader
- Assignment of tasks
- Assessments of tasks
- Communication of progress

3.2.1 Weekly Coordination Meeting

The project team should meet once a week to discuss coordination issues. This meeting could be part of regular technical meetings or a separate meeting. The meeting should be scheduled for the same time each week. This will ensure that team members can always make the meeting. The outcome of the meeting should include:

1. Assessment of progress from the previous week.
2. Assignment of tasks for the coming week.
3. Re-evaluation of the WBS, adding or removing tasks or updating start dates and task durations.
4. Re-evaluation of the project Gantt chart, making any necessary amendments.
5. Updating the team calendar.



	A	B	C	D
1	DAY	DATE	CALENDER ENTRIES	
2	Monday	10/20/03		
3	Tuesday	10/21/03	10 AM Administrative meeting	
4	Wednesday	10/22/03		
5	Thursday	10/23/03		
6	Friday	10/24/03		
7	Saturday	10/25/03	3 PM Meet in the engineering library to do background work	
8	Sunday	10/26/03		
9	Monday	10/27/03		
10	Tuesday	10/28/03	10 AM Administrative meeting	5 PM Revised Problem Statement D
11	Wednesday	10/29/03		
12	Thursday	10/30/03	John out of town to student conference	
13	Friday	10/31/03		
14	Saturday	11/1/03		
15	Sunday	11/2/03	12 noon John returns to campus	
16	Monday	11/3/03		
17	Tuesday	11/4/03	10 AM Administrative meeting	
18	Wednesday	11/5/03		
19	Thursday	11/6/03	2 PM Meeting w/ Prof. Johnson to go over aerodynamic aspects	
20	Friday	11/7/03		
21	Saturday	11/8/03		
22	Sunday	11/9/03		
23	Monday	11/10/03		
24	Tuesday	11/11/03	10 AM Administrative meeting	5 PM First Progress Report Due
25	Wednesday	11/12/03		
26	Thursday	11/13/03		
27	Friday	11/14/03		
28	Saturday	11/15/03		
29	Sunday	11/16/03		

Figure 6. Sample calendar worksheet in the project management workbook

At the first meeting the team should:

1. **Create the project management workbook in Excel**. It should consist of four parts (1) a team contact worksheet, (2) a team calendar, (3) a work breakdown structure and (4) the Gantt charts.
2. **Create the initial WBS.** This is based on best current estimates on what tasks are to be performed and an approximate duration for each task.

Decide from the WBS which tasks must be carried out sequentially, and which ones can be done in parallel. The team should use this information to construct an activity network, determining the critical path and calculating slack times for all other paths. If the critical path time (CPT) exceeds the allotted time for the project, the team needs to reduce the time they assigned to the critical path tasks until the CPT equals the allotted project time. Enter the appropriate start dates for each task. The Gantt chart will be created automatically.

3.2.2 Selection of a Coordination Leader

The role of the leader is to lead team discussions during the coordination meeting. She ensures 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.

3.2.3 Assignment of Tasks

Teams often have a few members not contributing their fair share to the project, yet benefiting from the communal group reward. Assigning individual and mini-group tasks each week serves to (1) ensure that all work that should be done in the following week is completed, (2) no team member carries an unnecessarily heavy work burden, and (3) *all* team members contribute fairly to the project.

3.2.4 Assessment of Tasks

Each week, 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 been completing their tasks from week to week, and therefore not fully contributing to the project.

3.2.5 Communication

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

1. A list of present and absent team members.
2. A summary of the current state of the project, indicating successes, challenges and failures.
3. 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 that should be noted and an explanation given. Often a task may not be completed due to underestimation of task duration, or inability to find a needed resource. Work not completed should be reassigned to the following week.
4. 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 email memorandum (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 way behind schedule) before they become critical

.4 Assessment

After its integration to design teaching, as discussed above, the assessment of the project management using Excel was completed during fall 2003. The assessment was done by a different faculty member than the course instructor. At the beginning of the semester between the two faculty members an agreement was established to collaborate on the project, in a way that one would implement the approach and the other would assess its effectiveness. Based on the implementation objectives provided by the teaching faculty, a data collection instrument was prepared and administered solely by the assessing partner.

Overall, the assessment of the implementation effectiveness in relation to students' perception was targeted. Major items investigated are given in Table 1 with related statements that were rated by students using a 1-5 Likert scale (1 being the rating for "Strongly Disagree" and 5 for "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 at least “agree” with the fact that project management techniques introduced made a difference in their design success (average rating > 4 = “agree”). Note that in part two of the assessment, ratings for the first two questions was expected to be low because a good understanding of project management should reduce the ambiguity in the project and its steps.

Table 1. Assessment Results

Assessment Items	**Average Rating Fall2003**
1. ***The importance of project management 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 project management 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

In addition to above mentioned “rated” statements, open ended questions relating to the project management techniques used were asked as a second form of evaluation. These questions and related answers provided by each student team are given in Table 2. In the table, student responses for each question are provided after each question is stated. During this compilation the content of the responses were not changed. However, minor mistakes in grammar/spelling were corrected, and duplication in content was omitted. Conflicting statements were especially left in the document.

As seen in Table 2, questions 1 and 2 dealt with the level of usage of the project management methods introduced by eight design teams. According to the responses, it can be stated 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 3 sought to understand the easiness of the project management applications using Excel. All students but one found it very easy to apply and understand. However, one student found it confusing. We believe it could be due to the unfamiliarity of the student with Excel applications; yet supporting information is not available.

Table 2. Assessment Results – Open Ended Questions

Question 1	Comments Received
How did you manage project activities (we had a leader who told us what to do next, etc.)?	Monitored project progression using Gannt charts Leader assigned tasks for the rest of the group in accordance to the team calendar/Gannt chart/work breakdown structure matrix Work breakdown structure Rotating team leadership system used One member showed leadership Had a leader that fully understood the project and based assignments off of that. When rotating leadership did not work roles were assigned Group decided what needs to be done together Tasks, work were divided up evenly among team members There were 2 people who started all the discussions and gave tasks to the others. Applied the stages of the design process sequentially Balanced all the work to allow ample time in case something took longer Given the Gannt chart information each of us volunteered or was assigned a duty.
Question 2	**Comments Received**
What techniques, tools you have used 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 email. 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. Gannt 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 3	**Comments Received**
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.

Table 4 (continued). Assessment Results – Open Ended Questions

Question 4	Comments received
Please provide your opinion on how the instruction for project management can be improved.	I felt the instruction was very good; sometimes it was a problem for our team to implement it though. You could have stressed how long the CAD work for project 2 could take depending on what you were doing. I think it could be simplified. There were areas that seemed to overlap and thus weren't needed. Everything was very straightforward on what we had to do. I really like it the way it is. This was a fun class and I learned a lot. Everything was explained very well. More focus on formatting the progress reports may be helpful. There could be more lectures on the topic. Maybe give past examples of poor project management, and good project management for inspiration. It depends on individual, discipline and responsibility. More emphasis on Gannt charts/work breakdown structure should be placed as in the beginning it was a bit unclear as to what is expected from these components although as the course progressed this became much more apparent.

Question 4 intended to get students' opinion on how the instruction could be improved. While most students found it very effective as is, a number of suggestions appeared as avenues for improvement such as more lectures on project management, reinforcement of the material and so on. These suggestions are currently being utilized. Since its first application in fall 2003, because of the success with its implementation, for selected sections of introductory engineering design at The Pennsylvania State University project management topics are integrated to the curriculum using the discussed Excel-based Project Management Workbooks.

5 Conclusion

This paper presented a spreadsheet-based method for integrating project management techniques to the engineering design teaching. An assessment for the implementation is also provided, which investigates (1) students' understanding on the importance of project management in design projects, (2) the effectiveness and timing of project management concepts introduced, (3) the impact of project management techniques used on their design performance, based on their perception of the project management implementation outlined. The results provided in the paper suggest that overall the implementation was very effective.

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