Experiences With An Integrated Online Course in Project Management

M. E. Ssemakula
Wayne State University, Detroit, USA

***Abstract*—A variety of social, economic and technological factors are converging to transform the nature of higher education. Educational institutions are under pressure to reduce costs, improve access, and cater to a changing population more interested in lifelong learning. Schools have responded by spawning a variety of methods and technologies for delivering education, including online distance learning. This, in turn, is transforming how knowledge is delivered. The traditional teacher-focused model is being replaced by a learner-centered approach, with students taking more proactive control of how and when they engage in learning activities, and the instructor being more of a coach. This paper gives a detailed description of the strategies that were followed in developing an online course in Project Management which embodies the new approach. Assessments conducted to determine the effectiveness of this approach in meeting the course's learning outcomes and to evaluate student reactions to the course in its new online delivery mode show high levels of student achievement as well as high levels of student satisfaction with the course.**

***Index Terms*—Distance Learning, Outcomes Assessment, Project Management, Resource Management.**

I. Introduction

A variety of social, economic and technological factors are converging to transform the nature of higher education. The undergraduate student body is increasingly composed of adults from diverse socioeconomic backgrounds, most already in the workplace, and perhaps with families, seeking the education and skills necessary for their careers. This change has been accompanied by a transition from student to learner, from faculty-centered to learner-centered curricula, from an emphasis on teaching objectives to an emphasis on learning outcomes [1, 2].

The learner focus has also led to a drive to reduce cost, and increase access and flexibility of course offerings. Sir John Daniel, Vice-Chancellor of the Open University put it this way: "Any industry whose costs increase faster than inflation over a long period is heading for trouble either for complete collapse or for unpleasant upheavals. We must reduce the costs of higher education." [3] Management consultant Peter Drucker commented that higher education is in deep crisis meaning that things will get either much better or much worse [4].

It is clear that educational institutions are under intense pressure to reduce costs, improve access, and cater to a changing population more interested in lifelong learning. The responses to these challenges have been quite varied, including interactive two-way video conferencing, live television broadcasts, computer-based multimedia instruction, and increasingly, synchronous as well as asynchronous online courses.

II. Design Strategy for Online Courses

Most students and instructors are used to the traditional lecture format, which introduces principles and examples of applications, with the textbook providing the details and reference material. The instructor can answer questions on the spot and change course if he senses the students are not grasping a particular point. For the typical online course however, the instructor usually does not have the benefit of immediate feedback. Therefore, the course has to be deliberately designed to anticipate student needs. The roles of both the instructor and the students need to change in comparison to those in a traditional classroom.

Because students in online courses do not have to follow a set schedule as in the traditional format, they have to be much more proactive and self-directed in their knowledge acquisition. The instructor becomes more of a coach in effect, and students take more active control of how and when they engage in learning activities. The course learning materials themselves should be designed to capture and retain the interest of students, and keep them actively engaged with the learning materials. Since an online course will inherently be accessed via computer, using computer-based animations and simulations becomes almost a necessity. Thus, the successful online course should build in a mix of the following characteristics [5 – 7]:

- Active involvement by students
- Multiple presentation techniques to capture and retain student interest
- Animations and simulations where appropriate
- Actual physical models if possible
- Multiple examples of practical applications

This paper discusses the implementation of this strategy in a specific course. For the course under discussion, computer-based instructional tools were applied in ways intended to capture, engage and keep student attention. Solved practical examples and online demonstrations were used extensively to enhance student learning.

III. Course Description

The course that is the subject of this paper is a semester-long course titled Engineering Project Management. The course provides the student with insights into human and organizational behavior affecting projects, in addition to the quantitative tools for the successful management of engineering projects. The course addresses a variety of project types and deals with how to select, initiate, plan, execute, monitor, control, and when appropriate, terminate a project. The role of project managers and their interaction with the rest of the organization is highlighted. The pre-requisite is a course in college algebra. The textbook used for the course is 'Project Management: A Managerial Approach' by Jack R. Meredith and Samuel J. Mantel Jr.; published by John Wiley & Sons. The course learning outcomes (CLOs), representing the skills and capabilities expected of students at the completion of the course, are shown in Table 1.

TABLE I
COURSE COVERAGE

Course Learning Outcomes	
1.	Evaluate individual projects and select those that best meet organizational needs.
2.	Describe functions and capabilities of a good project manager and project team.
3.	Develop a project plan including schedules, milestones, and resource needs.
4.	Develop a project budget reflecting the expected costs of planned activities.
5.	Use graphical tools such as Gantt charts or Arrow networks to represent a project schedule and show inter-activity relationships.
6.	Allocate the available but limited human and physical resources to a project.
7.	Collect appropriate project information and use it to ensure that the project proceeds according to plan.
8.	Determine whether a project is meeting its goals and when it should end.

The course was first offered in our department in 2008 in a traditional classroom setting and subsequently migrated to online delivery in 2010. It is a required course in all the six programs offered in the department, and it is offered every semester.

IV. Implementation Examples

The following discussion describes in detail how the principles outlined in section II have been implemented in this course. To make the discussion more concrete, it will focus on the implementation of one CLO. The CLO chosen is the allocating resources to a project, which is learning outcome #6 in Table I. To capture student interest, the topic is presented in the form of a simple 'project' that students can easily understand. This allows the instructor to present the underlying principles in detail without being lost in the minutiae of the project tasks. The project scenario is set up as follows:

A home-cleaning company has been hired to clean out a rental property prior to new tenants moving in. The primary cleaning tasks, with the time (in hours) needed for each task; as well as the number of workers assigned to each task are given in Table II. We are interested in the timely execution of the project, but also need to carefully monitor the utilization of workers on the project since workers are the single largest project expense.

TABLE II
PROJECT DESCRIPTION DATA

Task	Description	Precedent	Time	Workers
A	Shampoo carpets	-	4	2
B	Clean basement	-	2	1
C	Kitchen/bathrooms	-	3	1
D	Touch up walls	A	2	1
E	Dust furniture	A	1	1

Each step in the analysis of the problem is communicated to students in the form of a PowerPoint presentation incorporating relevant explanatory text. The first step in the investigation is to generate a fully analyzed network diagram for the project. Students would have already learned the required process from the previous CLO. Fig. 1 shows the resulting network diagram for the project.

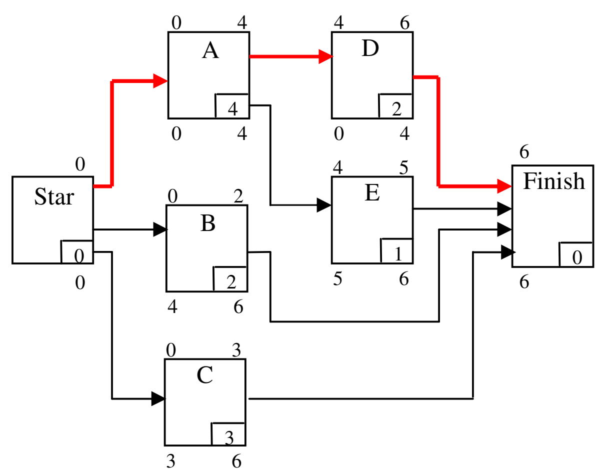


Figure 1: Project Network Diagram

From Fig. 1, it can be seen that this project can be completed in six hours. The network critical path is constituted by the tasks '*Start-A-D-Finish*'. Students will have learned from CLO5 that an activity along the critical path has no slack and if it is delayed, it would result in a delay to the whole project. The second step is to generate a Gantt chart for the project, assuming that each task is done as soon as possible. This can be done conveniently in Excel and students would have already acquired this skill in CLO5. Fig. 2 shows the resulting Gantt chart in this case. This chart goes beyond the standard by including the worker demand in each time period for each task. The grey stripes represent slack on the corresponding activity. The carpets (A), and walls (D), have no slack since they are critical tasks. The bottom row in Fig. 2 shows the aggregate resource demand for each time period.

Timeline	1	2	3	4	5	6
Start						
Carpets	2	2	2	2		
Basement	1	1				
Kitch/Bath	1	1	1			
Walls					1	1
Furniture					1	
Finish						
# Workers	4	4	3	2	2	1

Figure 2: Project Gantt Chart (Including Worker Demand)

Based on this resource demand profile, four workers would need to be assigned to the project to meet this schedule. It is visually compelling and informative for students to see the resource demand profile in graphical form. The aggregate resource loading graph for this project is shown in Fig. 3.

Timeline	1	2	3	4	5	6
	4	4				
Workers			3			
				2	2	
						1

Figure 3: Aggregate Resource Loading Graph

The problem facing the project manager (PM) can be clearly seen in Fig. 3. If 4 workers are assigned as the current schedule demands, then some of the workers will be idle during hours 3-6. This is an undesirable waste! The red area represents idle time for the workers. There are a total of 8 idle worker-hours in this case.

One way to address the problem of idle workers is by rearranging the timing of some of the tasks involved in the project. Advantage is taken of the fact that the timing of tasks with slack can be adjusted (within their range of slack) without affecting overall project duration. Adjustment starts with these tasks. The strategy is to reduce overlap among tasks during periods of high resource demand. In this case, basement cleaning has a slack of 4 hours and is a good candidate for adjustment. Fig. 4 shows what would happen if this task is delayed by 3 hours. As expected, the overall project duration is not affected. However, the most interesting observation given the context of this discussion is that the resource demand profile is changed dramatically. Now, the maximum demand is for 3 workers instead of 4.

Timeline	1	2	3	4	5	6
Start						
Carpets	2	2	2	2		
Basement				1	1	
Kitch/Bath	1	1	1			
Walls					1	1
Furniture					1	
Finish						
# Workers	3	3	3	3	3	1

Figure 4: Revised Project Gantt Chart

That simple change alone would allow the PM to reduce the number of workers assigned to the project, without delaying the project. This is eye-opening for students. The corresponding resource loading graph is shown in Fig. 5. The assigned workers are all busy for hours 1-5 and two workers would be idle just for the last hour. In this case, there only 2 idle worker-hours, a big improvement compared to the 8 idle worker-hours in the previous assignment. This strategy assumes that the workers are interchangeable between tasks! The PM would have to ascertain the validity of the assumption.

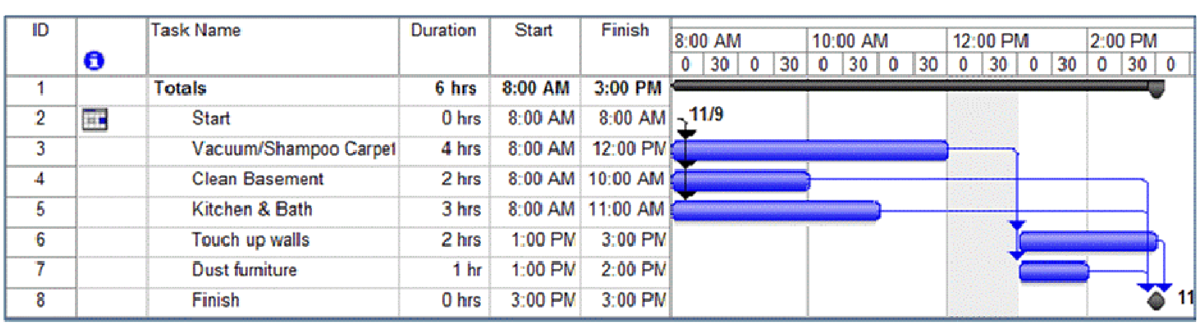
Timeline	1	2	3	4	5	6
Workers	3	3	3	3	3	
						1

Figure 5: Revised Resource Loading Graph

At this point, students are advised that there are alternative ways to rearrange the tasks to achieve an improved resource demand profile, and are encouraged to explore those alternative solutions.

V. Integrating with Microsoft Project

Microsoft Project (MSP) is the most widely used project planning software in industry. At this point in the course, students would have already been introduced to the basic functions of the program and they would know how to create a project plan, Gantt chart, and network diagram in MSP. The MSP project plan for the example under discussion is shown in Fig. 6.



ID	Task Name	Duration	Start	Finish
1	Totals	6 hrs	8:00 AM	3:00 PM
2	Start	0 hrs	8:00 AM	8:00 AM
3	Vacuum/Shampoo Carpet	4 hrs	8:00 AM	12:00 PM
4	Clean Basement	2 hrs	8:00 AM	10:00 AM
5	Kitchen & Bath	3 hrs	8:00 AM	11:00 AM
6	Touch up walls	2 hrs	1:00 PM	3:00 PM
7	Dust furniture	1 hr	1:00 PM	2:00 PM
8	Finish	0 hrs	3:00 PM	3:00 PM

Figure 6: Project Plan and Gantt Chart in MSP

MSP includes features to support the resource allocation procedures. These are presented interactively in the online course as detailed below. Fig. 7 shows a slide from the online course introducing students to the use of MSP's resource allocation functions. Note the inclusion of MSP screen shots that help the student to see exactly what their work will look like as they work in the program.

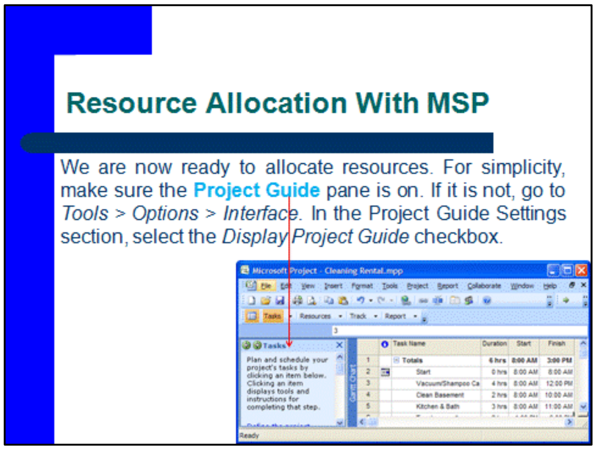


Figure 7: Introduction to Resource Allocation in MSP

There follows the step-by-step procedural description of how to set up resources, and then allocate the resources to individual project tasks. The description is interspersed with screen shots of MSP so the students can easily follow the instructions. Delivering the course in online format allows the instructor to give more detailed instructions than would be feasible in a textbook. From the student perspective, this adds to the value of the online delivery. The instructions for allocating resources are summarized below:

- Select *View* > *Resource Sheet* (This displays the project resources)
- Select *Tools* > *Options* > *Schedule*
- Set *"Show assignments units as a:"* to Decimal
- Click OK
- Enter the value 4 in the '**Max. Units**' column of the Resource Sheet. This is the number of cleaners available. Do not change any other values.
- Select *Resource* > *Assign people and equipment to tasks.* (This returns you to the Gantt Chart view.)
- In the task list, select a task to assign resources to.
- In Project Guide pane, select "Assign resources"
- Click "Assign" in the new dialog box.
- In Project Guide pane (scroll to bottom of pane), select "Edit task or assignment information".
- In the new window set task type to 'Fixed Duration'
- In the units column, enter the amount of resource required for the task (for example, 2 for carpet)
- Click "OK" in the dialog box, then "Done" in left pane.
- Repeat until all tasks have resources assigned
- Return to 'Gantt Chart' view. To see resource utilization graph, select *View* > *Resource Graph*

By following this procedure, students are able to generate a resource loading graph within MSP. Fig. 8 shows the graph that would result for our previous example when done correctly. By default, MSP includes a lunch break between 12:00 Noon and 1:00 PM. This explains the blank space in the middle of the MSP graph. It is instructive to compare Fig. 8 to the previously generated graph in Fig. 3

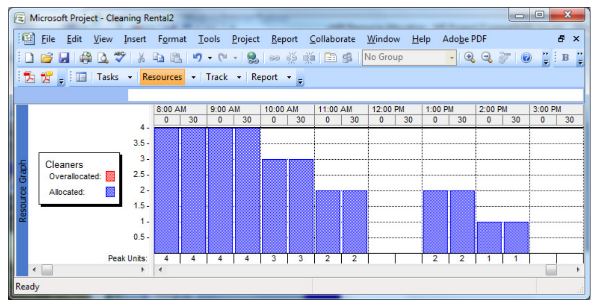


Figure 8: Aggregate Resource Loading Graph (MSP Version)

MSP can be used for resource leveling following the principles we outlined earlier, namely: when a task has slack, its timing can be adjusted within its slack range to shift its resource usage. In MSP, this is done by adjusting task times manually in the *'Schedule'* view. To adjust the timing of an individual task, the cell representing its early start time is changed to some a new value. To adjust Clean Basement by three hours for example, the 8:00 A.M. early start time can be adjusted to 11:00 A.M.

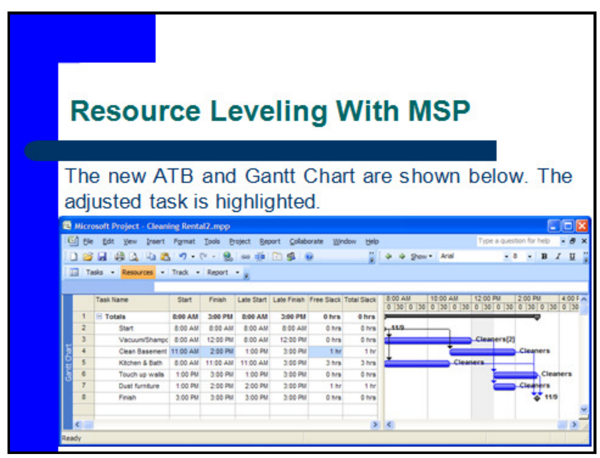


Figure 9: Adjusting Task Times to Level Resource Demand in MSP

MSP asks the user whether to keep or remove any links associated with the task when it is adjusted. In this example, the choice was to keep. MSP recalculates the new task times automatically, and the Gantt chart is redrawn. The resource loading graph will also be redrawn automatically. After the change in timing for the 'Clean Basement' task we have discussed, the resulting MSP resource loading graph is shown in Fig. 10. Other than for the lunch break, this is comparable to the graph in Fig. 5. This procedure can be repeated until the PM comes up with a satisfactory resource loading profile.

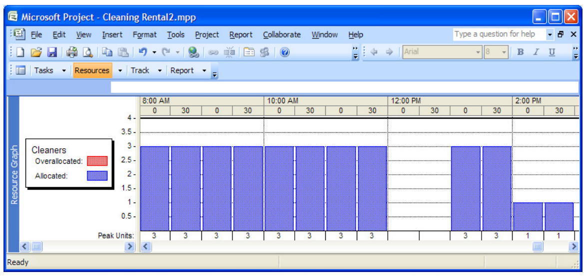


Figure 10: Revised Resource Loading Graph in MSP

VI. Constrained Resource Allocation

Continuing with the investigation of our property cleaning example, we next consider a scenario where there is a constraint on the number of available workers. For example, what if in fact there are only two workers available for the project instead of four; how could the project be done if at all? Students are informed of several heuristic rules that could be used to address this situation. For illustrative purposes, this discussion considers the *'minimum slack first'* heuristic, which is one of the more popular heuristics for this situation. This heuristic requires that available resources are first assigned to the task with the minimum slack. Once it is assigned resources, a task cannot be interrupted and it continues until completed. Applying the heuristic requires keeping track of the slack associated with each task. Thus, initial project schedule of Fig. 2 can be reformatted as shown in Fig. 11 to show slack values.

Timeline	1	2	3	4	5	6	7	8	9	Slack
Start										
Carpets	2	2	2	2						0
Basement	1	1								4
Kitch/Bath	1	1	1							3
Walls					1	1				0
Furniture					1					1
Finish										
# Workers	4	4	3	2	2	1				

Figure 11: Template for Constrained Resource Allocation

Fig. 11 shows that at the start of the project, the task Carpets has 0 slack. Thus, this is the fast task to be assigned workers. Because the task requires 2 workers and there are only 2 workers available, this means that all the other tasks will have to wait until the carpets task is complete. The other tasks are then scheduled, with care being taken to observe the pertinent precedence relationships. The resulting project Gantt chart is shown in Fig. 12. A negative slack means the related task is late by the amount of time shown.

Timeline	1	2	3	4	5	6	7	8	9	Slack
Start										
Carpets	2	2	2	2						0
Basement					1	1				0
Kitch/Bath					1	1	1			-1
Walls					1	1				0
Furniture					1					1
Finish										
# Workers	2	2	2	2	4	3	1			

Figure 12: Constrained Resource Loading (Step 1)

As seen in Fig. 12, now only 2 workers are required for periods 1-4. However, periods 5 and 6 are over-allocated since they each need more than the 2 workers available. Clearly, reallocation is needed. The Kitch/Bath task now has minimum slack at -1, so the available workers are assigned to it next. The Kitch/Bath task needs only 1 worker therefore 1 worker would still be available for assignment. The second worker can be assigned to either Basement or Walls which both have a slack of 0. To break the tie, Walls is chosen because it has been critical for longer. Once both workers are assigned, the impact on the project is reviewed. Fig. 13 shows the results.

Timeline	1	2	3	4	5	6	7	8	9	Slack
Start										
Carpets	2	2	2	2						0
Basement							1	1		-2
Kitch/Bath					1	1	1			-1
Walls					1	1				0
Furniture							1			-1
Finish										
# Workers	2	2	2	2	2	2	3	1		

Figure 13: Constrained Resource Loading (Step 2)

Now, we need to reassess the tasks in period 7, since this period has more than 2 workers assigned. The Kitch/Bath task already started in period 5, and so its assignment can't be changed. The choice is between Basement and Furniture. Basement is assigned first because it has minimum slack. Furniture can start once Kitch/Bath is complete. Fig. 14 shows the results. Now, worker allocation does not exceed 2 workers in any time period and so we have a final solution.

Timeline	1	2	3	4	5	6	7	8	9	Slack
Start										
Carpets	2	2	2	2						0
Basement							1	1		-2
Kitch/Bath					1	1	1			-1
Walls					1	1				0
Furniture								1		-2
Finish										
# Workers	2	2	2	2	2	2	2	2		

Figure 14: Constrained Resource Loading (Final)

In the final solution, it can be seen that the project will be two hours late, but it is accomplished without exceeding the resource availability. Would this solution be acceptable to the client? The PM must explore that before making the final decision. Note that all tasks are now implicitly critical.

In MSP, resource-limited scheduling is accomplished in a manner similar to the above procedure. The constraint on available resources is set by adjusting the value in the **Max. Units** column on the Resource Sheet. The resource loading graph will show red for any periods in which resources are over-allocated. If the value of available workers is changed to 2 for the current example, then the resource loading graph we had in Fig. 10 changes to the one shown in Fig. 15.

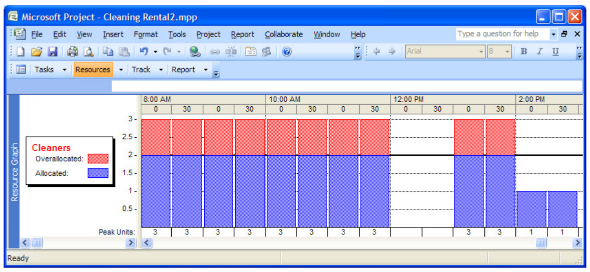


Figure 15: MSP Resource Loading Graph (Over-Allocation in Red)

Resource over-allocation can be eliminated by changing task timing within MSP, similar to the procedure above in Fig. 12. Using the *'minimum slack first'* rule, workers are allocated to carpets. The available workers are used up so the other tasks have their start times changed and moved out of this time slot. This process can then be repeated in MSP just like we did in Fig. 13 and Fig. 14, until all tasks have been allocated the necessary resources. Fig. 16 shows the final MSP Gantt chart, and Fig. 17 shows the corresponding Resource Loading Graph.

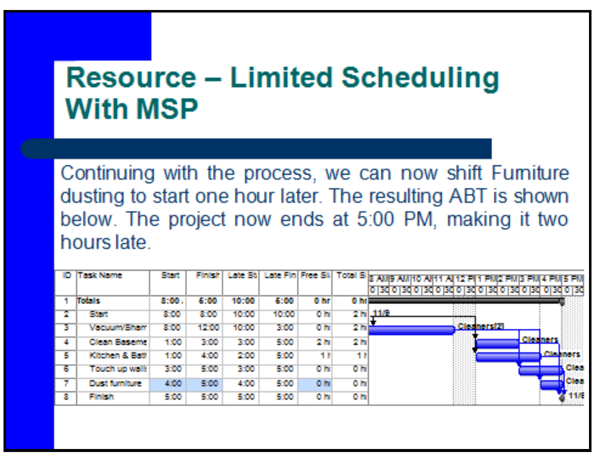


Figure 16: MSP Gantt Chart (Final)

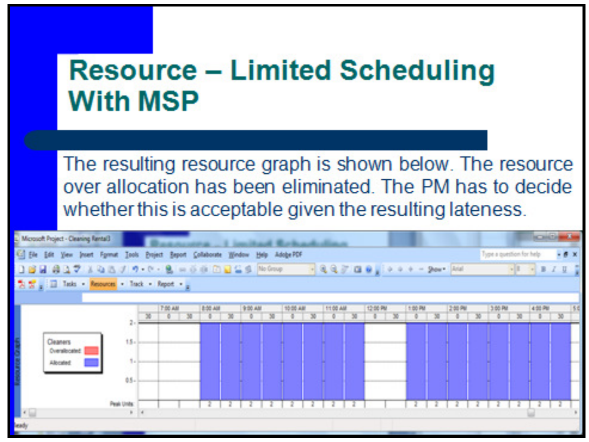


Figure 17: MSP Resource Loading Graph (Final)

The foregoing discussion focused on CLO #6 but the same approach was utilized throughout the course. A concept would be introduced at the theoretical level, illustrative examples or simulations involving real-world applications would be presented, followed by exercises where students would get to test out their understanding and skills. To help students stay on track with the course material, homework assignments were given on a weekly basis. All assignments were done online except for the final exam for which students were required to appear in person.

VII. Evaluation

The ultimate impact of a course, whether delivered online or in the traditional in-class format, depends on what students learn in the course. To that end, two types of assessment were carried out to gage the effectiveness of this course. The first type of assessment entailed the instructor evaluating student performance on each CLO. The assessment was in the form of homework assignments, tests, and examination problems. Performance on the CLOs is a direct measure of student outcomes. The second type of assessment was an indirect measure where students filled out an end of semester survey with a variety of questions covering their reaction to the course.

Table III shows the results of the direct assessment of CLOs for this course for one assessment cycle. The target for satisfactory performance on each assessment item was set at achieving a score of 70%. This target was chosen because it would be equivalent to a passing grade on the assignment.

As can be seen in Table III, the assessment tools included a mix of homework assignments and several tests/exams. To help the reader understand the table, MC represents a multiple choice online assignment, Pt2 represents an online assignment requiring submission of a detailed solution file in Word format, P# represents an individual problem with a detailed solution procedure. The majority of CLOs were assessed multiple times. A CLO is considered satisfied if its performance target is met in at least one of the assessments.

Examination of the assessment results shows that the performance targets for CLOs #6 and #7 were not met on some of the early assessment measures. This low performance led the instructor to provide extra solved examples before the end of the semester. The relevant concepts were re-tested on the final exam and the performance on this was satisfactory in each case, indicating that the extra intervention had been effective. Consequently, these improvements were deployed on an ongoing basis in subsequent offerings of the course.

TABLE III
EVALUATION OF COURSE LEARNING OUTCOMES

ET 5870 Engineering Project Management					Course Learning Outcome								Met Target?
Assessment		Max	Mean	%	1	2	3	4	5	6	7	8	
HW2	MC	88	72	81.8	X								Y
HW3	MC	100	78	78.0	X								Y
HW4	MC	100	93	93.0		X							Y
HW6a	MC	70	66	94.3			X						Y
HW6b	Pt2	30	25	83.3			X						Y
HW7	MC	100	85	85.0				X					Y
HW8a	MC	60	54	90.0					X				Y
HW8b	Pt2	40	32	80.0					X				Y
HW9b	Pt2	50	45	90.0					X				Y
HW10	P3	40	24	60.0						X			N
HW11a	MC	50	43	86.0						X			Y
HW11b	Pt2	50	34	68.0						X			N
Final Exam	P1	35	26	74.3						X			Y
HW12a	MC	50	46	92.0							X		Y
HW12b	P1	25	16	64.0							X		N
Test2	P3	40	26	65.0							X		N
Final Exam	P2	35	28	80.0							X		Y
HW13a	MC	50	47	94.0								X	Y
HW13b	Pt2	50	46	92.0								X	Y
CLO Satisfied?					Y	Y	Y	Y	Y	Y	Y	Y	

Our university has a standardized instrument for student evaluation of teaching (SET) used throughout the university and administered at the end of each course offering. There are a total of 24 questions on the instrument, as well as room for optional instructor generated items. The SET instrument uses a rating scale of 1 - 5, with 5 being best. The SET was deployed in this course and Table IV gives the results during one assessment cycle for a subset of the questions on the instrument. These items were selected because of their direct relationship to evaluation of student perceptions of the course's effectiveness. The average rating on each question is given by μ, while *Md.* gives the median value.

Q1: How would you rate this course?
Q2: How much have you learned in this course?
Q4: The presentations were clear and understandable.
Q9: The instructor encouraged student questions.
Q24: How would you rate the instructor's teaching?

TABLE IV
RESULTS OF STUDENT EVALUATION OF TEACHING

Q1		Q2		Q4		Q9		Q24	
μ	Md.	μ	Md.	μ	Md.	μ	Md.	μ	Md.
3.7	4.0	4.2	4.0	4.4	4.5	4.6	5.0	4.1	4.0

Table IV shows that student perceptions on the selected items were all favorable. In particular, the results for Q4 and Q9 were most gratifying. They show that the students found the online course materials to be clear and understandable, and they had ample opportunity to interact with the instructor through the online discussion features of the course delivery system.

VIII. CONCLUSION

The process of developing and delivering this course shows that with proper design, online courses can be very effective. The course materials should deliberately incorporate elements that facilitate online education. In particular, advantage should be taken of any appropriate computer based programs and tools and have them integrated into the course delivery. This enhances the value of the course and avoids the pitfall of just having an online textbook. Students are able to learn more effectively as a result. Direct measures of student performance on the course learning outcomes showed that the students had a good understanding of the course material well. Student evaluations of their experiences with the course were also very positive. This gives us confidence in our continuing drive to diversify the modes of course offerings we use and we expect to expand our online course delivery efforts.

REFERENCES

1. J. Duderstadt, "Transforming the University to Serve the Digital Age," *Cause/Effect,* Vol. 20, No. 4, Winter 1997-98, PP 21-32.
2. T. A. Litzinger, L.R. Lattuca, R.G. Hadgraft, and W.C. Newstetter, "Engineering Education and the Development of Expertise." *Journal of Engineering Education,* vol. 100, no.1, pp. 123-150, Jan. 2011.
3. J. Daniel, "Survival of Higher Education: Using New Technologies," *Loma Linda University Annual Education Conference,* May 14, 1998. URL http://www.open.ac.uk/vcs-speeches/lomalinda.html
4. R. Lenzner and S.S. Johnson, "Seeing Things as They Really Are," *Forbes,* March 10, 1997. URL http://www.forbes.com/forbes/97/0310/5905122a.htm
5. M.E. Ssemakula: "Learning Effectiveness in Online vs. Traditional Courses." Proceedings, *ASEE Annual Conference & Exposition*, June 12 – 15, 2005, Portland, OR.
6. M. E. Ssemakula: 'Development of a Fully Online Course in Engineering Economic Analysis' Proceedings, *ASEE Annual Conference & Exposition,* June 20-23, 2004; Salt Lake City UT
7. M. E. Ssemakula: 'Using Computer Animations in Teaching Statics Concepts' Proceedings, *ASEE Annual Conference & Exposition,* June 18-21, 2006; Chicago, IL.

AUTHOR

M.E. Ssemakula is a full professor in the Division of Engineering Technology at Wayne State University, Detroit, MI 48202. (email: m.e.ssemakula@wayne.edu)

Submitted June 7, 2012.