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The sky's the limit: An activity for teaching project management: an experiential learning activity

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THE SKY'S THE LIMIT: AN ACTIVITY FOR TEACHING PROJECT MANAGEMENT

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This article describes an experiential learning activity (ELA) for illustrating foundational project-management principles. The activity simulates a "real world" application of a project-management scenario requiring teams to plan, design, and build structures to achieve stated objectives within a limited time frame. ELAs provide students with a common shared experience that serves as a building block to facilitate higher levels of learning. The article provides an overview of the exercise, detailed instructions for classroom integrations and evidence of effectiveness. The activity may be adapted for use in a variety of course settings to emphasize various learning objectives within a course.

Keywords: *experiential learning; simulation; critical thinking; project management*

At the beginning of a new term, optimism abounds and we, as instructors, have high expectations for our students. Sometimes by the end of the term, we are scratching our heads wondering what happened. Although the ultimate goal is to have our students leave with a profound knowledge and understanding of the material, the reality is that many students will achieve only a part of the goal and some students may not achieve any of the goal at all! Many instructors attempt to bring clarity to the class material through the use of an Experiential Learning Activity (ELA) by simulating a "real world" application of the material. This article presents an experiential exercise for

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illustrating foundational project-management principles. The use of the exercise in an introductory operations-management course is provided. The primary goal of the ELA introduced in this article is to expose the student to the broad range of issues involved in successfully managing a project. In particular, the instructor may use the project triangle as a framework to discuss the interrelationship of time, money, and performance or scope within projects. The ELA provides the initial "hook" for the lecture to enable the instructor to explore deeper project-management concepts in the lecture. The following describes how to conduct the exercise and how this activity encourages higher levels of learning.

Exercise Overview

ELAs are commonly seen to be a multiphase process that consists of the following: (a) planning phase, (b) introduction phase, (c) activity phase, and (d) feedback phase (LaForge & Busing, 1998).

During the planning phase, it is crucial for the instructor to establish the basis for the exercise, including the learning objectives, which are reinforced throughout the activity. During the introduction phase, students are provided with the basic knowledge to engage in the activity. The introduction usually consists of an objective overview, detailed set of instructions, and a short demonstration to clarify the mechanics of the activity. The activity phase is the time allotted for the students to achieve the objectives stated in the introduction. The challenge facing the instructor using an ELA lies in the design of an activity component that presents a realistic environment without the full range of complexity that actually exists and is directly relevant to the course material (Halpern & Hakel, 2003). An effective activity should require the students to make key decisions and trade-offs so they can engage in a rich, reflective observation during the final feedback phase after the exercise is completed (Kolb, 1984; Wheeler & McLeod, 2002). We will use the process of planning, introduction, activity, and feedback to discuss the exercise outlined in this article.

PLANNING

Project management consists of knowledge, skills, tools, and techniques applied to a wide range of activities to meet specific requirements of a project (Project Management Institute, 2000). The field of project management includes five distinct processes—initiating, planning, executing, controlling, and closing—as well as nine knowledge areas. The nine knowledge areas focus on management expertise in project integration, project scope, project

TABLE 1
Learning Objectives for the Project-Management Lecture

1. Explain the project planning cycle and the three major components of the project triangle: time, cost, and performance.
2. Explain the common project organizational structures (pure project, functional project, and matrix project) and their relationship with project management.
3. Construct and explain a work breakdown structure in project management.
4. Construct and explain a project network diagram and a Gantt chart.
5. Apply the critical path method (CPM) to analyze a project network.
6. Analyze networks with deterministic times including:
   - calculate the expected duration of a project;
   - calculate earliest start time (ES), latest start time (LS), earliest finish time (EF), and latest finish time (LF) for any activity;
   - calculate the critical path(s) for a project;
   - calculate the duration of all paths; and
   - calculate individual activity slack time.
7. Analyze the trade-offs between time and expediting costs by crashing a project network (i.e., the concept of "crashing").

time, project cost, project quality, project human resources, project communications, project risk management, and project procurement.

Project management emerged as a discipline in the late 1950s and early 1960s due to the changing nature and scope of projects. Today on a global basis, both corporations and governments are forced to make strategic decisions at a rapid rate (Eisenhardt, 1989). The use of project-management techniques enables organizations to complete both strategic and operational tasks in an effective and efficient manner. As a result, it is vital for students to not only have a fundamental understanding of the basic concepts, but they should be able to apply these fundamentals to a realistic project setting.

A key element in the planning and design of an ELA is establishing a clear link between the exercise, the lecture, and the course-learning objectives. The relationship among the preceding class elements is the critical difference between the students viewing the exercise as a useful part of the class or seeing it as a waste of class time. Table 1 summarizes the learning objectives associated with our project-management lecture. The ELA is designed to support each learning objective either directly from the activity or indirectly as a link in the lecture that follows the activity. In particular, the activity emphasizes the complexities involved within the project triangle and the trade-offs when crashing a project network. The activity may also be used to demonstrate the construction of a work breakdown structure, project network diagram, and a Gantt chart.

The ELA presented in this article is titled *The Sky's the Limit*, and has been designed so that it can be easily adapted to a variety of management class set-

tings and scenarios. There have been several skyscraper building–related activities previously published that were designed to demonstrate and reinforce various topics, including strategic concepts, leadership concepts, team dynamics, and new product introduction (Coff & Hatfield, 2003; Kolb, Rubin, & McIntyre, 1971; Meisel & Fearon, 1999; Moskowitz & Ward, 1998).

The exercise presented in this article provides the student a unique opportunity to experience the challenges from the perspective of the project manager and project team member. The exercise allows the student to experience the complete project cycle from the initial planning and design phase, the construction phase, and the final selection of the team that does the best job achieving stated objectives in the designated time period.

INTRODUCTION—SETTING THE STAGE

The current application of *The Sky's the Limit* demonstrates the critical elements and challenges associated with managing a project. The activity is conducted prior to the lecture portion of the class and provides a common shared experience to the students while simultaneously highlighting fundamental aspects of project management. The basic framework of the activity involves student teams designing, developing, and constructing skyscrapers composed entirely of spaghetti and miniature marshmallows within a specified time frame. At the end of the exercise, the student groups are required to conduct a group debriefing session to reflect upon their experience. To stimulate the discussion, each group is provided with a designated set of questions. A debriefing session is conducted to help students understand the complexities of managing a project and to establish the framework for the material presented in lecture. Finally, a series of tests are performed to discern the "best" skyscraper based upon predetermined criteria. On average, *The Sky's the Limit* activity takes approximately 50 to 60 minutes from the setup to cleanup. Prior to its use in the project-management lecture, *The Sky's the Limit* activity has been successfully used in a required undergraduate course and an MBA-level operations-management course. The complete guidelines for using *The Sky's the Limit* activity are provided in the appendix.

On the day of the activity, as the students enter the room, they are naturally curious as to why spaghetti and marshmallows are present. The instructor may want to reassure the students the materials in the room will be used for a classroom activity. *The Sky's the Limit* is designed to be used by teams ranging from three to five students; our experience indicates that four students is an ideal group size. The initial phase of constructing teams should be done quickly. One method for team formation is to simply direct students to form self-selected teams. Regardless of the team formation method chosen, it is

critical that the formation process occurs quickly to ensure that the exercise is completed in a timely manner. A potential exercise variant would be to intentionally assign different-sized teams. This would provide a forum to discuss the implication of the team size on the resulting structures.

After the setup is complete, all teams are concurrently provided the same set of operating instructions in both written format and verbally by the instructor.

> Your team has 20 minutes to construct a skyscraper made out of spaghetti and marshmallows. The criteria for the skyscraper are it must be durable, tall, and strong. To be successful, the skyscraper must stand for 20 minutes after being built and be able to support a weight equal to 50 sheets of paper. The team with the best skyscraper based on height, durability, and strength will WIN. . . . Good Luck!!!

The instructor will need to explain to the class that during the next 20 minutes, project teams are responsible for both designing and constructing the skyscraper. It is also very important for the instructor to further elaborate on the terms of acceptable use of the materials. Students should be reminded that they may only use the marshmallows and spaghetti that have been provided, and no additional resources or materials may be used. For example, they may not use any type of paper clips, textbooks, or coffee cups. Teams are instructed that they may not alter the configuration of the marshmallows in any manner. For example, they may not split the marshmallow into two separate pieces or join two marshmallows to create a larger single marshmallow. In addition, the groups are reminded that if they choose to consume or snack on the marshmallow resource they are in fact cannibalizing their own resources. Typically, this comment will generate laughter throughout the room. Finally, the students are informed that they may break the spaghetti into any desired length for their construction. We recommend that either one or both of the resources be limited to the amount initially provided in the materials distribution. By limiting the resources, some new dimensions can be added to the debriefing discussion.

THE ACTIVITY—ACTION PHASE OF THE EXERCISE

On dissemination of the materials and instructions, the teams are directed to begin the process. At this point, some form of timing device should be introduced. The timing device may be the clock in the room or a clock projected onto a screen. Initially, the instructor should write the remaining time on the board every 5 minutes. As the activity time elapses, the instructor should decrease the interval of time and write the remaining time every 1 to 2

minutes. The intent is to create an environment where the students must operate with a sense of urgency.

At the start of the actual construction phase, confusion will erupt in the classroom and each team will operate in a different manner. During the construction phase, it is recommended that the instructor walk around the room and observe the classroom dynamics. From our experience, there will be four typical team-operating patterns you may observe. The first team-operating mode will be the team that will seek additional clarification concerning the building criteria. This type of team is very uncomfortable with the ambiguity of the instructions and the criteria provided. The second team-operating mode will be the "ultra" planning group. This type of team will commence a detailed drawing of their proposed skyscraper. Often this team will struggle to complete their skyscraper due to the inordinate amount of time spent on planning. The third type of team-operating mode will be the "confused" variety. Commonly this type of team will appear to have a glazed look throughout the entire activity. You may also observe they are wasting resources and are simply "jabbing" strands of spaghetti into marshmallows. This team will continually be visually checking the progress of their peers. The final type of team-operating mode is the group that appears to do minimal initial planning and proceeds in a hurried fashion. They typically will choose to split up the task or revisit their plan in midstream. Often they will appear to adjust their plan based on progress.

Frequently teams are forced to adjust their plans and perform damage control to save their skyscraper from collapsing. Many teams adopt the "flying buttress" approach similar to the great cathedrals in Europe. However, unlike the cathedrals, the buttresses seldom prevent the student skyscrapers from collapsing. This phenomenon provides the students a firsthand experience of why a project plan must be dynamic and be able to quickly change as a project evolves. Furthermore, it provides an opportunity to talk about disaster recovery and the importance of contingency planning in project management. Thus, the activity may be used to introduce new topics and help students to comprehend topics that are typically not covered in general operations-management textbooks.

At the end of the allotted 20 minutes, the groups are informed that the time limit has expired. All teams are instructed to immediately stop working on their skyscraper. In our experience, students always attempt to continue working on their skyscraper after time has expired. They need to be reminded the penalty of working past the deadline is the risk of disqualification from the process because time limitation was one of the articulated project constraints.

FEEDBACK—DEBRIEFING THE EXERCISE

After the design and construction phase is complete, each student group is given the set of debriefing questions provided in the appendix. The teams are instructed to spend approximately 10 to 15 minutes discussing the questions within their group. After the groups have completed their discussion, the instructor initiates and leads the class debriefing session.

As part of the class debriefing, the first step is to gather from each group their time estimates associated with how long each team spent planning versus constructing the skyscraper. The times are recorded in a manner to allow the entire class an opportunity to view the responses from each individual team. For an example of a data-recording table, refer to the appendix. The majority of the teams will report minimal planning time, 2 minutes or less. Invariably the team that spent the longest time planning their skyscraper will potentially have one of the worst end products with regards to the criteria. This activity helps students experience firsthand that you may actually overplan and that effective project management has strict timelines that force critical resource decisions. In fact, occasionally the group that spent an excessive amount of time planning may not have left enough time for actually building their design. This type of group always wants to show the class their paper plan. The instructor may want to highlight that a great plan, which could not be executed, may be deemed worthless to an organization, which is an invaluable and transferable lesson for any discipline.

Another class lesson is the working definition of "planning." The majority of the students will report the time spent initially before construction as planning. The instructor may want to emphasize the time during the construction when the groups were working, discussing various scenarios, altering the design could all be considered to be part of planning. We believe that this debriefing helps students to comprehend the material in a more meaningful fashion. Often we will integrate discussion about local projects and encourage students to think about how planning elements have resulted in both success and failure. In Chicago, we often talk about the Soldier Field Renovation project. It is pointed out that one of the reasons the project went over budget and over time was the fact the project leaders never planned on the Chicago Bears football team making the playoffs in 2000. The good fortune of the franchise actually postponed the project from starting on time and eventually ended up costing the city and the organization millions of extra dollars. The intent is to expand the students' definition and understanding of the critical components of project planning and to help them realize project planning is a continuous cycle.

Another class lesson is the concept of the project triangle (Chatfield & Johnson, 2003). The instructor can use the project triangle as a framework to discuss the interrelationship of time, money, and performance or scope within projects. To be a successful project manager, it is vital to understand how all three essential elements apply to all projects. First, time is often one of the most important constraints to manage. In many projects, the team may not be aware of the project budget or the scope of work in great detail, but they are typically aware of the project deadline. As demonstrated through the ELA, many of the students simply focus on the time element without regard to the performance or budget. Next, cost is often a limiting factor in many projects. Many projects have a restricted budget and in the event it is exceeded, additional action will be required. Initially the students may not understand how cost is a factor in their activity, especially because many of the students simply think of cost as dollars. The broader meaning of project cost can be explained and expanded to include all resources required to carry out the project, including people and equipment, the materials, and all the other events and issues that consume resources. Finally, the performance or scope, which considers both product and project, may be discussed. The product scope describes the performance characteristics such as the quality, features, and functions of the product. The project scope describes the work required to deliver product or service. The product scope focuses on the customer or the end user of the product and the project scope is concerned with the people who will conduct the project. The project manager who manages *project* scope must also understand *product* scope. After the ELA, the students typically understand the impact of the specified product scope through the specified performance criteria. Through the ELA, the students are able to see firsthand how changes to their project plan may influence the project triangle. For example, if you decrease the project duration, you might need to increase budget (cost) because you must hire more resources to do the same work in less time. If you are not able to increase the budget, you may need to reduce the scope because the resources you have may not be able to complete work in the reduced time frame.

Next, the instructor may want to identify and direct specific questions to the teams that spent either the longest or the shortest amount of time on planning. Typically, the groups that fall in this classification (shortest or longest) will have structures that ultimately fail at least one of the prescribed criteria. Specifically, the instructor should explore the answers to the debriefing question dealing with how these groups managed the components of time constraints, cost (scarce resources), and performance (meeting criteria). Furthermore, these discussions can also focus on how organizations must balance conflicting criteria and make trade-offs with regard to time, cost, and perfor-

mance. Ultimately the student needs to realize that planning is always a crucial element of project management but trade-offs must be balanced. The students may now understand at a deeper level the implications of trade-offs because they have all just personally experienced the associated trade-offs and the pending consequences of their decisions.

At the completion of the class debriefing discussion, the instructor will need to conduct the final tests. By this time, many of the structures will no longer be standing and effectively have failed the durability test. For the remaining structures, two tests are conducted to assess height and strength. For the height test, the instructor will need to quickly measure with a tape measure or yardstick and record the associated results. For the strength test, the instructor will need to place 50 sheets of notebook paper on top of each of the structures. The structure must maintain its integrity for one minute while bearing the load of the paper. The instructor may consider enlisting help from student teams whose structures have already failed to assist in the administering the height and strength tests. Employing student help can effectively reduce the total time for the final testing phase. If there is still a tie after testing has been completed, the class will vote as to which skyscraper they deem the "best" based on their own individual criteria. At the conclusion of the testing and voting (if necessary), the winning team is awarded a small incentive prize.

Classroom Integration

Upon completion of the exercise, we immediately begin the lecture portion of the class. A direct transfer of knowledge may be seen as the lecture begins. The ELA affords the instructor the opportunity to pose questions that will enable the students to think deeper about the material and promote higher levels of learning. Instructors are able to move through many of the basics very quickly because a common basis of experience has been formed through the ELA. For example, the instructor may use the activity to demonstrate the construction of a work breakdown structure, project network diagram, and a Gantt chart such as the sample diagrams provided in the appendix. Rather than cover only rote-level learning objectives, students are given more time to think about material and apply newly learned concepts to the skyscraper situation they just experienced. Proponents of critical thought often advocate that the ability to contemplate and question ultimately leads to deeper levels of understanding (Meyers, 1986; Smith, 2003).

Another benefit of conducting the exercise is that students learn how to analyze the weaknesses of the more analytical project-management approaches.

TABLE 2
Results for Learning Objectives—Pretest and Posttest

If given the exam today, I would receive full credit for the question listed . . .		*Sample Size*	*Mean*	SD	t *Test*
1. Explain the three major components of the project triangle: time, cost, and performance.	PRE	121	3.36	1.65	–12.701*
	POST	111	5.78	1.25	
2. Construct and explain a work breakdown structure in project management.	PRE	121	3.15	1.70	–11.652*
	POST	112	5.41	1.24	
3. Construct and explain a project network diagram and a Gantt chart.	PRE	121	2.02	1.20	–19.52*
	POST	110	5.19	1.27	
4. Analyze the trade-off between time and expediting costs by crashing a project network.	PRE	122	2.66	1.48	–22.077*
	POST	111	6.24	0.97	

NOTE: 7-point Likert-type scale: 1 = *strongly disagree* and 7 = *strongly agree*.
*$p < .01$.

For example, one of the common techniques taught in project management is the critical path method. An outcome of the critical path method is that the sequence of events determines the overall length of the project. A tenet of the critical path method is the notion of task independence. After participating in *The Sky's the Limit*, the students will often question this assumption and note how many of the elements are highly dependent and contingent upon previous events.

Evidence of Effectiveness

To assess student learning, we collected pretest and posttest data with respect to the course-learning objectives. The students completed the pretest on the first day of the term and the posttest on the last day of the term. The pretest and posttest consist of a variety of learning objectives that are specifically linked to various ELA used throughout the course. Table 2 presents the means, standard deviations, sample sizes, and *t* tests for data corresponding to the learning objectives directly associated with the project-management lecture and *The Sky's the Limit* activity. For each learning objective in Table 2, there is a significant difference in the pretest and posttest responses.

Figure 1 and Figure 2 depict the distribution for the number of responses for the pretest and posttest on a scale of 1 to 7 with 1 = *strongly disagree* and 7 = *strongly agree* for two selected project-management learning objectives. These figures highlight a similar pattern observed in the other learning objec-

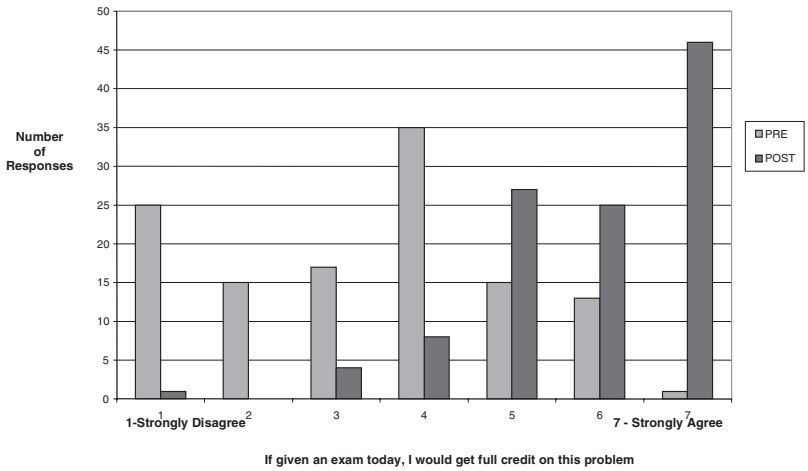

Figure 1: Explain the Three Major Components of the Project Triangle: Time, Cost, and Performance

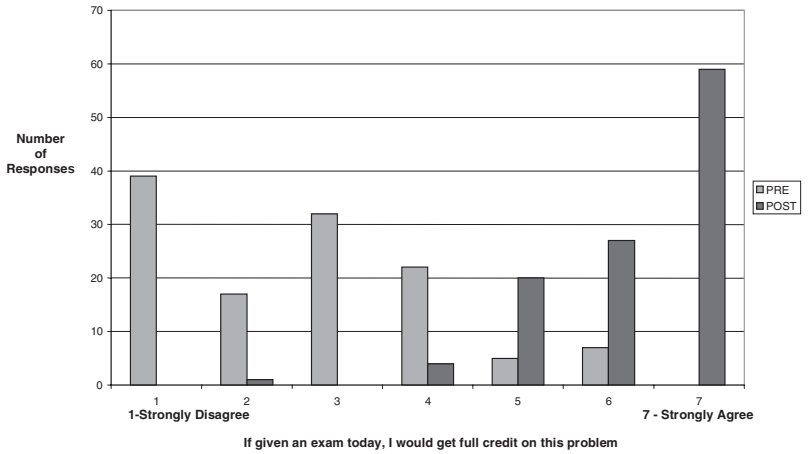

Figure 2: Analyze the Trade-Off Between Time and Expediting Costs by Crashing a Project Network

tives where the pretest results are skewed toward the left or *strongly disagree*, indicating the student is unfamiliar with the topic. The posttest results are skewed toward the right or *strongly agree*, indicating the student has a high level of familiarization with the topic.

To help assess if the variance was attributable to the exercise or other elements of the course, we asked students to rate the overall effectiveness of the exercise on a 1 to 5 Likert-type scale. The student feedback helps the instructor assess the overall impact of the exercise and determine if any adjustments should be made to the exercise. For all sections taught using *The Sky's the Limit*, more than two thirds of the students reported that it was effective in helping them understand the class material. Across the various sections, the overwhelming majority of students found the exercise to be an extremely effective means to teach project management. This evidence in combination with the pretest and posttest learning-objective questions provides some evidence that the activity had a positive impact on learning. Although the data demonstrate learning, it is difficult to isolate the specific attributes of the class exercise versus the ensuing class lecture. Thus, the attributes specific to the class exercise and the class instruction via lecture may be confounded.

Conclusions

This article presented *The Sky's the Limit*, an experiential learning activity designed to teach project management. This exercise has helped us to teach many students about the challenges project managers are forced to struggle with every day. Our experience has been that the majority of the lecture would cover only the basic levels of knowledge without the use of *The Sky's the Limit*. The use of an ELA can be a very effective method to promote higher levels of learning. Research has clearly demonstrated that experiential learning can be critical to enhancing the overall learning process (Kolb, 1984; Serva & Fuller, 2004). When properly designed, the ELA will emphasize the complexities in the material that are often not covered via traditional lecture or textbook readings.

Appendix

Activity: *The Sky's the Limit*

Materials Required

- Spaghetti noodles (approximately one 4 oz. box per group)
- Miniature marshmallows
- 12 oz. bowls or cups for miniature marshmallows
- Tape measure or yardstick
- 50 sheets of paper secure with a binder clip
- Clock and/or timing device

Optional:

- Incentive prizes
- Garbage bag
- Paper towels and mild cleaner

Total material cost for the entire exercise is approximately $10 for 12 groups of 4 students.

Classroom Setup

Each student team should receive a box of spaghetti, one level bowl or cup of marshmallows and an instruction worksheet outlining the parameters for the exercise. Distribution of the materials prior to class will help to ensure finishing the exercise in a timely fashion.

Note

Remind your students that they should NOT cannibalize their marshmallow resources. The marshmallows may be beyond the expiration date and if consumed they could be hazardous to their health.

Conducting the Exercise

The exercise is conducted in two separate phases:

Phase I: Introduction and Activity—Approximately 25 to 30 minutes

Instructions

Your team has 20 minutes to construct a skyscraper made out of spaghetti and marshmallows. The criteria for the skyscraper are it must be durable, tall, and strong. To be successful, the skyscraper must stand for 20 minutes after being built and be able to support a weight equal to 50 sheets of paper. The team with the best skyscraper based on height, durability, and strength will WIN . . . Good Luck!!!

Activity

Student teams are directed to begin the process. Initially write the remaining time on the board every 5 minutes and as time progresses write the remaining time every 1 to 2 minutes. At the end of the 20 minutes of allotted time, inform groups time is up and do not let any groups work on the structure after time has expired. In our experience, students always try to work on the structure after time has expired—just inform them that no late designs are accepted and they will be disqualified.

Phase II: Reflection and Feedback—Approximately 25 to 30 minutes

TABLE A1
Debriefing Questions for *The Sky's the Limit*

1. Estimate *approximately* how much time was spent on planning and how much time was spent on building during the 20 minutes allotted for construction of the skyscraper.
2. Explain the team process of planning the structure.
   - Did everyone have the same background, skill level, and so on?
   - Was it a team effort or did individuals work by themselves?
3. Explain the team process of building the structure.
   - How did your team actually build your structure?
   - How did your team reduce the project into manageable tasks?
4. Analyze how your team managed the following components: time, cost, and performance.
   - How would you define each element: time, cost, or performance?
   - Which component was the most important: time, cost, or performance?

Student Group Reflection

At the end of the exercise, each group should be given the set of questions in Table A1 to answer. The student groups should be given approximately 10 to 15 minutes to answer the questions.

Class Reflection

After the groups have completed their discussion, the instructor initiates and leads the class debriefing session. Depending on the remaining class time, the following topics are suggested:

1. Collect and record data on how long each group spent planning versus constructing the skyscraper.
2. Discuss the working definition of *planning*.
3. Discuss the concept of the project triangle and the trade-offs made by various groups with respect to the triangle.
4. Discuss the concept of project crashing.
5. Construct and explain a work breakdown structure, a Gantt chart and a network diagram as shown in Figure A1, Figure A2, and Figure A3.
6. Discuss the limitations and challenges with the assumption of independent activities in the network diagram (see Figure A3) for activities 4 and 5.

Feedback

After the 20 minutes for testing has expired, collect the performance metrics for the exercise. We use Table A2 to illustrate the performance metrics to the class. It is

ID	WBS	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	1	Sky's the Limit Tower	0.04 days	Fri 3/4/05	Fri 3/4/05		
2	1.1	Initial Project Planning/Design	5 mins	Fri 3/4/05	Fri 3/4/05		Dave,Mike,Sarah,Lisa
3	1.2	Construct Base	0.01 days	Fri 3/4/05	Fri 3/4/05		Dave,Mike,Sarah,Lisa
4	1.2.1	Build Spaghetti and Marshmallow Ba	5 mins	Fri 3/4/05	Fri 3/4/05	2	Lisa,Dave
5	1.2.2	Status Update/Adjust Plan	3 mins	Fri 3/4/05	Fri 3/4/05	4FF	Sarah,Mike
6	1.3	Construct Walls	8 mins	Fri 3/4/05	Fri 3/4/05	5	Mike,Sarah
7	1.4	Construct Second Level	8 mins	Fri 3/4/05	Fri 3/4/05	5	Dave,Lisa
8	1.5	Final Construction/Stabilization	2 mins	Fri 3/4/05	Fri 3/4/05	6,7	Mike,Dave,Sarah,Lisa

Figure A1: Sample Work Breakdown Structure for *The Sky's the Limit*

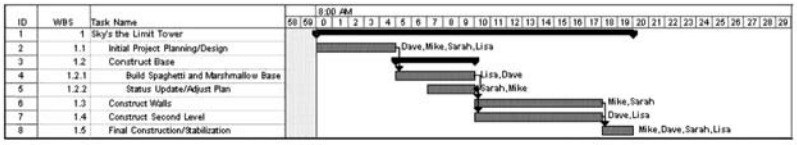

Figure A2: Sample Linked Gantt Chart for *The Sky's the Limit*

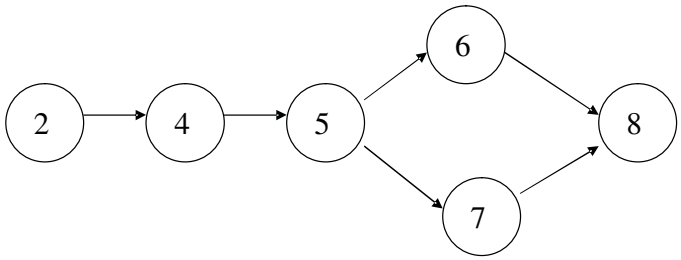

Figure A3: Sample Project Network for *The Sky's the Limit*

NOTE: The node numbers correspond to the ID numbers in the corresponding sample work breakdown structure and Gantt chart.

essential to spend at least 10 minutes discussing the results and how they relate to the discussion questions.

Cleanup

Students are instructed to clean up their workspace. Unused resources should be returned to the instructor to use for future activities.

Advanced Exercise Variant

To further enhance the experience with each element in the project triangle, the instructor may elect to introduce a cost component into the activity. The instructor would assign a project budget for the material cost associated with the direct use of each marshmallow and strand of spaghetti. The teams would be required to monitor,

TABLE A2
Sample Performance Metrics for *The Sky's the Limit*

Team #	*Planning Time (minimum)*	*Construction Time (minimum)*	*Durability Pass/Fail*	*Height (inches)*	*Strength Pass/Fail*
1	0.5	19.5	FAIL	NA	FAIL
2	1	19	FAIL	NA	FAIL
3	2	18	FAIL	NA	FAIL
4	5	15	PASS	20	PASS
5	10	10	PASS	28	FAIL

track, and report the total material costs for their structure. The associated cost would be considered as an additional performance metric in the assessment of the "best" skyscraper. For example, each team could be charged $1 per marshmallow and $1 per stick of spaghetti with the total budget for the structure not to exceed $100. During the debriefing discussion, the instructor could emphasize that some teams may be low cost, but fail to meet the criteria for structural integrity, whereas others may meet strength criteria but fail for cost. The additional time required for the exercise variant is approximately 10 minutes.

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