

Methods to Assist in Teaching Planning and Scheduling

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Many students struggle with the concepts of planning and scheduling when first introduced to it. This struggle extends from the introduction of work breakdown structure to network logic through the meaning of critical activities and continuing with other planning and scheduling topics. This paper explains methods used in Civil Engineering construction courses to assist students in understanding scheduling concepts. The basis for explaining these concepts is the student's schedule of classes that comprise the requirements of their Civil Engineering degree. The technique of using material that students are familiar with to explain something new is a recognized educational theory.

Key Words: Education, Construction, Planning, Scheduling

Introduction

The topic of planning and scheduling is difficult to understand for some students who are studying construction. This is particularly true for students without construction experience as they try to understand the relationships of construction activities. Further, the use of alphabetic characters to represent activities, such as, "Activity C follows Activity B and precedes Activity D", while providing a mechanism to teach the topic of planning and scheduling does not provide a basis for true understanding of the material. This paper presents methods to assist in teaching planning and scheduling using something that students are familiar with: their academic schedule of classes required for their particular degree. This paper uses a Civil Engineering curriculum to illustrate examples; however it could be any curriculum where the topic of planning and scheduling is taught. The methods presented in this paper can easily be adapted to various courses depending on the preferences of the individual teaching the course. These methods range from simple ones that can easily be incorporated into an existing lecture to methods that can be the basis of a project.

The importance of planning and scheduling in construction cannot be overestimated. The US Department of Labor, Bureau of Statistics, includes an industry definition of a Construction Manager (CM) that states they will "...typically schedule and coordinate all design and construction processes..." (USDL, 2005). In a study entitled "What does a Construction Manager really do?" performed by the Construction Management Association of America, it was found that one of the most important general areas "... was time management, in which CMs reported their most important function is to develop a construction schedule, followed by developing and managing a critical path schedule for the job..." (CMAA, 2005). Glavinich (2004) answers the question, "Why Schedule the Construction Project?" with the following: to communicate the construction plan, establish production goals, monitor and establish progress, and to manage change.

ABET, the accreditation commission for engineering programs, does not include a requirement for planning and scheduling in the Program Criteria for Civil Engineering (ABET, 2004). However, the American Society of Civil Engineers (ASCE) in their Body of Knowledge expansion of the ABET outcomes for Civil Engineering Programs suggest in the commentary of Outcome 13 that an important element is planning and scheduling (ASCE, 2004). For Construction Engineering programs, ABET has a requirement for understanding planning and scheduling (ABET, 2004). The American Council for Construction Education in the criteria for accreditation of baccalaureate construction degree programs, as part of the required fundamental construction topics, includes planning and scheduling (ACCE, 2004). From this it is evident that students interested in studying construction will have planning and scheduling in their coursework.

Construction schedules are the key part of the project management basics needed by construction professionals. An examination of the table of contents of any number of scheduling texts reveals that a thorough understanding of planning and scheduling is needed to not only plan projects, but to use for direction, forecasting, control, changes, claims, managing subcontractors, resource planning, and reporting (Newitt, 2005; Weber, 2005; Glavinich, 2004; Callahan et. al., 1992; and Stevens, 1990).

Educational Theory

The use of current knowledge to help extend learning is not new. The educational theory called "constructionism" is the idea that students can assist their learning by extending current ideas (their class schedules) into the new ideas that they are attempting to master in school (planning and scheduling). This theory is discussed by Bruner (1960, 1973).

The ideas discussed in this paper could also be classified as an inductive method of learning. The educational theory called "assimilation to existing knowledge" is to provide familiarity or linking to prior knowledge/experience. This can be accomplished by tapping into a student's experience and intuition (their class schedule) to connect to new material (planning and scheduling). This theory is discussed by Ausubel (1968) and Mayer (1999).

Methods

This section presents techniques that use a student's class schedule that can be included in lessons on planning and scheduling. They do not require major modification of existing lectures or exercises. They can be used as examples to illustrate the topics.

Work Breakdown Structure

The development of a Work breakdown structure (WBS) is illustrated using the Civil Engineering curriculum at Michigan Technological University (Michigan Tech). The first level is the College or School. In this case it is the College of Engineering. The second level is the engineering disciplines available. The third level is Civil Engineering. The fourth level contains General Education courses, Civil Engineering courses, and required courses. Under Civil Engineering the six specialty areas of the Civil Engineering Curriculum used at Michigan Tech is presented: construction, environmental, geotech, structures, transportation, and water resources. The last level lists the courses in the specialty areas. By having the students work through this it is possible to develop a WBS during class. The tasks (classes) identified in the WBS can then be used to develop the network logic. An example of a work breakdown structure for the construction area of Civil Engineering at Michigan Tech is shown in Figure 1. Students may come up with variations in the WBS such as identifying them by year (Year 1, 2, 3, and 4) or by semester (Year 1 Fall, Year 1 Spring, Year 2 Fall).

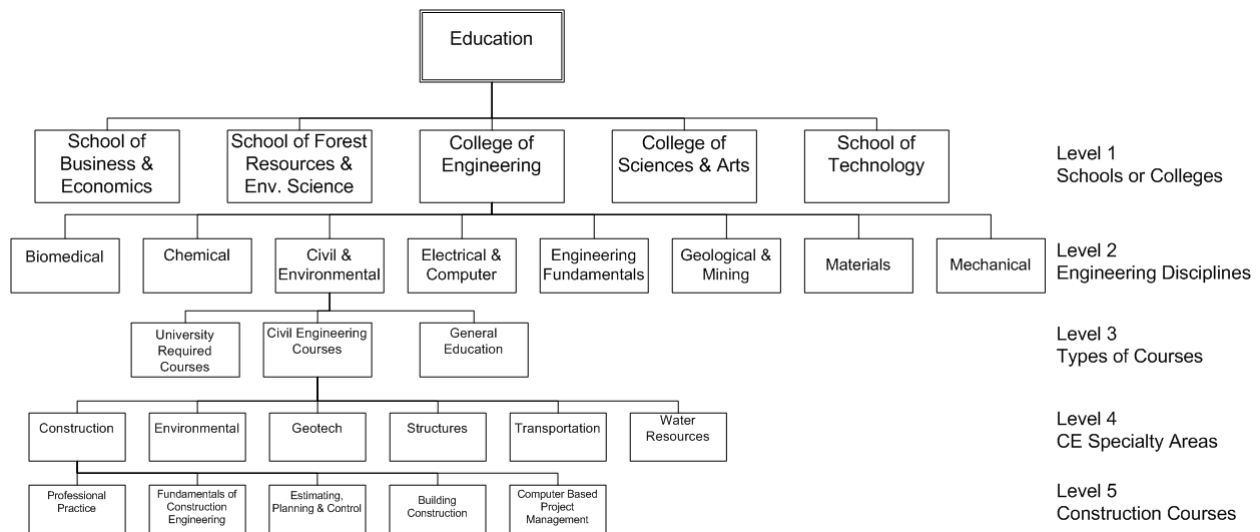


Figure 1 Work Breakdown Structure of Civil Engineering Curriculum

Network Logic

Many students have difficulty in the initial planning process of network schedules. This may be due to a lack of classes on the technology of construction but is more likely a functional lack of construction field experience. One method to overcome this limited knowledge is to provide schedule logic. However, this does not provide a true learning experience for students as it is more of an activity that they may consider “busy work”. An alternative for teaching planning and scheduling is to first use a student’s class schedule for a particular discipline. Most students have knowledge of their class schedules and the relationship of classes to one another. They understand and realize the importance in following it as closely as possible. The class schedule information is usually provided as a flowchart as shown in Figure 2 or in tabular form as shown in Table 1 for the Civil Engineering curriculum at Michigan Tech. The flowchart of Figure 2 provides students with an overall graphical picture of class schedules for each of the four years. Also shown are predecessors (prerequisites) of certain classes. Many classes do not have predecessors and the importance of every activity in a construction schedule having a predecessor and successor (except for start and finish) can be emphasized. The activities without predecessors and successors can be linked to the start, the finish or intermediate milestones. Acceptance into the university can be used as the start and graduation can be the finish. The instructor can use the flowchart to explain these concepts or can have the students draw out the network. The use of the tabular format of Table 1 requires students to determine the relationships of classes to one another from the course catalog. An ancillary benefit to using class schedules to explain network logic is that students become more familiar with their curriculum and the “bigger picture”.

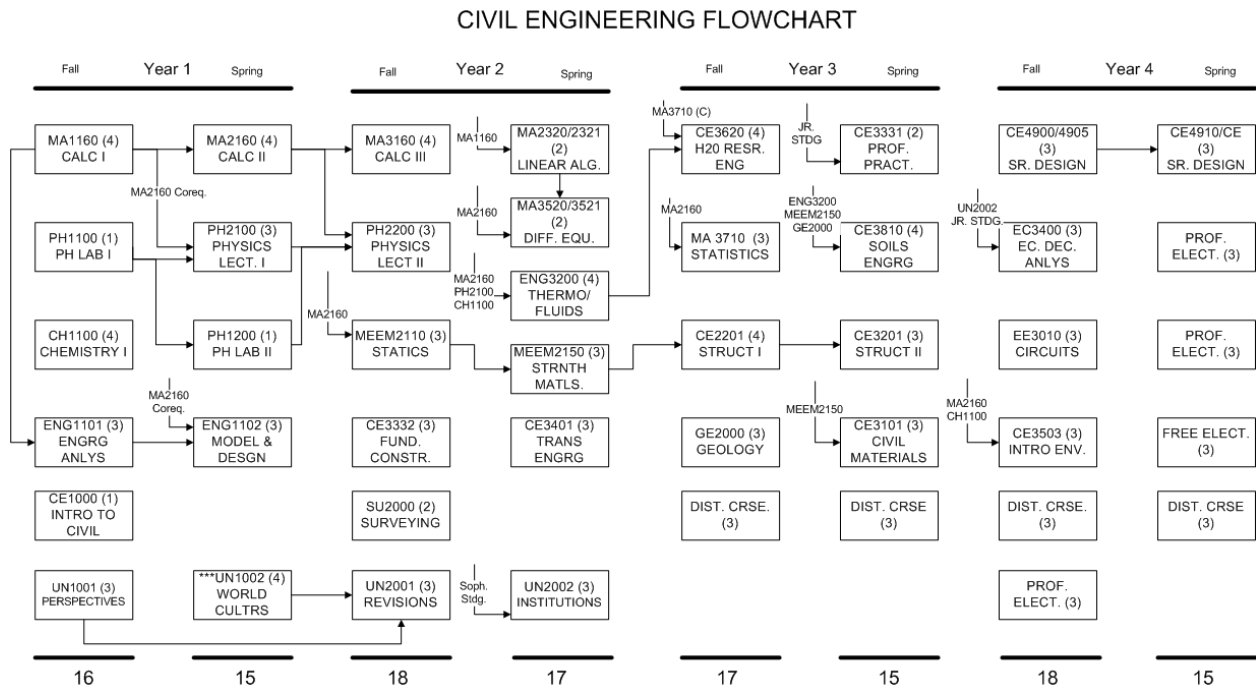


Figure 2 Sample Civil Engineering Flow Chart

Critical Activities

Following the development of the network the next step is to determine the duration of the project. With this comes the identification of critical activities. While the method presented in this paper does not help to explain forward/backward pass calculations it does provide a method to explain (at least conceptually) what critical activities are. A definition of critical activities is presented to students such as: a critical activity is an activity that if delayed delays the completion of the project. For engineering students this class is usually calculus which they easily identify. For other curriculums it may be a different class. Students can easily relate to failure to complete calculus as scheduled but also the implications that this has on the completion date of the project (graduation) and

the increased cost of completing (cost to retake calculus, associated cost of staying at school longer, and lost income from not starting a job when planned).

Table 1
Sample Civil Engineering Curriculum (Only years 1 and 2 shown)

Fall Semester			Spring Semester		
Year 1					
CH1100	General Chemistry	4	ENG1102	Eng. Model & Design	3
ENG1101	Eng. Anal. & Prob. Solv.	3	MA2160	Calculus II	4
MA1160	Calculus I	4	PH1200	Intro. Physics Lab II	1
PH1100	Intro. Physics Lab I	1	PH2100	University Physics I	3
UN1001	Perspectives on Inquiry	3	UN1002	World Cultures	4
CE1000	Intro. To Civil Eng.	1	ENG1003	AutoCAD (Optional)*	(1)*
		Total Credits			Total Credits
		16			15/16
Year 2					
MA3160	Multivariate Calculus	4	MA2321	Linear Algebra	2
CE3332	Fund. of Const. Engg	3	MA3521	Differential Equations	2
MEEM2110	Statics	3	ENG3200	Thermo/Fluids	4
PH2200	University Physics II	3	CE3401	Transp. Engineering	3
SU2000	Surveying & GIS Fund's	2	MEEM2150	Mechanics of Materials	3
UN2001	Revisions I	3	UN2002	Institutions	3
		Total Credits			Total Credits
		18			17

Resources

Resources for students are the number of credits each class is worth. They can identify that time is the factor that limits the number of classes that they take each semester. A brief discussion usually leads them to the identification of credits as an indication of the required level of effort and time. The measure of their workload is the total number of credits that they take during a semester. This is similar to contractors that may limit the amount of work that they take on based upon the resources (equipment, labor, etc.) that they have.

An examination of the sample Civil Engineering Curriculum credit totals in Figure 2 or Table 1 reveals that the resources (credits) for the most part have already been leveled for the suggested schedule. In fact many students, who are not following the suggested schedule, have already practiced resource leveling (balancing credit hours in a semester) in their scheduling of classes by the time this discussion occurs in class.

The discussion of resources continues with a student that has not stayed on track and needs to retake a class. The options available are to delay the completion of the project (graduation) as discussed in the section on critical activities or to take additional credits beyond what is set out in the flowchart or table that describes the curriculum. If a student takes additional classes, they usually try to balance some hard classes with some classes that are easier (they level their credit resources).

Float

The section on resources already mentioned the taking of harder classes with some easier classes if there is a need to adjust the suggested schedule for any reason. Students, not following the suggested schedule, already understand the concept of float and use it to level the number of credits that they take each semester. A definition of float such as the following should be provided: float is the amount of time an activity can be delayed without delaying the completion of the project. Most students can easily identify classes that have this characteristic. In the flowchart of Figure 2 this could be any number of classes that do not have any other classes dependent on them. This discussion is usually limited to total float.

Progress Curve

A progress curve can be illustrated by using credit hours, leading to a degree, as the unit being measured. For a student that is on schedule a plot of the progress curve will be a straight line. Depending on the ability to move

classes around (float) a student who is behind at the beginning of their studies will have a shape that may be slightly different. The same holds true for a student who has advanced placement credit. Additionally, the progress curve can be used to plot actual progress in terms of credits versus planned progress to show whether a student is ahead or behind the suggested schedule and to explain how a contractor uses similar methods. Figure 3 is a plot of the planned progress of the Civil Engineering curriculum of Figure 2 using credits for each semester. In the discussion of this topic with students, the traditional construction “S curve” can be mentioned and how it is less steep at the start, steeper in the middle and flattens out at the end.

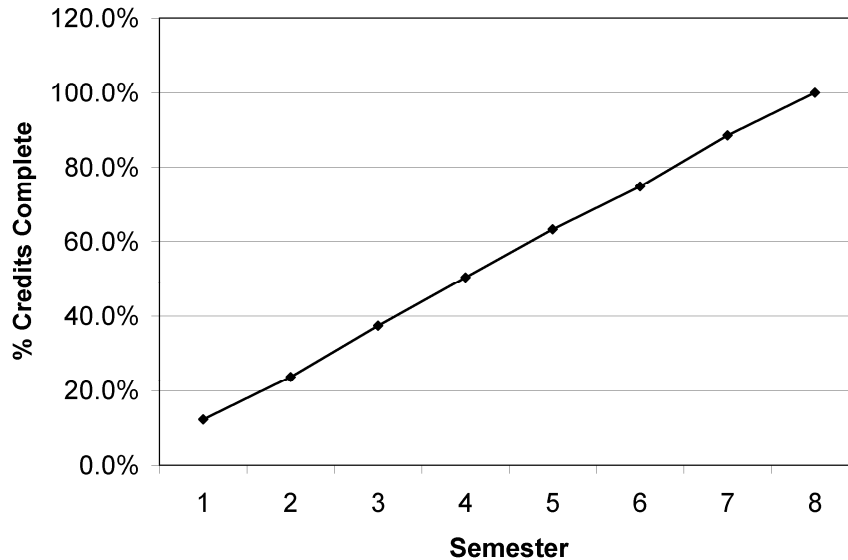


Figure 3 Planned Progress (Credits)

Cost of Change, Ease of Change

An additional topic that fits nicely into this discussion is the explanation of the cost to make changes and the ease of making those changes. While this may be more of a scope definition topic the introduction at this point is easy to implement. Students are aware that it is easier to change their majors early in their college education. They are also aware of the less impact on the cost of doing this early versus doing it after their second or third year. The effect of this is shown in Figure 4. The similarities between this and a construction project can be mentioned.

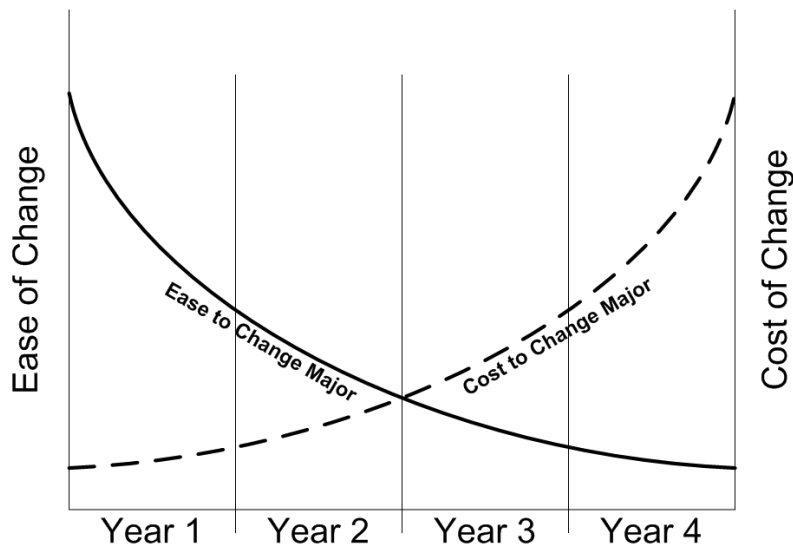


Figure 4 Cost and Ease of Change Plot

Time, Cost, Quality Triangle

The traditional time, cost, quality relationship triangle is presented in Figure 5. The traditional explanation of this is that as time for a project decreases, cost will increase and quality will decrease. Similarly, as quality increases the project will take more time and cost more. If quality is measured in terms of grades, students usually realize that their grades may suffer if they take too many credits which is similar to how a contractor's quality may suffer when they have too many things occurring at the same time. Also, if there is a delay in graduation because of a need to retake a critical class, there is an additional expense caused by the need to retake the class which is similar to a contractor's additional expense related to faulty work that needs to be redone.

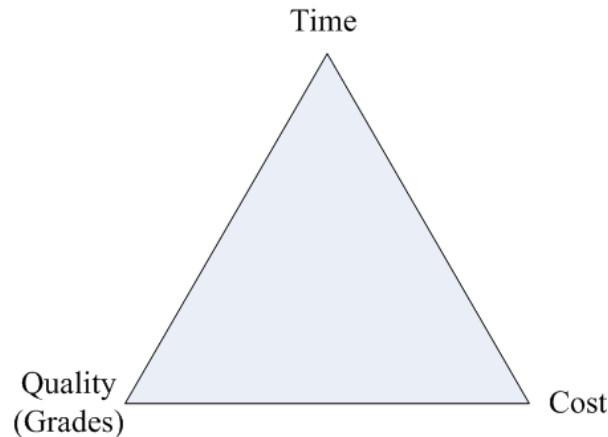


Figure 5 Time, Cost, Quality Triangle

Implementation

Many of the above examples can be utilized in the general discussion of planning and scheduling. They require no major changes in the lecture that an instructor is already using. They can be used as additional examples or to conceptually explain the material.

To further use class schedules as a means to explain planning and scheduling they can become the basis for an exercise using computer scheduling. In many instances students become frustrated with construction terminology and the identification of logic of the schedule. Using the student's class schedule can help to alleviate these problems and focus the energy on learning the software. This also helps if in the class there are students from other disciplines that are unfamiliar with construction. It should be noted that students studying Civil Engineering and who plan to specialize in construction will later take classes that help with the terminology and logic necessary to accurately build construction schedules. Additionally, they will develop and use construction schedules in later classes.

Figure 6 shows the Civil Engineering class schedule of Figure 2 and Table 1 created in MS Project[®]. Only the first two years are shown in detail. The last two years are shown as summary tasks. The critical path is not shown.

The third author incorporated student class schedules in a Computer Applications Class for second year students at the United States Air Force Academy where students other than Civil Engineering students were in the class. The students have already been introduced to basic critical path calculations in another class. In previous years, a construction project had been the basis of the work that the students did using computer scheduling software. The problems that occurred were that student's were unfamiliar with construction terminology and logic. In order to alleviate some of this and to be able to teach the software, each student used their class schedule. Since there are only six lessons available for this topic it is only an introduction to computer based scheduling and only the basics were covered. The use of student schedules as a basis for teaching computerized scheduling was found to reduce the questions about terminology/logic and freed up time to ask questions about the software.

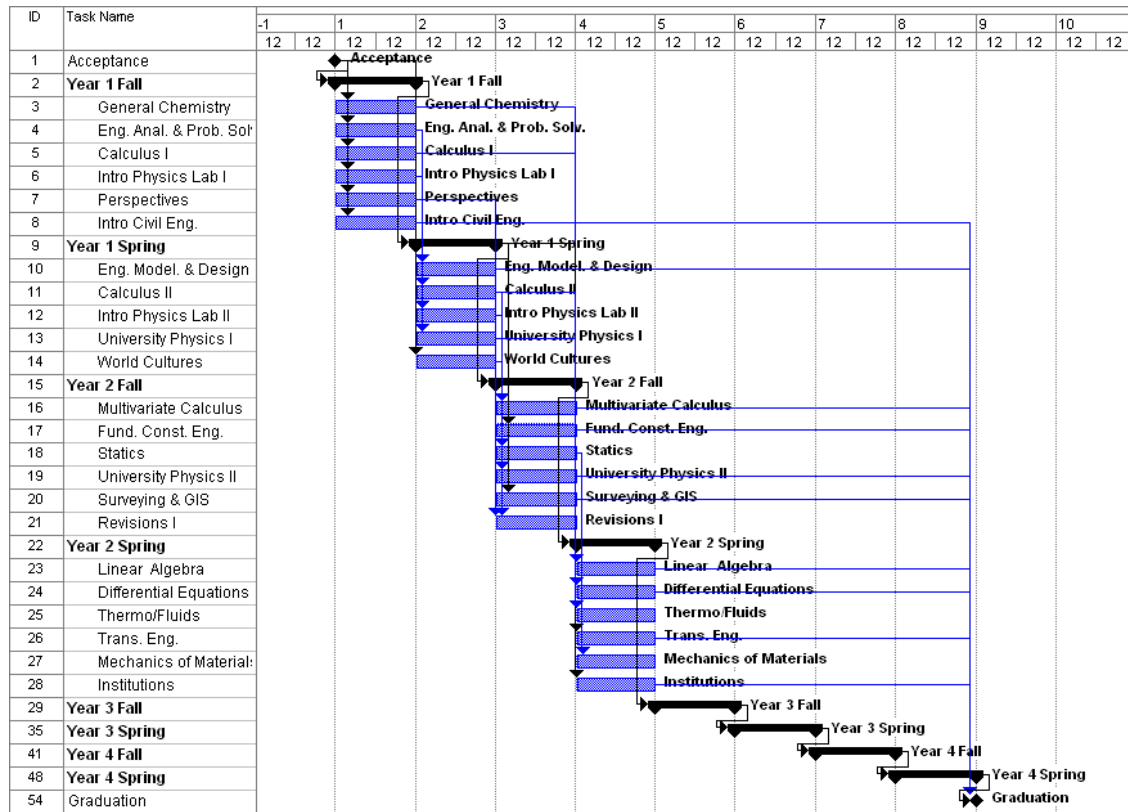


Figure 6 Civil Engineering Schedule Created in MS Project®

Summary

Many students struggle with planning and scheduling because of their lack of knowledge about construction planning and scheduling. This varies depending on the type of curriculum and when the topic of planning and scheduling is covered. The methods presented in this paper can help instructors improve student understanding of planning and scheduling. They can be used as examples that students understand and may have experienced. The first author has successfully used the above methods to assist in explaining the topics of network logic, critical activities, resources, float, progress curves and WBS. This was in an introductory construction course in Civil Engineering at Michigan Tech where planning and scheduling is five weeks out of fourteen. The first and second authors used student schedules to develop a WBS during an in class activity and used that WBS to review computerized scheduling. The third author's use of student's schedules to teach scheduling software helped to focus the attention on learning the software in a computer applications course for students from different disciplines. While the methods presented in this paper are useful in helping students conceptually understand planning and scheduling they are not a substitute for having students plan and schedule construction projects in their classes.

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