

# **Progress at NTUA: Training Engineers in Project Scheduling**

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## **Abstract**

The teaching of quantitative approaches to project management, especially the Critical Path Method and Program Evaluation and Review Technique has been included in construction management curriculums for many years. However, not many clearly educational tools to support this process exist. This paper presents the design and development of an educational software, baptised Progress@NTUA, that is used for supporting the teaching of CPM and PERT. Progress@NTUA educational aid is mostly applicable as a self-learning tutorial for students or as a support element in distance learning and blended courses. Its design is based on sound guidelines for educational software and interface usability. Progress@NTUA uses common time scheduling problems in order to offer a structured reinforcement of previously learned concepts. Taking into account the probable lack of necessary experience or theoretical background, the user is guided to the desired outcome by an interactive educational process. The needed theoretical concepts about the methods are being taught through the constructivism approach and are presented through a trial and error process that is followed by the learner. Progress@NTUA is interacting with the student through questions and answers and gives appropriate feedback.

## **Keywords**

Project Management, CPM, PERT, Educational Software

## **1. Introduction**

Project scheduling is one of the basic project management knowledge areas and includes the processes required to achieve the timely completion of a project (PMI, 2013). The use of project scheduling methods not only assists in reducing the deviation among the desired and the actual time of a project's completion, but also enables the project manager to monitor the progress of the project. Subsequently a project manager should be proficient in the use of the basic project scheduling methods. The two basic project management methods are the Critical Path Method (CPM), which is a method used to estimate the minimum project duration and determine the flexibility of the schedule (Kelley and Walker, 1959, Kelley, 1963), and the Program Evaluation and Review Technique (PERT), which is a technique based on CPM, with the addition that it utilizes a three point estimate to define an approximate range for the duration of each activity (Fazar, 1959, Malcolm et al., 1959). Although PERT is no more used in practice, it is included in most of the current academic curricula. This is because PERT introduces students to the inclusion of uncertainty in estimations and thus, it is a very good first step towards the applicable in practice Monte Carlo Simulation.

In order for the relevant competencies to be achieved, the education of a future project manager should incorporate a deep understanding of these methods. While, currently, the educational process is assisted by the use of computers, there are few educational software packages dedicated to project management techniques. Usually, Academic curricula include computer practicals using state of the art scheduling software. Although this is highly desirable, these commercial software do not have a mechanism to aid understanding of the theoretical concepts that support each method.

The main objective of this research is to provide an educational software aid that enables students to deeply understand the theoretical aspects by focusing on the operations research part of CPM and PERT.

The rest of this paper is organised as follows. Section 2 presents briefly the current research on project scheduling computer aided education along the basic principles for educational software design. Section 3 presents the design philosophy of the proposed tool and the programming tools used. Section 4 gives an overview of the tool from the tutor's and the student's end. Section 5 presents the outcome of the initial evaluation of the tool from undergraduate students and Section 6 draws the conclusions and limitations of the paper and proposes further research.

## **2. Current research and principles**

### **2.1 Research on project management educational software**

The inadequacy of the commercial project management software to assist in the educational process has motivated researchers to a series of efforts in order to develop educational software appropriate for project scheduling training.

Deblaere et al. (2011) presented a complete aid for project management, namely RESCON. RESCON presents a set of project scheduling procedures through several types of visualization. The tool aims to provide adequate training on the Resource Constrained Project Scheduling Problem and utilizes the user's interaction with the parameters of the problem aiming at the understanding of the basic theoretical principles.

Salas-Morera et al. (2013) developed an educational tool that focuses on software project management, named PpcProject. To this goal, PpcProject illustrates the most common methods of project scheduling by using the most common types of diagrams. Beside Gantt charts, PERT and CPM this software emphasises on resource allocation and levelling with both renewable and non-renewable resources.

Cohen et al. (2014) offered an aid with slightly different point of view on the educational process. By integrating the concepts of project and product, a simulation-based educational tool was produced. Project Management Trainer (PMT) is a simulation software tool that attempts to guide the user through the execution phases of the simulated project.

Gregoriou et al. (2013) created an educational software called PROMES attempting to supplement training on basic methods of project management. The methods that this software tool addresses include CPM, PERT and Responsibility Assignment Matrix (RACI) in an attempt to teach the basics of project management.

Given the fact that RESCON, PpcProject, PMT, PROMES and Progress@NTUA overlap regarding the methods that each one covers, the principal difference is the target group of each software aid. The case for all other, to the author's knowledge, project management educational software tools, is that they require for the trainee to already have at least a basic knowledge of project management principles as well as a level of experience. Progress@NTUA focuses on teaching the fundamentals of project scheduling so that the trainee would be able to use it independently or in a class regardless of the level of prior knowledge

### **2.2 Towards a good educational software**

In order to guarantee that an educational software aid is user friendly, it is pivotal to implement basic usability guidelines, during the phase of the user interface design. The usability principles should be

applied to educational software, with respect to the specific needs of the educational process and the specific knowledge area that it covers (Niederhauser and Stoddart, 2001, Maddux et al., 2001).

Nielsen (1994) proposed that the software should at all times notify the user on the current system status by providing feedback within reasonable time and confirm the user's choice before it is applied, when it comes to critical matters. The user should not be brought upon dead-end situations, and at all times should be able to return to a previous state if desired. However, the user should not be obligated to retrace previous states, and with this aim the software interface should at all times provide all the useful information. Accordingly, the available options should be clearly defined, and leave no doubt on what purpose they serve and the notation and lingual descriptions should be adjusted to those commonly accepted in project management. In the case that, despite all the precautions, a software error occurs, it should be accompanied by an appropriate explanatory error message, providing the user with information on how to proceed (Squires and Preece, 1999, Squires and Preece, 1996).

### **3. Design principles and programming tools**

#### **3.1 Design philosophy**

At the beginning of the design stage, a handful of critical decisions were to be made in order for Progress@NTUA to be constructed in a way that would actually be beneficial for the educational process. The main principle, on which Progress@NTUA was designed, is that proper training would be achieved by solving a set of problems. This structure allows it to be flexible to suit the goals that each tutor sets for a specific class, by giving the tutor the option to create a set of problems according to the needs of the trainees. Meanwhile the preloaded set was chosen to cover all the elementary aspects of CPM and PERT, to provide the student with educational independence.

The interactive process of solving a problem was structured in a manner that the trainee is discreetly guided to the correct solution and simultaneously the basic theoretical background is provided. By this, the trainee is being challenged to produce the correct solution and in order to achieve that the user is prompted to exploit the provided theoretical information. When the process is concluded the trainee receives feedback on the final solution and in the case of mistakes they are pointed out to the right track and in parallel they are reminded the theoretical aspects on which more attention should be paid. Furthermore the trainee is encouraged to explore different projects (problems) and even change their variables in order to observe the behaviour of the project and the reaction of a schedule to the change of the initial parameters.

With the aim of enabling the user to focus on the aspects of project scheduling, Progress@NTUA incorporates a calculator module that assists the user to perform all the necessary calculations without obligating him to interrupt the use of Progress@NTUA.

#### **3.2 Programming tools**

Progress@NTUA was developed using C# programming language. C# was suitable for the purpose of this software being an object-oriented general purpose programming language. Furthermore, it suited the need of developing independent software components which were merged during the latter stages of the development. Low memory and processing power requirements were additional factors that contributed to the choice of C# (Hejlsberg et al., 2003).

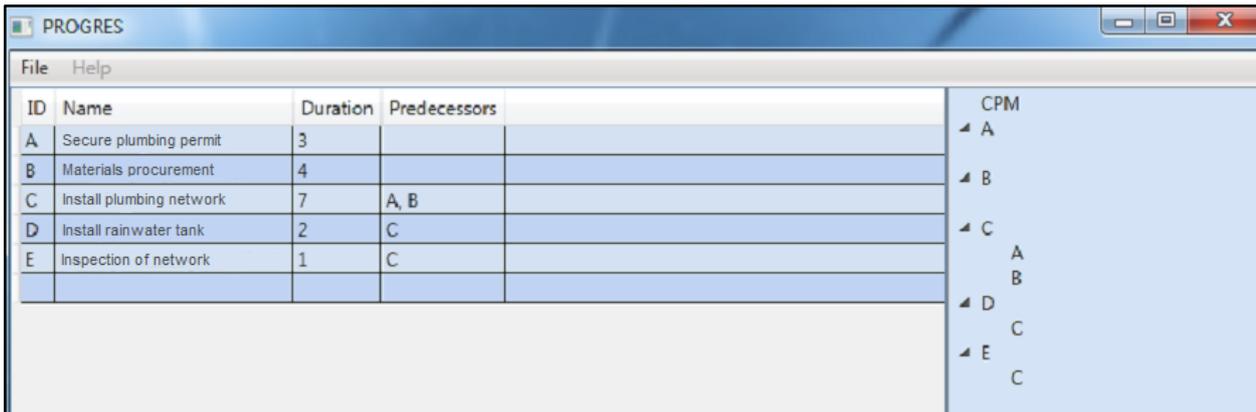
For the structure of the files that Progress@NTUA uses, Extensible Markup Language (XML) was used. XML offers a simple textual data format that is highly customizable to suit the needs of a specific project (Bray et al., 1998). Based on that attribute, it was possible to design and implement a file format that was tailored to the needs of Progress@NTUA in order to store, edit and transfer the required data.

## 4. Progress@NTUA

### 4.1 Progress@NTUA from the tutor's end

To better suit the requirements of the educational process, Progress@NTUA provides to the tutor the ability of creating and modifying the initial set of problems.

At the beginning of this process, the tutor is prompted to decide between creating a new problem, which leads to the creation of a new file, and editing an existing problem, in which case an existing file is loaded. In both cases the tutor is presented with the data entry component of the interface (Figure 1). Data entry consists of a data grid, in which the tutor inserts the parameters of the problem, while a tree view element assists the overview of activities relationships within the project.



The screenshot shows a window titled "PROGRES" with a menu bar containing "File" and "Help". The main area is divided into two parts. On the left is a data grid with the following content:

ID	Name	Duration	Predecessors
A	Secure plumbing permit	3	
B	Materials procurement	4	
C	Install plumbing network	7	A, B
D	Install rainwater tank	2	C
E	Inspection of network	1	C

On the right is a tree view labeled "CPM" showing a hierarchical structure of activities:

- CPM
  - A
    - B
      - C
        - D
          - E
            - C

Figure 1: A complete CPM problem as inserted by the tutor

For each activity, the tutor is asked to provide the activity's name, duration and predecessors, while a discrete identity is assigned to each activity by the software. In the case of a PERT problem, Progress@NTUA requests three estimations for the duration of each activity (optimistic, pessimistic and most likely) and provides the tutor with the option of extending the problem by requesting answers regarding the probabilistic distribution of the project's duration value. At any point the user is able to save or discard the changes that are made to a problem.

When this process is concluded, the tutor is able to preview the solution of the problem (Figure 2). Progress@NTUA performs all the necessary calculations and presents a network diagram and the critical path along with the answers of the requested questions.

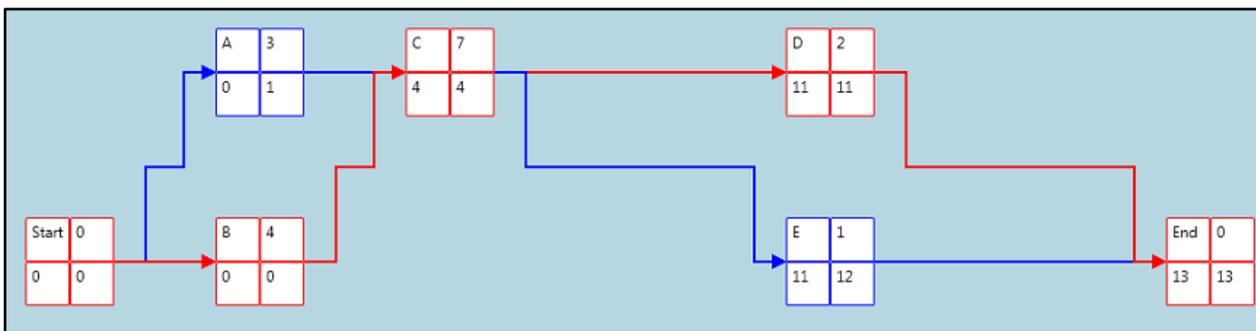


Figure 2: The preview of a CPM problem solution

## 4.2 Progress@NTUA from the student's end

When it comes to practicing, a student is able to choose on whether a CPM or a PERT problem should be initiated. Additionally, Progress@NTUA provides the option of resuming the solution of a previously saved attempt.

When the decision is made the corresponding project (problem) file is loaded and the project's parameters are presented on a data grid. The user is provided with a canvas on which the process of solution takes place. The user is able to insert nodes and arrows in order to create the network diagram. Each node needs to be filled in with the early and late start times of the corresponding activity, as well as the activity's ID and duration.

At any point that the student considers suitable, the solution can be submitted for correction. Progress@NTUA performs the necessary calculations and checks whether the solution that was provided by the user is in accordance with the correct one. If this is the case, a congratulatory message emerges, and the user is able to proceed with the next problem. If the solution is incomplete or incorrect, Progress@NTUA prompts the student to revisit the part of the solution that wasn't accepted. The students are not directly offered the right solution but instead they are urged to try again based on the relevant prompts. The erroneous answers are pointed out and explanatory details are given on the nature of the student's errors (Figure 3). These details assist the student to understand the theoretical background and make an improved attempt to solve the problem. In case that the student cannot find the solution, they always have the opportunity to ask the tutor for the correct one.

Throughout the process, the user is assisted by a calculator component that is designed to perform the mathematical calculations that are necessary to solve a CPM or a PERT problem. The user is at all times able to undo or discard the changes that have been made to the solution or save an incomplete solution in order to resume the solution process at a later time.

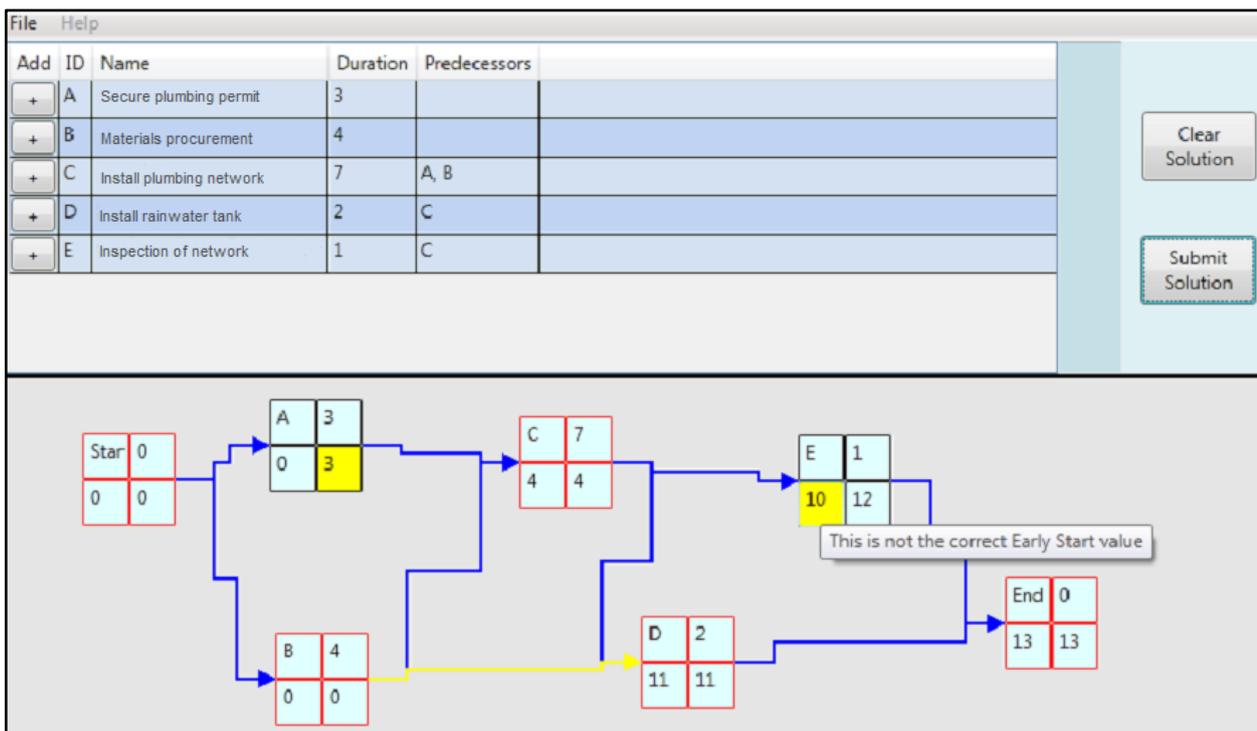


Figure 3: The wrong solution of a CPM problem and the corrections

## 5. Initial tool evaluation from students

During the final stage of the software development, an evaluation of Progress@NTUA by project management undergraduate students took place. A total of 40 students were asked to use Progress@NTUA and then answer a short questionnaire. Initially, they were asked to fully solve one CPM and one PERT problem using the software and without guidance by a supervisor.

**Table 1: Students' evaluation of Progress@NTUA**

	Very Good	Good	Neutral	Bad	Very Bad
Guiding Messages	22.95%	27.87%	39.34%	9.84%	-
CPM Component	13.11%	62.30%	4.92%	14.75%	4.92%
PERT Component	27.86%	57.36%	9.84%	-	4.92%
Problem Presentation	4.92%	80.32%	9.84%	4.92%	-
User Interface	9.84%	62.30%	22.94%	-	4.92%

After the completion of the problems they were prompted to evaluate Progress@NTUA. The basic part of the questionnaire focused on the evaluation of the software, the overall ease of use and stability (Table 1). Students evaluated Progress@NTUA in comparison to Microsoft Project, which they were taught throughout the semester. Their comments included that Microsoft Project is not designed to assist the educational process and does not offer guidance on how to schedule a project. On the contrary they proved to be favourable to the educative aspects of Progress@NTUA as they were able to use it and complete the schedules without the need for additional guidance

## 6. Conclusions, limitations and further research

Progress@NTUA is a useful aid in project management training designed to assist the education of students on project management before they encounter real life project management issues. By being able to adapt to each tutor's needs it provides significant assistance for achieving the educational goals that have been set in any class. Designed to be used either in a classroom environment or as a standalone tool by a single independent trainee, Progress@NTUA provides sufficient guidance for the user to gain experience in project scheduling and understand the underlying theoretical concepts of relevant methods.

It is however necessary to further evaluate the effectiveness of Progress@NTUA. To that aim it would be essential to experiment more on the use of the software in educational environments. Obtaining information by this process could lead to the improvement of several aspects, such as the user interface and the enhancement of the educational modules of Progress@NTUA. Furthermore, long term use would provide results on whether it is in fact a useful aid to the educational process, thus achieving the aim on which Progress@NTUA was developed.

Another important issue that the authors would like to explore is the actual effectiveness of the tool on the educational process. An experiment is going to be designed in order to reveal whether the software achieves better results than the typical lecturing process in terms of methods' understanding, skills developed and students' experience.

Regarding the upcoming development of Progress@NTUA the aim is to expand the software by incorporating additional algorithms that are useful in several aspects of project management. The component structure of the software is designed in a way that allows more components to connect to the existing and thus include more project management methods and techniques to the features of Progress@NTUA.

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