PpcProject: An educational tool for software project management

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Abstract

The University degrees about engineering in general, and software engineering in particular, contain subjects related with Project Management. In this subject, the most commonly used software for practical classes and homework is MS-Project. Nevertheless, the students find that MS-Project is not easy to use and that it requires a high knowledge about Project Management and about the use of the software package. To fill this gap, a new educational software tool, called PpcProject, has been developed and introduced in Software Project Management classes in front of MS-Project. When assessed in practical classes, it was shown to be more useful for educational purposes than Microsoft Project both, in terms of usability and of students performance.

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1. Introduction

A project is a temporary endeavor organized to obtain a product, service or result. In this sense, a project could be the construction of a building or a machine, the development of a software application, or the implementation of a business as well as any other effort undertaken to obtain a benefit that could be entrepreneurial or social (PMBOK) (PMI, 2008). The temporary character of projects implies the existence of a definite beginning and an end and the consumption of a certain amount of resources available for the project. Thus, the implementation of projects involves an organization tasked with achieving the project objectives. In this way, the term Project Management can be defined as the process of directing the achievement of the project objectives (Munns & Bjeirmi, 1996) and includes such components as defining the requirements, allocating the required resources, planning the execution of the work, monitoring the progress of the work and adjusting for deviations from the plan.

It is widely accepted that Project Management is an area of knowledge essential to any field of engineering (e.g., electrical, mechanical, civil or software engineering, among others) and that Project Management must be taken into consideration in the design of undergraduate engineering curricula. Accordingly, Accreditation Board for Engineering and Technology (ABET, 2011) recognizes a separate program in the field of Engineering Management whose main points of focus are the engineering relationships between the management tasks (i.e. planning, organization, leadership, and control) and understanding and dealing with the stochastic nature of the management systems. Furthermore, management skills are taken into account in many of the engineering programs proposed for accreditation, including but not limited to architectural, civil or software engineering.

Although software engineering programs are included in the general engineering accreditation boards, as mentioned above, specific differences exist between software engineering and other so-called traditional engineering professions that require a separate treatment (Duggins, 2007). Thus, the Association for Computing Machinery and the Institute of Electrical and Electronics Engineers (SE2004) (ACM/IEEE, 2004) have established the main differences between software engineering and traditional engineering as the following: the foundation of software engineering is located primarily in computer science rather than natural science, the focus is on discrete rather than continuous mathematics; the concentration is on abstract/logical entities instead of concrete/physical artifacts; the absence of a
manufacturing phase; and the maintenance of software primarily refers to continued development or evolution and not to conventional wear and tear.

Despite these differences, both SE2004 and SWEBOK (IEEE, 2004) have considered Project Management as core knowledge in the field of software engineering that is divided into such sections as project planning, resource allocation and project control, among others.

Modern university curricula in software engineering include not only knowledge-based training but also the acquisition of practical skills or the ability to apply the knowledge to practical situations and problem-solving using initiative, autonomy and creativity (Merrill & Collofello, 1997; Ministerio de Educación, 2009). Thus, engineering education in general and software engineering in particular is becoming increasingly complex and requires an integrated approach to teaching theory, practice and non-technical skills (González-Morales, Moreno de Antonio, & Roda-García, 2011; Jazayery, 2004). Therefore, practical classes that include project planning/control and resource allocation are widely used to analyze real situations in the context of project management (Caulfield, Veal, & Maj, 2011; Ku, Fulcher, & Xiang, 2011).

In accordance with the above mentioned, most of the university courses about Software Project Management contain topics about Project Management body of knowledge, planning, scheduling and control (Ivanovic, Putnik, Budimac, & Bothe, 2012), and the most widely used software for practical classes and homework assignments is Microsoft-Project. For example, the courses “Principles of Software Project Management”, of Columbia University (Musser, 2002); “Software Project Management”, of University of Texas (Thouin, 2012); and “Information Systems Project Management”, of North Carolina University (Amoako-Gyampah, 2003), among others, use MS-Project for Project Management teaching. Nevertheless, students find that MS-Project is not easy to use and that it requires a high knowledge about Project Management and about the use of the software package (Tatnall & Reyes, 2005). Thus, there is a gap in the field of educational tools for Project Management teaching.

Educational approaches in this area should include the Critical Path Method (CPM) (Kelley & Walker, 1959), the Program Evaluation and Review Technique (PERT) (Fazar, 1959; Malcolm et al., 1959), the Monte Carlo Analysis (Van Slyke, 1963) and the Resource Constrained Project Scheduling Problem (RCPS) (Brucker, Drexl, Mühling, Pesch, & Neumann, 1999).

Therefore, the software tools for learning project management should demonstrate the following features with respect to the CPM method:

- Creating the project network by entering tasks and their precedence relations, entering the estimated completion time of every task (fixed time in the CPM method) and drawing of the project graph and the GANTT chart;
- Determining the estimated completion time of the project;
- Measuring the critical path and the floats (also called slack) of each task (Spinner, 1992) (total float, free float and independent float).

With respect to the PERT method, these features include:

- Introducing the optimistic, most likely and pessimistic completion times for each task and optionally selecting the distribution function of the task durations (beta, triangular, uniform, etc.);
- Determining the distribution function of the project duration;
- Calculating the probability that the project will be completed within a given time frame.

Finally, with respect to resource management, the tools should cover:

- Assigning of resources to the tasks (the resources may be renewable or non-renewable);
- Resolving the constraints of resource assignment;
- Addressing the problem of resource leveling.

Unfortunately, although a number of free and proprietary software tools address these types of problems, none of them are able to fully meet the entire set of requirements required by the engineering program for the variety of subjects related to project management.

The rest of this paper is organized as follows. First, the main proprietary and free software tools available for project management are summarized. Next, a new free educational software tool known as PpcProject is presented, followed by demonstrated use of PpcProject integrated into the global teaching strategy for topics related to Software Project Management (within the Software Engineering degree) and comparison with Microsoft-Project in terms of usability and the students performance. Finally, the conclusions and future work are presented.

2. Software for project management

2.1. Microsoft Project, OpenProj and similar tools

Microsoft Project is a successful proprietary software tool for project management designed to assist project managers in developing a plan, assigning resources to tasks, tracking progress, managing a budget, and analyzing workloads. In this sense, it is a useful program for project management in general because it includes a wide range of such utilities as calendar management, resources cost assignments and monitoring and control of the execution of project tasks.

Nevertheless, its utility as an educational tool for Project Management is limited. First, there is no strict analysis of the probabilistic duration of tasks according to the PERT method, although introducing optimistic, pessimistic and most likely durations of tasks is allowed. Nevertheless these three durations are only used for calculating the average estimated duration of every task, and not for stochastic analysis. Therefore, it is not possible to calculate the probability of finishing the project on a given date. Furthermore, Microsoft Project uses the Activities on Nodes (AON) graph and only considers total and free floats and not independent float. With respect to resources management, Microsoft Project only uses renewable resources, and its resource assignment algorithm is ranked by Kolisch (1999) as the third out of five groups by order of efficiency.
OpenProj is a project management open source software that is able to open native Microsoft Project files and contains similar capabilities. This program runs on the Java platform and is therefore able to run on any operating system. However, the Projity company that originally developed OpenProj was acquired by Serena Software in 2008, and the development of OpenProj was subsequently suspended. Other similar free tools include GanttProject, Planner and LibrePlan.

Table 1 presents a comparative list of software tools analyzed with respect to the desired features identified for educational purposes.

### 2.2. Primavera P6 project management

Primavera P6 (Schumacher & Jackson, 2010) is a professional software package for multi-project planning and control that can be used alone or in combination with other tools. Primavera is designed specifically for organizations that must simultaneously manage multiple projects and supports multi-user access and an unlimited number of projects. This software uses the CPM technique for project scheduling and resource leveling.

As shown in Table 1, the accomplishment of Primavera P6 is similar to that of Microsoft Project, although its large number of options makes it more complicated to use as an educational tool than Microsoft Project. With respect to resource allocation, Trautmann and Baumann (2009) proved that the solutions found by Primavera were superior to those of Microsoft Project with the necessity of investigating a large variety of priority rules.

### 2.3. RESCON

RESCON (Deblaere, Demeulemeester, & Herroelen, 2011) is a free educational software tool for project scheduling that mainly focuses on the RCPSP problem. This tool incorporates several classical algorithms for resource allocation, including simple list scheduling, tabu search and branch-and-bound, and it is capable of receiving other user-defined algorithms. The results of the project scheduling analysis are shown in the corresponding GANTT and resources diagrams. RESCON also takes into account project scheduling with stochastic activity durations and accepts project files from PSPLIB (Kolisch & Sprecher, 1996).

However, RESCON has certain limitations: only AON graphs are used and not Activities on Arrows (AOA), only renewable resources are allowed and it uses only total floats. Nevertheless, students appreciated the user-friendly features of the software (Deblaere, Demeulemeester, & Herroelen, 2011), e.g., ease of entering of the problem data, the graphical representation of the activity network, the ease of analyzing various situations, and the immediate visualization of the impact of changes in the project structure, activity durations and precedence relations.

### 2.4. ProMES

ProMES (Gregoriou, Kiriropoulos, & Kiriklidis, 2010) is a free software tool designed for academic purposes in the field of project management that takes an educational approach to the CPM, PERT and RACI (Singh Toor, 2009) methods. The CPM module allows the trainees to construct the project network by introducing the precedence relations and the activity durations and calculating the critical path and the activity total floats. For its part, the PERT module allows the users to do the same but with the addition of activities of aleatory duration using the three activity duration estimates (optimistic, most likely and pessimistic) as well as calculation of the probability that the project can be completed by a given date. The RACI matrix module permits the users to assign responsibility, accountability, and consultancy, as well as designate the representative who must be informed for each project activity. Nevertheless, a module for project resource allocation is not available.

### Table 1

Comparison of software tools analyzed.

<table>
<thead>
<tr>
<th>Feature</th>
<th>MS Project</th>
<th>OpenProj</th>
<th>Primavera P6</th>
<th>RESCON</th>
<th>ProMES</th>
<th>Ppcproject</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GENERAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entering tasks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entering precedences</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Entering tasks duration (fixed time)</td>
<td></td>
<td></td>
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<tr>
<td>PSPLIB import</td>
<td></td>
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<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Gantt chart</td>
<td></td>
<td></td>
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<td>✔</td>
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<tr>
<td>Graph AOA</td>
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<tr>
<td>Graph AON</td>
<td></td>
<td></td>
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<td></td>
<td>✔</td>
</tr>
<tr>
<td>Project duration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Critical path</td>
<td></td>
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<td></td>
<td>✔</td>
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<tr>
<td>CPM</td>
<td></td>
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<td></td>
<td>✔</td>
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<tr>
<td>Total float</td>
<td></td>
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<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Free float</td>
<td>❌</td>
<td>❌</td>
<td>✔</td>
<td>❌</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Independent float</td>
<td></td>
<td></td>
<td></td>
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<td>✔</td>
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<tr>
<td>PERT</td>
<td></td>
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<td>✔</td>
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<tr>
<td>Distribution functions of tasks duration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Optimistic, most probable and pessimistic time</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>✔</td>
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<tr>
<td>Distribution function of project duration</td>
<td></td>
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<td>✔</td>
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<tr>
<td>Probabilities</td>
<td></td>
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<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td><strong>RESOURCES</strong></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Renewable resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Non-renewable resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Resources assignment</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Resources leveling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
</tr>
</tbody>
</table>
When used by the students, ProMES was shown to be a user-friendly tool, particularly in its user interface and help function. In contrast, the students noted the lack of Gantt charts and Monte Carlo simulation capabilities.

3. PpcProject

PpcProject is a multiplatform software tool for education and research in project management and it is licensed as free software under a GNU General Public License v3.1. The main objective of PpcProject is to place an educational software tool, that can be used entirely for teaching and learning the concepts of project management, at the disposal of lecturers and students by meeting the following requirements:

a) Ease of use;
b) Integration into the teaching strategy without creating any distortion;
c) Ability to meet at least the same requirements as other commercial and free software distributions and to be at least comparable in use by students.

Thus, PpcProject meet the basic requirements of formulating and solving problems in project scheduling and providing solutions through a graphical interface that is easy to use and interpret.

3.1. Critical Path Method module

The CPM (Shaffer, Ritter, & Meyer, 1965) is a project modeling technique, developed in the 1950s by Morgan R. Walker of DuPont and James E. Kelley, Jr. of Remington Rand, with the objective of streamlining the management of industrial facilities maintenance. The CPM is used with a wide range of projects types, including construction, software development, research projects and maintenance. To successfully apply the method requires knowledge of the Work Breakdown Structure (WBS) (PMI, 2006), the duration of each activity and the precedence relationships among them. These data can be completely entered by the user through the interface, or alternatively, can be imported from a standard PSPLIB file. The CPM approach allows the user to identify the critical activities that compound the critical path, which is the longest path within the project and determines its expected duration. Obviously, the critical activities are those that must not incur any delay in their execution because such a delay would cause the delay of the entire project. Therefore, it can be said that these activities have no total float. Other data to be calculated are the free float (the amount of time that an activity can be delayed without delaying the early start date of any immediate successor activity within the network path) and the independent float (the amount of delay that can be assigned to any activity without delaying subsequent activities or restricting the scheduling of preceding activities). Moreover, the project calendar is usually represented in a GANTT chart, and the precedence relations between the activities are represented by means of AON or AOA graphs.

Therefore, the CPM module of PpcProject allows the students to: a) enter the list of activities, activity durations and precedences; b) obtain the total, free and independent floats of each activity; and c) obtain the critical activities, the critical path(s) and the graphical representation of the project scheduling (GANTT Chart) and of relationships between the activities (project network). The use of this module is intended for students to deepen their understanding of the concepts of decomposition of project tasks, to analyze the precedence relationships among tasks and to learn how to identify the tasks that cannot be delayed to achieve the expected completion date of the project as well as to draw and to correctly interpret the project graph.

Fig. 1 shows the main screen of PpcProject. The figure shows an example of the data introduction interface and the GANTT chart with the project scheduling. The project completion time and the activities floats are calculated by means of the Zaderenko (1968) algorithm.

3.2. PERT module

PERT is a method for analyzing the completion time of a project and is specifically designed for those cases in which the durations of the activities are uncertain. This program was developed for the U.S. Navy Special Projects Office in 1957, practically at the same time as the CPM method, but with the difference that the PERT method allows the calculation of not only the total completion time of the project but also the probability of finishing the project by a given date. The method assumes the beta distribution for the activity durations, but other distribution functions (e.g., triangular or uniform) are widely used as well.

Thus, the PERT module of PpcProject should allow the introduction of the same data for the activities as that of the CPM in addition to the parameters required for the stochastic analysis of the activity durations. More specifically, the optimistic (\(t_o\)), the pessimistic (\(t_p\)) and the most likely duration (\(t_m\)) are defined as the estimated activity duration based on the best possible scenario, the worst possible scenario and the estimate of the time required to accomplish a task (assuming everything proceeds as normal), respectively. In this way, the expected duration of every activity of the project is calculated as the weighted average (1):

\[
t_E = \frac{t_o + 4t_m + t_p}{6}
\]

Equation (1) represents the average expected duration of the activities in the case of a Beta density function. In other cases, such as those that apply the triangular or uniform density function, the appropriate substitution must be made.

After the activity durations have been introduced and the density function has been chosen by the user, it is possible to calculate the expected completion time of the project and the probability of finishing the project by a given date.

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1 PpcProject can be downloaded, along with its manuals from [http://code.google.com/p/ppcproject/](http://code.google.com/p/ppcproject/)
The interface shows the standard deviation and the mean of the distribution function of the project duration and also allows calculations of the probability that the project ends within a certain period of time, before a given date and after a given date. Similarly, it is also possible to determine the duration of the project with a given probability of being fulfilled. In addition, the interface maintains the history of all calculations.

In the same way, the PERT module allows statistical simulations of the activity durations and obtains the estimated project completion date for comparison with the theoretical durations predicted by PERT.

Using this module, students are expected to be able to calculate the project completion date in a probabilistic context and analyze the paths and critical activities during the project implementation.

3.3. Resource-allocation module

Resource allocation consists of assigning resources (e.g., human resources, equipment or materials) such that the tasks can be correctly carried out. Resource allocation is fundamental to project management, and conduction of an efficient allocation of resources permits optimal use of time and money and ensures compliance with the deadlines promised to the customer.

PpcProject includes four types of resources:

- Renewable: A limited number of resources are available for each unit of time in the project implementation (e.g., machines or workers).
- Non-renewable: A total amount of resource units is available for the entire project. These resources can be distributed among the required periods (e.g., building materials or money).
- Double-constrained: These resources combine the features of the previous two categories; that is, they are limited by a total amount of resource units for the entire project as well as for each period.
- Unlimited: The amount of resource units available for the project is unlimited.

Thus, through the resource allocation module of PpcProject, the user is able to add or edit the resources and assign the number of units available for the entire project or for each one of the units of time as well as introduce the number of units of each resource required for the execution of the activities.

The problem of resource allocation can be solved from two points of view:

- Resource leveling: The objective is to limit the variation in resource usage from period to period. (Fig. 2).
- Resource allocation: The objective is to schedule the activities and the required resources such that the predetermined constraints of resource availability and project time are not exceeded.

By using this module, the students should to be able to understand the influence of resource limitations on the project scheduling and propose alternative scheduling to improve the use of resources.

4. Use of PpcProject as a teaching tool compared with Microsoft Project

The subject Projects addresses the topics of software project management, particularly (and according to the definitions given by PMBOK, SE2004, and SWEBOK) those of evaluation and planning, WBS, task scheduling, effort estimation and resource allocation, among others. The global teaching strategy used in this subject includes combinations of lectures, on-line quizzes, practical classes and group tutorials (Salas-Morera, Cubero-Atienza, Redel-Macías, Arauzo-Azofra, García-Hernández, 2012). Traditionally, the practical classes consist of a series of software project management problems with increasing difficulty that must be solved using Microsoft Project. These problems analyze the
activity durations and precedence relationships of a given WBS to obtain a project implementation schedule that includes resource allocations. The practical classes are organized in working sessions of two hours in PC classrooms with two groups of up to 27 students. The lecturer presents the problem to be solved by the students, and in the rest of the session, the students work on the problem individually with the help of the lecturer. Finally, the students must deliver a report with the solutions obtained. The content of the practical classes consists of two types of project management problems. In order of difficulty: 1) entering durations and precedences of the activities, resource allocation, identification of critical path and activities floats, and obtaining the project scheduling; 2) all the previous steps plus correct the initial planning depending on the degree of progress of project implementation and resource re-allocation. In the last year, PpcProject also has been included as a specific software tool for practical classes in addition to Microsoft Project. To do this, each one of the student groups solved the same practice problem, but one of them used PpcProject while the others used Microsoft Project. In the next practical class, the group that had previously used PpcProject then used Microsoft Project and vice versa. By using this strategy, all of the students resolved the problems using both tools, which was helpful for testing the use of PpcProject versus Microsoft Project in terms of usability and in terms of student performance to develop, correct and evaluate project plans. Finally, the students completed a survey that asked for a comparative assessment of their use of PpcProject versus Microsoft Project.

In the students’ comparative assessment, the mean evaluation was more favorable for PpcProject than for Microsoft Project for all of the concepts assessed except for Assigning resources to the activities. To determine the statistical significance of the rank differences observed for each answer associated to each question over the two different softwares used, we have carried out a non-parametric Wilcoxon signed-rank test. Previously, a Kolmogorov–Smirnov’s test at a significance level $\alpha = 0.05$ was used to evaluate if these answers followed a normal distribution. Only 1 of the 24 sets of answers (12 questions for each software used) obtains a $p$-value upper than the significance level (see Table 2).

Table 2 Results of Kolmogorov–Smirnov test.

<table>
<thead>
<tr>
<th></th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th>Q7</th>
<th>Q8</th>
<th>Q9</th>
<th>Q10</th>
<th>Q11</th>
<th>Q12</th>
</tr>
</thead>
<tbody>
<tr>
<td>PpcProject</td>
<td>0.000</td>
<td>0.001</td>
<td>0.001</td>
<td>0.014</td>
<td>0.010</td>
<td>0.015</td>
<td>0.008</td>
<td>0.049</td>
<td>0.054</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Microsoft Project</td>
<td>0.006</td>
<td>0.035</td>
<td>0.046</td>
<td>0.008</td>
<td>0.017</td>
<td>0.031</td>
<td>0.026</td>
<td>0.028</td>
<td>0.007</td>
<td>0.011</td>
<td>0.035</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Fig. 2. Example of project scheduling with the priority of resource leveling.
Table 3
Efficiency assessment of PpcProject versus Microsoft Project. Wilcoxon test results.

<table>
<thead>
<tr>
<th>Assess PpcProject and Microsoft Project from 1 (worst) to 5 (best) for the following concepts</th>
<th>PpcProject</th>
<th>Microsoft Project</th>
<th>Z statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Entering activities</td>
<td>4.42 0.72</td>
<td>4.24 0.71</td>
<td>−1.597</td>
<td>0.110</td>
</tr>
<tr>
<td>2 Entering activities durations</td>
<td>4.31 0.73</td>
<td>4.04 0.77</td>
<td>−2.087</td>
<td>0.037</td>
</tr>
<tr>
<td>3 Entering precedences</td>
<td>4.24 0.83</td>
<td>3.27 1.29</td>
<td>−3.582</td>
<td>0.000</td>
</tr>
<tr>
<td>4 Assigning resources to activities</td>
<td>3.71 0.84</td>
<td>3.87 0.92</td>
<td>−0.905</td>
<td>0.366</td>
</tr>
<tr>
<td>5 Critical path identification</td>
<td>4.09 1.00</td>
<td>3.51 1.08</td>
<td>−2.268</td>
<td>0.023</td>
</tr>
<tr>
<td>6 Paths identification</td>
<td>4.16 0.80</td>
<td>3.49 1.08</td>
<td>−2.949</td>
<td>0.003</td>
</tr>
<tr>
<td>7 Obtainment of early and last times</td>
<td>3.91 0.95</td>
<td>2.98 1.01</td>
<td>−4.086</td>
<td>0.000</td>
</tr>
<tr>
<td>8 Obtainment of activities floats</td>
<td>3.69 0.97</td>
<td>3.04 1.13</td>
<td>−2.441</td>
<td>0.015</td>
</tr>
<tr>
<td>9 Obtainment of dates of milestones achievement</td>
<td>3.47 1.24</td>
<td>3.44 0.97</td>
<td>−0.243</td>
<td>0.808</td>
</tr>
<tr>
<td>10 In general, the use of the application is simple</td>
<td>4.42 0.84</td>
<td>3.58 1.23</td>
<td>−3.808</td>
<td>0.000</td>
</tr>
<tr>
<td>11 Solving the problems of practical classes has been easy</td>
<td>4.58 0.66</td>
<td>3.62 1.25</td>
<td>−3.235</td>
<td>0.001</td>
</tr>
<tr>
<td>12 Understanding the concepts of Project Management has been easy</td>
<td>4.60 0.58</td>
<td>4.24 0.86</td>
<td>−2.859</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Thus a normal distribution cannot be assumed. So, we applied the Wilcoxon’s signed-rank test for all pairs of answers over the 12 questions (Table 3). This test is used when comparing two related samples, matched samples, or repeated measurements on a single sample to assess whether their population mean ranks differ (i.e. it is a paired difference test). As shown in Table 3, the opinion of the students is rated better for Microsoft Project than for PpcProject only in the case of “Assigning resources to activities” even though the difference found was not significant. In contrast, for the rest of the items assessed, PpcProject was rated better than Microsoft Project. In this case, the differences found in “Entering activities” and “Obtainment of dates of milestones achievement” were not significant. It is worth taking note of the assessments assigned by the students to the three last concepts: “In general, the use of the application is simple”; “Solving the problems of practical classes has been easy”; and “Understanding the concepts of Project Management has been easy”. These three concepts attempt to gather the general opinion of students regarding the utility of each one of the analysis tools in applying the concepts of Project Management and mastering the topics defined in the syllabus. In this sense, PpcProject has been shown to be markedly more effective than Microsoft Project, with significant differences in all cases.

In other way, the marks achieved by the students from the two group were compared in order to determine whether the differences found were significant or not (Table 4). The marks obtained for the students when they used PpcProject were superior to the ones obtained by them when used Microsoft Project both, in the initial basic problems and in the more advanced problems. Specifically, the difference observed in the mean marks of the students (in a scale from 0 to 10 points) in the first practical class was 0.85 points in favor of PpcProject, while it was 0.69 points in the second practical class always in favor of PpcProject. All the differences observed were significant in the corresponding t-test conducted. This fact, corroborates the hypothesis of PpcProject is more useful for the students to learn the concepts of projects planning and scheduling.

5. Conclusion

This article presents PpcProject, a free and open-source tool for educational use in software project management. PpcProject has been shown to meet all of the original objectives under consideration, including the creation of project network, the creation of Gantt charts and PERT graphs, the identification of critical activities and critical paths, and resource allocation and leveling using both renewable and non-renewable resources. In comparison with other proprietary and free software tools for project management, PpcProject is able to provide all of the features necessary for learning project management skills.

An intensive comparison between PpcProject and Microsoft Project has been carried out during practical classes with two groups of 27 students in the Software Engineering degree program with significant results in favor of PpcProject.

Specifically, in the opinion of students who used both tools in their problem-solving, the tasks of entering activity durations, entering activity precedences, identification of paths and the critical path, and generation of early/late times and activity floats were significantly easier with PpcProject than with Microsoft Project. In the same way, the general usability aspects of PpcProject were assessed more favorably by the students in comparison with Microsoft Project. In contrast, the item of Assigning resources to the activities was rated lower for PpcProject than for Microsoft Project even though the difference was not significant. Consistently with these results, when assessing concepts as ability to develop, correct and evaluate project plans, the marks obtained by the students who used PpcProject in practical classes were significantly better than the marks obtained by the students who used Microsoft Project.

Therefore, future work should be aimed at improvement of the least favorably assessed items in the comparative analysis and specifically the topic of assignment of resources to the activities. Furthermore, other algorithms for resource allocation and leveling should be implemented to improve the solutions obtained.
References


