Enhancing skills in solving open-ended problems using game-based exercises

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ABSTRACT: Some requirements for engineering programmes, such as an ability to use the techniques, skills and modern engineering tools necessary for engineering practice, as well as an understanding of professional and ethical responsibility or an ability to communicate effectively, need new activities designed for measuring students' progress. Negotiations take place continuously at any stage of a project and, so, the ability of engineers and managers to effectively carry out a negotiation is crucial for the success or failure of projects and businesses. Since it involves communication between individuals motivated to come together in an agreement for mutual benefit, it can be used to enhance these personal abilities. The main objective of this study was to evaluate the adequacy of mixing playing sessions and theory to maximise the students' strategic vision in combination with negotiating skills. Results show that the combination of playing with theoretical training teaches students to strategise through analysis and discussion of alternatives. The outcome is then more optimised.

INTRODUCTION

There are different quality requirements for any engineering programme. Several organisations have produced detailed information, such as the Accreditation Board for Engineering and Technology (ABET), which has identified 11 criteria. Some of these quality requirements are present in all engineering programmes, and there is enough experience on how to teach and measure the outcome. There are others, such as *an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice*, as well as *an understanding of professional and ethical responsibility or an ability to communicate effectively,* that need new activities designed for measuring student progress [1].

In order to ensure these competencies can be achieved, specific activities have been prepared to cultivate a flexible and high-quality learning process. Therefore, innovation provides valuable information to school students for accumulating knowledge as a source for enhancing learning quality and motivation. It is acknowledged that teaching must meet the needs of social development, deploy modern technology and be able to bring teachers' creativity into play to elevate students' learning satisfaction, so that their learning effectiveness is enhanced [2].

Negotiations take place continuously at any stage of a project and so the ability of engineers and managers to negotiate effectively is crucial to the success or failure of projects and businesses [3-6]. Negotiation is defined as a joint decision-making process of two or more parties working together to reach a mutually acceptable agreement on one or more issues [7]. It involves communication, direct or tacit, formal or informal, between individuals who are motivated to come together in an agreement for mutual benefit [6].

From previous studies, it has been demonstrated that learning by playing is an effective way to make students learn the subject area of negotiation and it can be an important tool for improving engineering students' performance, as well as motivating and enhancing other non-technical abilities [8].

Based on that experience, the authors' main objective was to evaluate the adequacy of mixing playing sessions and theory to maximise the students' strategic vision in combination with negotiating skills. This was accomplished through research carried out with the participation of students at the School of Industrial Engineers of the Technical University of Madrid (Universidad Politécnica de Madrid) (UPM). This is the first approach in responding to students' needs arising from construction projects, and the learning process will continue with other subjects, for example, *Projects in Engineering* and *Integrated Management of Construction Projects*.

This article presents the use of activities based on role playing to acquire necessary skills for engineering practice and to better develop the competencies of effective communication and ethical responsibility. In this exercise, student teams have to play at negotiation first and, then, using some of the new skills, to bid on a contract working as a Consortium. It is expected to determine how playing sessions and theory can be used to learn an approach to solve open-ended problems.

METHODOLOGY

For the negotiation role playing, each team was formed of three participants who played different roles (Agents A, B and C) that involved different degrees of complexity [8]. The role of each participant is now presented, as well as the conditions in the beginning:

- Agent A is a construction company project manager. He is making an offer for a bridge construction that needs the participation of two subcontractors (Agent B as girder supplier and Agent C as concrete deck supplier).
- Agent B is the production manager of a company that manufactures girders, either steel or composite.
- Agent C is the production manager of a concrete deck company, providing in situ ready mix concrete or precast slabs.

Three different scenarios were created with different Zones of Possible Agreement (ZOPA) referring to price, time schedule, quality, etc. Those scenarios were run on different days. Day 1 and Day 2 scenarios had a smaller ZOPA, so it was more difficult for the team to achieve an agreement; every agent played *against* the other partners on the same team in order to close the negotiation [5][9]. On Day 3, every team collaborated as a consortium and played *against* the other teams in order to get the contract.

Table 1 shows the data information of the different scenarios for negotiation per day. It can be seen that the Day 3 scenario is totally open since students have first to discuss the strategy to follow and agree with the technology they want to offer, since the bid price limit varies according to the technology and delivery time of the project.

Table 1: Role play negotiation strategy.

		DAY 1	DAY 2	DAY 3	
AGENT A	Bid price limit	250,000 € total 100,000 € fixed cost	250,000 € total 100,000 € fixed cost	250,000 €, 255,000 € or 260,000 € total according to technology used 100,000 € fixed cost	
	Delivery time	65 days	61 days	58 days	
	Bonus for objectives	Reduction on delivery time, offer increases 1,000 €/day The Agent will increase the bonus 50 % of offer increment	Reduction on delivery time, offer increases 1,000 € The Agent will increase the bonus 50% of offer increment	Reduction on delivery time, offer increases 1,000 € The Agent will increase the bonus 20% of offer increment	
	Constraints	Restrictions on storing and assembling cast girders 10 days for girder assembly			
AGENT B	Job order	100 IPN 1,000 girders			100 composite girders
	Offer price	5 girders/day 700 € 2 extra/day and weekends 770 € Subcontracted girder 1,800 €	5 girders/day 700 € 2 extra/day and Saturdays 770 € Subcontracted girder 1,200 €	5 steel girders/day 700 € 2 extra/day and Saturdays 770 € Subcontracted girder 1,200 €	5 composite girders/day 750 € 2 extra/day and Saturdays 825 € Subcontracted girder 1,600 €
	Bonus for objectives	Agent will increase the bonus 20% of offer increment			
	Constraints	Limited storage of casted girders			
AGENT C	Job order	1,000 m^3 of concrete			2,200 m^2 precast slabs
	Offer price	150 m^3/day 40 € 250 m^3/day 55 €	135 m^3/day 40 € 250 m^3/day 55 €	125 m^3/day 40 € 250 m^3/day 55 €	250 m^2slab/day 20 € 500 m^2slab/day 26 €
	Bonus for objectives	Agent will increase the bonus 10% of offer increment			
	Constraints	Product with only 1:30 hour delivery time			--

Figure 1 shows the methodology followed with students at ETS of Industrial Engineers at Universidad Politécnica de Madrid (UPM). Eight teams were involved in the game. Roles were distributed according to the student's experience, since it was understood there were differing levels of role difficulty, especially when there was set a time limit for negotiation.

Four teams formed the Experimental Group (EG) and four were used as the Control Group (CG). The Experimental Group received a theoretical class (F) about principles of negotiation to see in what way the lecture helped them to improve the skills learned by playing. Experimental groups were Team 1, Team 4, Team 6 and Team 8. Control groups were Team 2, Team 3, Team 5 and Team 7.

At the end of each game, a survey was filled out by each student. This survey included all the student's information regarding the results of the negotiation, perception of the difficulty to reach the agreement, perception of the negotiators and general satisfaction with the agreement. Between the initial day and the final, students received information about the other groups' evolution, but not about their own. Partial results of the survey are presented in this article and the focus here is on the quantitative results.

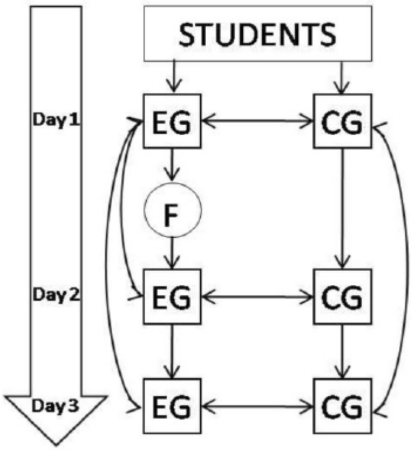

Figure 1: The methodology used to evaluate the improvement of both experimental groups and control groups.

The whole purpose of negotiating is to find out what each party really wants and what it is willing to give - and give up - to get it. During the introduction of the course, the framework of the negotiation was explained together with the skills and qualities a good negotiator needs. The aspects that were most marked were:

1. The first step to carry on a successful negotiation is the need to be properly prepared; the preparation must be appropriate for different negotiating situations; looking at the purpose, the desired outcomes on both sides, who will be there and what is known about them, including interests and the positions of all parties. The difference between an interest and a position and why it is important to separate them, is highlighted.
2. A strategy must be created that will cover the entire negotiation. Strategy is a comprehensive plan developed to help achieve an important goal. It includes all the key steps that will be followed to capture the ultimate objective.

RESULTS

Results of Day 3 that involves decision-making are presented in this section. Figure 2 shows the low and upper limits for alternatives in this scenario. It can be seen that if the choice is to run with traditional technology, the cost becomes lower but the upper limit is also low, especially when delivery time is shortened. Since the rate increment of costs is higher than rate increment of bid limit, the possibility of getting higher benefit is better for 60 days delivery time. If a team decides to implement two industrialised technologies, then the rate increment of cost is quite similar to the rate change of delivery time.

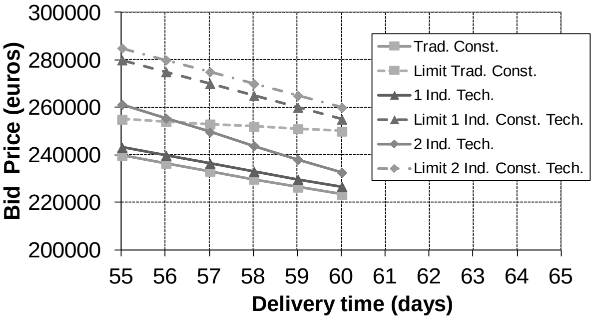

Figure 2: Relationship between delivery time and price for Day 3 construction alternatives.

In order to see the alternatives better than in Figure 2, Figure 3 shows the students' results separated into three graphs: in the left and right graphs, the results from teams that selected traditional technology and completed industrialised technologies are plotted; the graph in the middle shows the four groups that selected one industrialised technology. Except for Team 7, the bid prices were slightly over the cost line, and far from the limit. Results from Teams 3 and 6 overlap.

It has been mentioned that Teams 1, 4, 6, and 8 in the theoretical class, illustrated the importance of preparing properly for the negotiation and setting a strategy. Only one group failed to choose the alternative of using one industrialised technology. The combination of practical and theoretical training prepares the students for analysing and discussing alternatives.

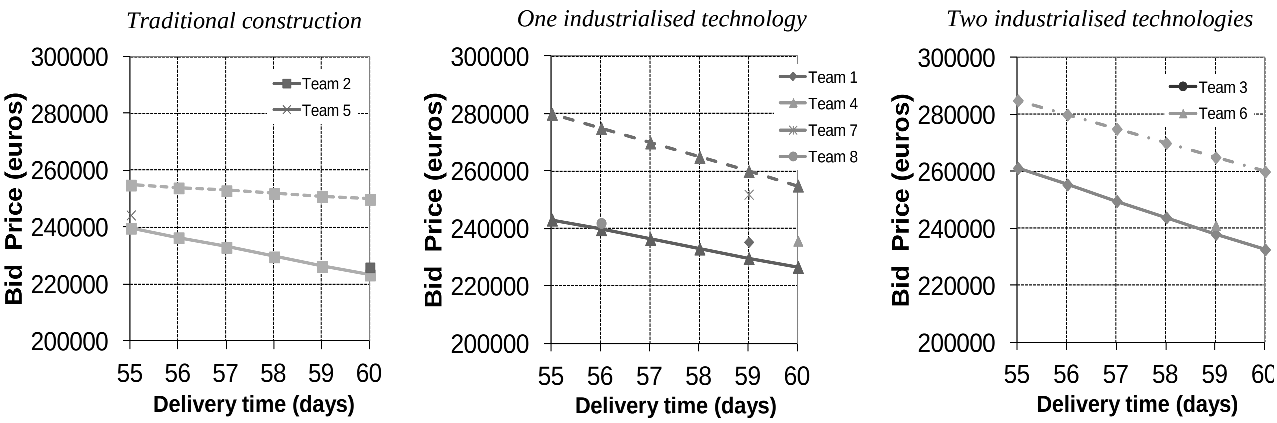

Figure 3. Negotiation bid prices for Day 3 construction alternatives.

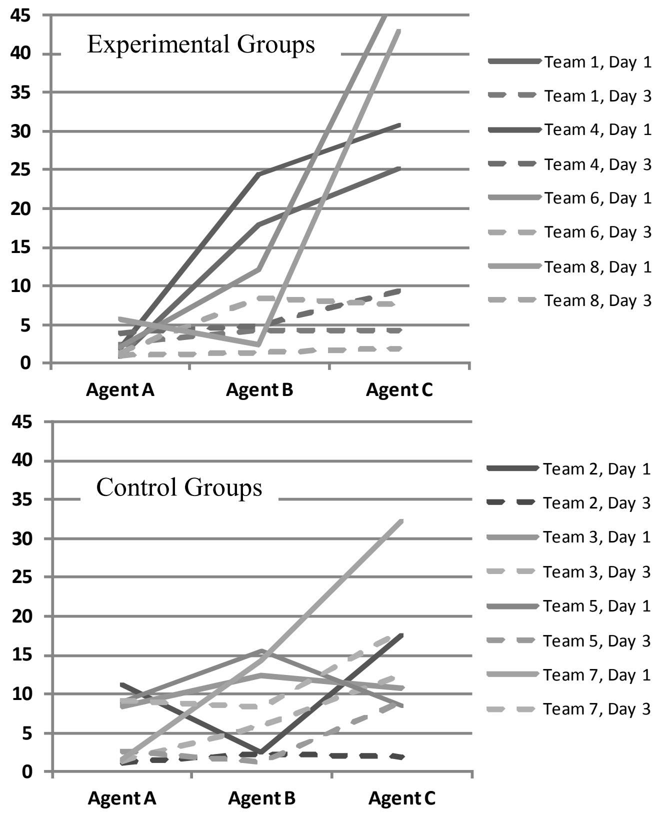

Figure 4: Effect of theoretical knowledge on negotiation (percentage of profit per agent type).

DISCUSSION

Even when at least four iterations were needed to reach an agreement, only the final results are presented. The data shows that, if one individual agent has a profit higher than 45%, it becomes very difficult to get the agreement. There is a change from Day 1 to Day 3, where individual profit is more controlled (see Figure 4). While Day 1 students employed all the available time set for negotiations, the Day 3 dispersion is higher regarding the time needed. It can be observed that even though in Days 1, 2 and 3 all the teams were able to reach a valid agreement, approaches were better day by day.

Effect of Theoretical Knowledge on Negotiating Results

Figure 4 shows a comparative profit distribution between Agents A, B and C, for Day 1 and Day 3. The continuous line is for results of Day 1 and the discontinuous line for results of Day 3. The upper graph represents the results from the teams in the experimental group, and the low graph, the results from the teams in the control group.

First, it can be observed that a more distributed benefit was obtained in Day 3 for all agents, in all the cases. However, it should be noted that teams with theoretical training got the best results. The attitude of Agents B and C has changed to be more collaborative instead of competitive.

RESULTS FROM THE SURVEY ON NEGOTIATION SKILLS

Generally, all students perceived smaller difficulties on Day 3, as compared with Day 1, even though the scenario and complexity of decision-making were easier on Day 1. It was observed, as well, that students who formed a sense of understanding had less difficulty.

Students had greater difficulty setting the bid price than delivery time, although both parameters are related; just how is shown in Figure 2. Students who have not had theoretical training felt the same difficulty in fixing the bid price on Day 3, as compared to Day 1; but students with theoretical training had a lower perception of difficulty. Teams with theoretical training not only had a minor degree of difficulty, they also acquired better alternatives in bid prices.

After Days 2 and 3, students were asked to answer a survey related to the development of competencies through the game. Figure 5 shows the results for the students' perception of the strengthening of competencies. The rectangular part of the plot extends from the lower quartile to the upper quartile, covering the centre half of each sample.

The centre lines within each box show the location of the sample medians. The plus signs indicate the location of the sample means. The whiskers extend from the box to the minimum and maximum values in each sample, except for any outside or far-outside points, which were plotted separately.

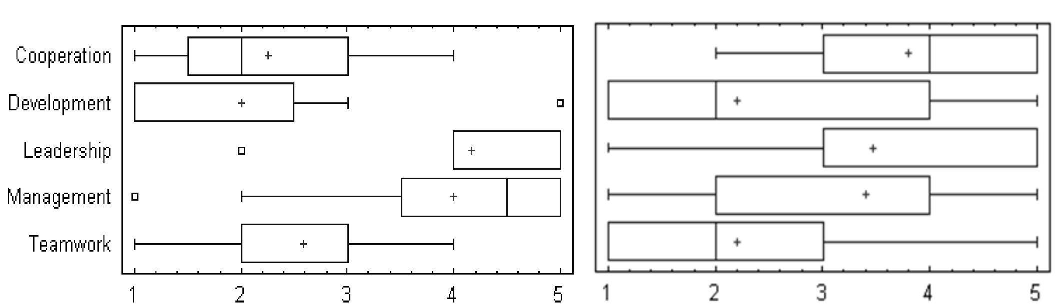

Figure 5: Competencies development; Left, without training; Right with training.

Students without training perceived the competencies of *leadership* and *management* strengthened by the game. However, students with theoretical training also considered *co-operation* as one of the competencies with the greatest improvement. This is in agreement with the profit distribution on Day 3 for those teams with training, as observed in Figure 4.

CONCLUSIONS

In addition to detailed technical knowledge in engineering education, other personal and contextual skills are important for students, for example, an ability to use the techniques, skills and modern engineering tools necessary for engineering practice, as well as an understanding of the professional and ethical responsibility or an ability to communicate effectively. The opportunity to develop these skills often is unavailable to students until they become employed. Introducing students to such experiences earlier can foster the development of these abilities; this means there is the need for some new activities to be designed for measuring the students' progress.

This experience has demonstrated that learning by playing is effective in student learning in the subject area of negotiation and it can be an important tool for improving engineering students' performance, as well as motivating and enhancing other non-technical abilities. The combination of playing and training has verified that students with no special skill in negotiation at the beginning of the experiment have reached even better final results than the ones with natural negotiation skills. Additionally, the learning from negotiation theory (looking at the purpose, the desired outcomes on both sides, including interests and positions of all parties, creation of an strategy, comprehensive plan), has proved to be beneficial to solving open-ended problems.

As confirmed, learning by playing is a method of instruction that challenges students to learn how to work co-operatively in order to seek agreements in real engineering problems and prepares them to think critically and analytically to use appropriate skills. These problems are used to engage students' curiosity and to initiate the learning of the subject matter. The independent research and learning aspects of these role plays provide the students with the skills necessary to identify, research and fill in the missing knowledge for the types of problems they may encounter during their professional lives.

The perception of both students and teachers is that the learning approach tested was valuable and more productive than only lecture-orientated approaches, despite the fact it required greater effort than the classical method.

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