LEARNING THROUGH A HANDS-ON ACTIVITY USING A PBL APPROACH

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ABSTRACT

This paper reports the project developed by students of the 4th semester of Civil Engineering Program at Pontifical Catholic University of Sao Paulo which has used the basic concepts of Mechanics of Rigid Bodies (MRB) course taught in classroom. In order to adopt the principles of the approach Project Based Learning (PBL) the professor whom teaches this course proposes the development of a project which the theme, in the two last years, was the Da Vinci’s Self-Supporting Bridge. The history tells that Da Vinci designed four types of bridges. The design of this bridge was the most simple and ingenious of them. The design of Self-Supporting Bridge was developed from 1485 to 1487 attending the request of his patron Cesar Borgia, and it was necessary simple assembly without woodworking skills by the troops. The design is held together by its own weight without requiring any ties or connections. The development of this project was part of the assessment process in the course. The students of the class were divided in teams with six members each one to set up the bridge. The project was developed in three steps. The first one was a bibliographic research on the issue. In the second step began the hands-on activity with the building of a prototype where test and analysis were made to understand the structures behaviour as result of a downward applied force. In the third step the hands-on activity was the bridge building in an enlarged size with the necessary adaptations related to the prototype, seeking to follow the original design, and under the condition of to allow and tolerate the weight of several people passing along the bridge. There was no competition between the teams but only the proposal of the students develop soft skills and a collaborative learning. The materials used were wood cylindrical pieces with the appropriated sockets. All the pieces were prepared by the team and each step with the description of the building and assembly processes were reported in a video available on You Tube. Finally, the students answered questioned through two questionnaires applied to them to obtain their opinions and perceptions on the project. A closed questionnaire based on Likert’s scale and an open questionnaire where they could analyse all the aspects involving their participation in the project and what suggestions they had to do to improve the experience. In addition, the students could tell how the PBL approach help them in the teaching/learning process.

Keywords: Hands-on activity; Project Based Learning; Ponte de suporte; Teamwork.

RESUMO

Aprendizagem através de uma atividade hands-on usando a abordagem PBL

Este artigo relata o projeto desenvolvido pelos alunos do 4º semestre do curso de Engenharia Civil da Pontifícia Universidade Católica de São Paulo, utilizando os conceitos básicos ministrados na dis-
ciência Mecânica dos Corpos Rígidos (MCR). Utilizando os princípios da abordagem Aprendizagem Baseada em Projetos (PBL), o professor propôs o desenvolvimento de um projeto cujo tema foi a Ponte Arqueada de Da Vinci. A história conta que Da Vinci projetou quatro tipos de pontes. O projeto desta ponte foi o mais simples e engenhoso entre todos. O projeto da ponte arqueada foi desenvolvido entre 1485 e 1487, atendendo ao pedido de seu patrono Cesar Borgia, com uma montagem simples sem exigir habilidades de carpintaria das tropas. A ponte é mantida fixa por seu próprio peso, sem exigir vínculos ou conexões. O desenvolvimento desse projeto fez parte do processo de avaliação do curso. Os alunos da turma foram divididos em equipes com seis membros cada. O projeto foi desenvolvido em três etapas. O primeiro foi uma pesquisa bibliográfica sobre o assunto. Na segunda etapa, iniciou-se a atividade prática com a construção de um protótipo no qual foram feitos testes e análises para entender o comportamento das estruturas sob a ação de uma força aplicada verticalmente para baixo. Na terceira etapa, a atividade prática foi a construção de uma ponte em tamanho ampliado, com as necessárias adaptações relacionadas ao protótipo, buscando seguir o projeto original e com a condição de permitir e tolerar o peso de várias pessoas passando sobre a ponte. Não houve competição entre as equipes, apenas a proposta dos alunos trabalharem em equipe desenvolvendo suas habilidades manuais, técnicas, sociais e colaborativa. Os materiais utilizados na construção da ponte foram peças cilíndricas de madeira com os encaixes apropriados. Todas as peças foram preparadas pelas equipes de trabalho e os passos do processo de construção e montagem da ponte foram gravados e estão disponíveis no You Tube. Finalmente os estudantes responderam a dois questionários (um fechado e outro aberto) com a finalidade de obter suas opiniões e percepções sobre o projeto e a metodologia adotada, além de uma análise crítica apresentando sugestões para melhoria do projeto. Além disso, eles foram questionados como a abordagem PBL ajudou-os no processo de ensino/aprendizagem.

Palavras-chave: Atividade mão na massa. Ensino baseado em projeto. Supporting Bridge; Trabalho em equipe.

1 INTRODUÇÃO

Currently the engineer professionals are needing a deep and hard inter/multidisciplinary skills and competences in order to face the real job market. The modern engineer profession requires skills on human relations as well as technical competences (MILL; TREAGUST, 2003). According to Campos, Dirani and Manrique (2011), the academic world is changing in its learning concepts and new methodologies and approaches are being used to prepare the engineering students for a future where we don’t know what must be taught. The Project Based Learning (PBL) is an approach that put the students to face a real world and help them to acquire competences, skills, teamwork and critical thinking.

This approach is a good teaching/learning educational tool that develops on the students the capacity of solving problems and projects through a self-directed learning, observation, organization, initiative and teamwork (MOREIRA; MESQUITA; VAN HATTUM-JANSSEN, 2011). When students use PBL approach they face new challenges and new roles in the learning process. The student roles include autonomy and responsibility about what they learn, how they learn and with whom. The activities related to that requires an interaction between team members during all the time of the project (ALVES et al., 2012).

According to Powell and Weenk (2003, p.35), “teamwork takes probably about 40 to 50% of learning activity. Thus, teamwork emphasized a continuous interaction between group members concerning the project activities, purposes, knowledge and goals”. They conclude that PBL approach gives to students the opportunity to face a real problem which solution needs theoretical concepts but the application must be discussed in a teamwork where each member must give a contribution.
to solve it. Based on Baine (2009), when engineering students carry out a project in teamwork each member of the team contributes, according to individual strengths and the resultant learning and/or design produces a superior product. People learn from each other, empower each other, and share the responsibility of finishing the project on time under the budget. Engineers must be able to communicate well with a wide variety of people. Each team member brings a different set of skills to the table. It is important to realize that this diversity of ideas and thinking is exactly what can make a product attraction or company bigger. A wide variety of people working together usually equates to more detail and better design or finished results.

In a complementary way, the purpose of the Mechanics of Rigid Bodies course is to give to engineering students the knowledge needed to analyse projects with several structures to different loadings (BEER, 1994).

The perceptions of the students on the Project Based Learning used during the development of the project showed that it was an adequate approach to learn technical concepts, competences, skills and an opportunity to them know how does it work a “factory floor” (CAMPOS, L. C; CAMPOS, B. C. O; SEVEGNANI, 2017).

In order to adopt these concepts the professor of the Mechanics of Rigid Bodies (MRB) course of the fourth semester of the Civil Engineering Programme at Pontifical Catholic University of Sao Paulo, proposed to his students the project of building the Da Vinci’s Self-Supporting Bridge as part of the assessment process in the course. The design is held together by its own weight without requiring any ties or connections. When a compression force is applied to the structure the braced members are forced to interlock and tight together through the structural concepts of shear and bending, (BERNARDONI; TADDEI; ZANON, 2015).

The history tells that Da Vinci (1452 – 1519) designed four types of bridges. The design of this bridge was the most simple and ingenious of them. The design of Self-Supporting Bridge was developed from 1485 to 1487 attending the request of his patron Cesar Borgia, and it was only necessary simple assembly without woodworking skills for the construction by the troops. The design is held together by its own weight without requiring any ties or connections. Figure 1 shows the Da Vinci’s Self-Supporting Bridge design.

Figure 1: Da Vinci’s Self-Supporting Bridge Design

Source: Adapted from http://naengenhariablog.blogspot.com.br (SCANTAMBURLO et al., 2017).

2 METHODOLOGY

The building of Da Vinci’s Self-Supporting Bridge was the theme of the project developed, in the two last years, by the students of Civil Engineering Programme at Pontifical Catholic University of Sao Paulo in the MRB course. The main purpose of this work was the learning of the MRB course from a full study of Physics’ aspects and concepts that can be used in the bridges building. The bridge that this work reports was chosen as the better project developed between all that made by
the teams of the class in 2017. After the development and presentation of the project the students answered two questionnaires to give their opinions on the project and how it has increased their MRB course learning. According to Campos, Campos, Sevegnani, (2017) the learning of the students with the use of PBL approach can be measured from the open and closed questionnaires applied to them.

The project was developed in three steps. On the first step a bibliographic research on the issue was made by giving to the students the knowledge of the project under scientific and cultural-history visions. The second step, begun with the hands-on activity, the students set up a prototype to analyse the structures behaviour as result of a download applied force and the application of structural concepts. On the third and final step the bridge was built in an enlarged size with the necessary adaptations related to the prototype, looking for follow the original design. This assembly must allow and tolerate the weight of several people passing along by the bridge. It is important to say that there was no competition between the teams but only the proposal of the students develop soft skills and a collaborative learning. The materials used were wood cylindrical pieces with appropriated sockets, (SCANTAMBURLO et al., 2017). All the pieces were prepared by the members of the team and each step with the description of the building and assemble processes were reported in a video available on You Tube (TV PUC-SP, 2017). The evaluation of each project was make only by the teacher from the teams’ presentation in classroom and the bridge assembly. Along the development of the project the students presented reports of all their steps performed monthly.

Figure 2: Sequence of assemble the pieces

![Figure 2: Sequence of assemble the pieces](source: Adapted from http://naengenhariablog.blogspot.com.br (SCANTAMBURLO et al., 2017))

Figure 3 shows the types of wood cylindrical pieces with the appropriated sockets, used to assembly the Bridge.

Figure 3: Type of pieces with their appropriated sockets

![Figure 3: Type of pieces with their appropriated sockets](source: Scantamburlo et al., 2017)

Figures 4 and 5 show the students working in the preparations of the necessary pieces to
assembly the bridge.

Figure 4: Preparation of the pieces

Source: Scantamburlo et al., 2017.

Figure 5: Preparation of the pieces

Source: Scantamburlo et al., 2017.

Figure 6: The types of pieces and their sockets

Source: Scantamburlo et al., 2017.
Table 1: Dimensions of the pieces

|     | PROTOTYPE | ENLARGED BRIDGE |
|-----|-----------|-----------------|
| A   | 250 mm    | 1200 mm         |
| B   | 16 mm     | 85 mm           |
| C   | 125 mm    | 600 mm          |
| D   | 15 mm     | 90 mm           |
| E   | 95 mm     | 455 mm          |
| F   | 25 mm     | 100 mm          |

Source: Scantamburlo et al., 2017.

Figure 7 and 8 show the final assemblies of the prototype and the enlarged bridge.

Figure 7: The prototype assembling assembling

Source: Scantamburlo et al., 2017.

Figure 8: The enlarged bridge assembling

Source: Scantamburlo et al., 2017.

Figure 9 shows the final project assembling with the members of the team and the MRB course teacher.

Figure 9: The enlarged bridge with the members of the team and the teacher
3 RESULTS

In this section are presented the results from the survey applied to students through closed and open questionnaires. The opinions and perceptions of the students on the project were based on the data collected in the end of the semester carried out individually, after the presentation in classroom of all the project developed along the semester.

A closed questionnaire based on Likert’s scale and an open questionnaire where they could analyse all the aspects involving their participation in the project and what suggestions they had to do to improve the experience. In addition, the students could tell how the PBL approach help them in the teaching/learning process.

A discussion analysing the opinion of each student on the project theme, the teamwork, the learning and competences acquired, teacher roles and the PBL evaluation are pointed out in the closed questionnaire.

Table 2 shows the dimensions, the statements and the average of each statement and each dimension of the closed questionnaire. It is important to announce that this work was the first research carried out in team by the students. This fact can be to explain the low score in the statement 13. Until that moment all the activities that the students have made were individually. The low score in the statement 8 can be explained by the fact that the students used more hands-on activities than writing text during the development of the project.

Relating to the high score in the statements 4 and 14 it is possible to suppose that these results are related to the enthusiasm demonstrated by the students on their task.

In general, according to Table 2 the results had a good score related to the work carried out by the students.

Table 2 shows the dimensions, the statements and the average of each statement and each dimension of the closed questionnaire.
Table 2: Results of closed questionnaire

| DIMENSIONS                  | STATEMENTS                                                                                                                                          | RESULTS AVERAGE |
|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| (1) Project Theme          | 1) The Project theme was relevant to my future profession                                                                                  | 4.4             |
|                             | 2) The Project theme was very interesting and motivator                                                                                  | 4.4             |
|                             | 3) There was a good articulation between the Project and the MCR course                                                                          | 4.3             |
|                             | 4) I am proud with the project that my team developed                                                                                       | 4.5             |
|                             | 5) The Project allowed me to understand the contents of the course more easily in the classroom                                                   | 4.1             |
|                             | 6) The development of the Project allowed me to view the applications of the course in real situations                                        | 4.3             |
|                             | 7) My participation in the Project helped me to develop my autonomy                                                                         | 4.1             |
| (2) Learning and           | 8) With the development of the Project I have improved my oral and writing communication competences                                        | 3.7             |
| Competences Acquired       | 9) With the PBL I have acquired and developed Project, time and conflict managements                                                            | 4.4             |
|                             | 10) My feedback suggestions to the members of the teamwork helped me to develop my critical thinking                                          | 4.0             |
|                             | 11) The prototype construction stimulated my initiative and creative ability                                                                   | 4.3             |
| (3) Teamwork               | 12) The teamwork allowed me to increase my motivation to learning                                                                            | 4.2             |
|                             | 13) I prefer to work in team than individually                                                                                                | 3.7             |
|                             | 14) Along to the semester I had an active role in the teamwork                                                                               | 4.5             |
|                             | 15) During the development of the Project my teamwork carried out formal meetings in order to discuss the steps of the Project                | 4.4             |
|                             | 16) The personal relations competences developed during the project will be very important to my profession                                    | 4.4             |
|                             | 17) I shared all my tasks and knowledges with the members of the teamwork                                                                     | 4.3             |
|                             | 18) I had ability to solve all the conflicts in the teamwork under a positive way                                                              | 4.0             |
| (4) Teacher Roles          | 19) The professor was available to give support to the students and help them to solve the doubts on the project                                 | 4.2             |
|                             | 20) The professor role was very important during the development of the project                                                                | 4.2             |
|                             | 21) The teacher gave technical support to the project                                                                                         | 4.2             |
| (5) PBL Evaluation         | 22) The grade related to the Project must be more than the traditional texts                                                                    | 4.0             |
|                             | 23) In general I was happy with the results of the Project developed by my teamwork                                                             | 4.3             |
|                             | 24) PBL approach has a positive behavior in the relation between professor and students                                                        | 4.3             |
|                             | 25) The PBL approach used in this Project was well organized                                                                                | 4.1             |

Source: Adapted from Campos, Campos and Sevegnani, 2017.

The results of the open questionnaire are presented below. Table 3 shows the results of the open questionnaire related to the aspects more positives of the project.
The results show that the students considered the teamwork, and the theme of the project, the development of autonomy, creativity, critical thinking and the hands-on activities as the aspects more positives in the development of the project besides the face to a real problem related to their future professional activity.

Table 3: Results of open questionnaire for aspects more positives

| Aspects more positives                                 |
|--------------------------------------------------------|
| Face to real problems of the profession                |
| Management of conflicts                               |
| Teamwork                                               |
| Development of autonomy, creativity and critical thinking |
| Hands on activities                                    |

Source: Adapted from Campos, Campos and Sevegnani, 2017.

The results show that the students considered three aspects as those less positives. The lack of commitment of some team’s member during the work, the difficulties of establishing a schedule where all members of the team could be present and be able to contribute with the work and suggestions and the few number of bibliographic materials related to the issue. These are problems that the team will ever face in the development of a work and a manager of project must be prepared to solve. All these problems are part of a teamwork and only the experience and a proper management can solve them. Table 4 shows the results of the open questionnaire related to the aspects less positives of the project.

Table 4: Results of open questionnaire for the aspects less positives

| Aspects less positives                  |
|-----------------------------------------|
| Lack of commitment of some team member  |
| Scheduling difficulties with the team member |
| Few bibliographical related to the issue |

Source: Adapted from Campos, Campos and Sevegnani, 2017.

Related to the improvement suggestions the students highlighted the attributed grade to the project face the work and time that it requires along the development. Currently the project represents only 20% of the final grade in the course. Other considerations were related to the way that the final project is presented to the class and the numbers of reports before its end. The students prefer a presentation by using a poster session with all the project developed were each team could to discuss with all teams than an individual power point presentation to the class.

Table 5: Results of open questionnaire for improvement suggestions

| Improvement Suggestions                      |
|---------------------------------------------|
| Increase in the grade related to the project |
| More discussions inter-time before the finalization of the work |
| Technical support by the teacher            |
| Biweekly reports                            |
| Presentation of results through a poster and no power point |

Source: Adapted from Campos, Campos and Sevegnani, 2017.
4 FINAL REMARKS

The data obtained in the two questionnaires show the student opinions on the impact that the project development gave to their learning. It is important to announce that this project was the first research carried out in team by the students.

According to the results and comments we must conclude that the development of a project in an Engineering Programme is a way to give to the students a suitable approach to learn technical concepts, competences, skills and opportunity for them know as the works happen in a “factory floor” using hands-on activities. During the project development students found a lot of challenges where the solutions required creativity, effort, dedication and discussions between the members of the teams and exchange of opinions to solve the problems faced by them. Despite of this project has been the first work in team that the students developed in their programme, they approved this new approach of teaching/learning and they hope that other courses implement other works like this.

Looking at the comments that some students gave, the most relevant aspect in the development of the project was related to the professional reality of Civil Engineering.

Some statements of the students are presented below:

Student A: “The development of this project brought us an enrichment in our knowledge through the hands-on activities and showed the practice applications of MRB course concepts...”

Student B: “We had some difficulties in the piece preparations due to the lack of hands-on skills and the used tools, but the enthusiasm with the task help us to win these problems...”

Student C: “In my opinion the project brought us besides a technical and scientific competence a cultural and human knowledge on the lives of the great geniuses and the legacy that they left for the humanity....”

The choice of a theme where they can face in future profession became the most important aspect of the project and contributed for the motivation during its development.

Some of the suggestions that the students gave in the open questionnaire, mainly related to the grade, were considered by the teacher in the new projects that are developed in the course.

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