THE OBSERVATION OF EVERYDAY LIFE STRUCTURES: A PROJECT TO STIMULATE THE STUDENTS' LEARNING OF MECHANICS OF STRUCTURES

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Abstract *– One of the main challenges professors of mechanics of materials face is how to motivate the students to study this subject normally considered too theoretical and abstract. In order to overcome this difficulty, a project of observation of structures was introduced in the first course of mechanics of materials of the civil engineering course of Escola Politécnica da Universidade de São Paulo. This project consists of the analysis of everyday life structures, that are examined and photographed by pairs of students. The main objectives of the project are: to make the students feel how important structures are to mankind, to make them understand how structures work and to make them see that the mathematical models examined in the course are indeed behind the structures of the real world. The project was given in 1999 and 2000, and its evaluation showed that its objectives were attained.*

Index Terms – Analysis of real structures, Project in the first course of mechanics of structures, Qualitative analysis of structures, Teaching mechanics of structures.

INTRODUCTION

One of the main challenges professors of structural analysis face is how to motivate their students and how to increase their interest for this subject, normally considered too abstract, and whose concepts are considered very difficult to grasp and to understand. One of the main factors causing this problem is the lack of a clear link between the mathematical models examined by the students in the classroom and the structures around them in the real world.

Motivation is an internal force originating within an individual [1], and to help to awaken the motivation to learn within the students several teaching strategies have been suggested, amongst them to "make study as active, investigative, 'adventurous', social and useful as possible" [2]. It has also been observed that the analysis of real world problems plays an essential role in the improvement of engineering students' learning [3].

Having these concepts in mind, aiming at motivating the students to learn mechanics of materials, over the last few years several new teaching tools have been introduced in the course PEF-2200 "Introduction to mechanics of structures", the first course on mechanics of structures of the civil engineering course of Escola Politécnica da Universidade de São Paulo. Among these new teaching tools are included the use of transparencies showing real structures whose mathematical models are being studied in the course's classes [4], the use of educational computer programs [5], the use of animations introducing some of the basic concepts of the course, a visit to the Museum of Art of São Paulo, whose building is a masterpiece of architecture and structural engineering, and the creation of an internet site presenting the concept of structure, the structural systems used in constructions and a short history of structural engineering.

In order to motivate the students to observe the real structures of everyday life, to make them feel the importance structures have in our lives and to help them see the relations between the mathematical models they study and these structures, in 1999 a project of observation of real structures was introduced in the course [6]. This first experience of having a project was evaluated, and it was verified that its goals had been achieved. With minor alterations, the project was repeated in 2000 and is now being once again repeated.

THE PROJECT GIVEN IN 1999

Description of the Project

The project proposed in 1999 consisted of the analysis of ten structures by pairs of students working together; these structures, chosen by the students, should include:

- Two natural structures;

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- Two roof structures;
- Two trusses;
- Two Brazilian structures of historical importance;
- Any two other structures at the choice of the students.

Among these structures there should be at least one made of wood, one made of metal and one made of concrete.

The analysis of these structures should include:

- Photographs of the structures and of their details, taken by the students;
- A short description of each one of the structures with information on:
  - The structural system;
  - The materials used;
  - Its dimensions;
  - Its location;
  - The date of its construction;
  - Name of its architect and of its structural engineer;
  - Interesting facts related to it.

Some of this information could be omitted when inapplicable or very difficult to obtain – as for example the date of construction of a spider's web or the name of the structural engineer of an ancient building.

A report with the pictures and the analyses of the structures examined was handed in at the end of the semester. The project was then corrected and given a mark, which weighted 10% on the final mark of the course, the other 90% being the marks obtained in three written exams done along the semester.

Objectives of the Project

In addition to the main objective of making the students not simply look at structures but also see what is behind them and of making them see how important structures are to mankind, the project had some more specific objectives:

1. To stimulate the students to observe the objects, machines and constructions around them and to identify their structures;
2. To stimulate the students to try to understand how structures work;
3. To make the students see that the mathematicals models examined in the course are indeed behind the structures of the real world;
4. To stimulate the students to identify Brazilian structures of historical importance;
5. To stimulate the students to research on technical information on structures;
6. To stimulate teamwork;
7. To stimulate the writing of technical reports.

The Evaluation of the Experience

At the end of the semester the students were asked to evaluate the project by answering a questionnaire. Six ot the questions should be answered by giving a mark ranging from 0 to 10.

The 95 students who evaluated the project gave the following marks to these questions:

1. Have the objectives of the project been attained? (the objectives enumerated were those listed in the previous subsection with the exception of "To make the students see that the mathematicals models examined in the course are indeed behind the structures of the real world")
   0 (positively not) – 10 (positively yes)
   Evaluation: mean 8.36; standard deviation 1.31
2. In order that the objectives of the project could be attained, the analysis of the following structures was:
   0 (not important at all) – 10 (very much important)
   The marks given to this question are shown in Table I.

TABLE I
MARKS GIVEN TO QUESTION 2

Structure	Mean	Standard deviation
Natural structures	7.01	2.34
Roof structures	8.88	1.44
Trusses	9.19	1.20
Brazilian structures of historical importance	8.39	1.55
Structures at the choice of the students	8.66	1.81

3. The analysis of the following structures gave me:
   0 (no satisfaction at all) – 10 (very much satisfaction)
   The marks given to this question are shown in Table II.

TABLE II
MARKS GIVEN TO QUESTION 3

Structure	Mean	Standard deviation
Natural structures	6.90	2.45
Roof structures	8.51	1.62
Trusses	8.88	1.59
Brazilian structures of historical importance	8.32	1.93
Structures at the choice of the students	8.64	2.08

4. The number of structures analysed was:
   0 (very small) – 10 (very large)
   Evaluation: mean 5.66; standard deviation 1.73
5. My overall opinion about the project is:
   0 (very bad) – 10 (very good)
   Evaluation: mean 8.47; standard deviation 1.43
6. Do you think that this project should be repeated?
   0 (positively no) – 10 (positively yes)
   Evaluation: mean 9.39; standard deviation 1.36

In addition to these, the questionnaire had three other questions:

7. In your opinion, which are the project's major strengths?
8. In your opinion, which are the project's major weaknesses?
9. Please feel free to make your comments and suggestions.

The answers to the first six questions show that, in the students' opinion, the project was very successful: they think that its objectives have been attained, have a good opinion on it, and positively think that it should be repeated.

The answers to question 7 showed that, according to the students, the project's principal quality undoubtedly was the fact that it had stimulated the observation and the analysis of the structures around us and had made the students start to develop a critical way of looking at structures. Half the students mentioned this as one of the project's major qualities. Although it had not been told to the students that "To make the students see that the mathematical models examined in the course are indeed behind the structures of the real world" was one of the project's objectives, 18% of them said that one of its major strengths had been the fact of having created a link between theory and practice. The third most cited quality was the freedom they had had in the choice of the structures they would analyse.

As to the project's major weaknesses, the three weaknesses most cited were: the difficulty to find information on the structures analysed (24% of the students), lack of enough knowledge to analyse the structures (19% of the students) and lack of orientation about the project by the professors of the course (18% of the students).

The correction of the project soon showed that its major weaknesses had been in fact the lack of a clear definition of what the students should have done and a lack of orientation to the students during the execution of the project. Due to these two facts, the students tried to do much more than it had been expected they would do, and tried to describe the structures and understand their behaviour in a too complete way. Of course, being in the beginning of the course, the students would not be able to do such a deep analysis, and the objective of the project was simply to make them think about the way a structure works and to make them try to give their own interpretation of this behaviour. It had not been expected that they would try to completely understand and exactly describe them. At the beginning of the term the project previously described was given to them with no further details and no orientation was given during its execution. It can now be seen that it was ingenuousness of the professors to think that a more clear definition of the project and an orientation during its execution would not be needed.

This shortcoming did not prevent the project from being very successful: the students made very careful choices of the structures and analysed them very carefully. It could be seen that some of them had really enjoyed very much doing it, having produced very high quality work. Most of the photographs were of very high quality, not only from the photographic point of view but also from the point of view of showing the structures and their details. Many of these photographs were later used to make more transparencies to be used in the classes of the course PEF-2200 "Introduction to mechanics of structures".

As both the professors and the students had considered the experience a success, it was decided to repeat it in 2000.

THE PROJECT GIVEN IN 2000

Description of the Project

The general philosophy of the project given in 2000 is the same as that of the project given in 1999.

The evaluation of the project of 1999 revealed that some kinds of structures had been more effective than others in making the project attain its goals. The structures whose analyses pleased the students most and which contributed most to the attainment of the objectives of the project were the structures more similar to those seen in the course. For example, the natural structures analysed by the students – trees, caves, ovenbird's nests, anthills, termitaries – were very different from the framed structures seen in the course; as they could not understand their behaviour properly, they had not enjoyed very much analysing them.

It was then decided to ask the students to analyse structures more similar to the framed structures they see in the course; it was also decided to reduce the number of structures from 10 to 8.

The structures which should be analysed in the project given in 2000 were:

- An umbrella;
- A piece of furniture;
- A crane;
- A precast concrete structure in which there are simply supported beams (with or without cantilevers);
- A plane roof truss;
- A space roof truss;
- A space tower truss;
- A structure in which there is at least one arch.

One of the main weaknesses of the project of 1999 was the lack of a clear definition of what the students were expected to do in the project. To overcome this problem, in 2000 it was more thoroughly explained what the students were expected to do.

It was then informed that the analyses of the structures chosen by the students should include:

1. Photographs of the structures and of their details, especially of the connections of their different structural parts and of their supports, taken by the students;
2. Analysis of the structures, with answers to the following questions:
   - Which are the materials the structure is made of?
   - Which are the loads acting on the structure?
   - Which is its structural form – made of bars, plates, blocks, disposed in which way, etc.?;
   - How are the connections of its parts;
   - How do you think the structure deforms?

- How do you think that the loads travel from where they are applied to the supports (obs.: the deformation of a structure gives a very good indication of how the loads travel through it)?
- Which forces do you think act in the different elements of the structure – tension, compression, bending, torsion, compression and bending together, etc. (obs.: the deformation of a structure gives a very good indication of which are the forces that act in its elements)?

To make it very clear which was the philosophy of the project, the following remark was made in addition to the instructions above:

"The professors of this course know which are the limitations of the students, and do not expect the answers to the last three questions to be absolutely perfect and rigorous.

The objective of the project is to make the students think on how the structures behave and work. It is the effort made by the students to understand the behaviour of the structures that will be valourised, not a complete and exact explanation of this behaviour, which, for many of the structures chosen, will be above the level of knowledge of the students of this course".

The Evaluation of the Experience

At the end of the course, the students were asked to evaluate the project by answering the questionnaire used in 1999, adapted to the project of 2000.

It was evaluated by 97 students, who gave the following marks to first six questions:

1. Were the objectives of the project attained? (all the objectives listed in the second subsection of section "The Project Given in 1999" were listed, with the exception of objectives 4 and 5, that did not apply in the project of 2000).
   0 (positively not) – 10 (positively yes)
   Evaluation: mean 8.34; standard deviation 1.50
2. In order that the objectives of the project could be attained, the analysis of the following strucures was:
   0 (not important at all) – 10 (very much important)
   The marks given to this question are shown in Table III.
3. The analysis of the following structures gave me:
   0 (no satisfaction at all) – 10 (very much satisfaction)
   The marks given to this question are shown in Table IV.

TABLE III
MARKS GIVEN TO QUESTION 2

Structure	Mean	Standard deviation
Umbrella	7.58	2.25
Piece of furniture	7.29	2.18
Crane	8.02	1.84
Precast concrete structure	8.49	1.69
Plane roof truss	8.47	1.73
Space roof truss	8.29	1.89
Space tower truss	7.92	1.97
Structure with an arch	8.36	1.71

TABLE IV
MARKS GIVEN TO QUESTION 3

Structure	Mean	Standard deviation
Umbrella	6.16	2.69
Piece of furniture	6.36	2.61
Crane	7.61	2.05
Precast concrete structure	7.91	1.88
Plane roof truss	8.10	1.72
Space roof truss	7.90	1.96
Space tower truss	7.53	2.18
Structure with an arch	8.17	1.90

4. The number of structures analysed was:
   0 (very small) – 10 (very large)
   Evaluation: mean 6.08; standard deviation 1.39
5. My overall opinion about the project is:
   0 (very bad) – 10 (very good)
   Evaluation: mean 8.22; standard deviation 1.54
6. Do you think that this project should be repeated?
   0 (positively no) – 10 (positively yes)
   Evaluation: mean 9.09; standard deviation 1.83

As it can be seen, the project given in 2000 was also well evaluated by the students, and in their opinion it should be repeated.

According to the students, the major strength of the project – pointed out by 37% of them – was the link it had created between theory and practice. Some of the opinions of the students on this point are: "It has demonstrated to the students that there is a practical application of the subject seen in the classes...", "It has made the students see a link between the subject and the reality, by showing that what we learn has a practical application", "It has put into practice what we see in numbers", "It has not only allowed us to have a practical learning about structures, but it has also allowed us to see the validity of the mathematical models employed", "It has created a link between the concepts learned in the classroom and the real constructions", "It has made the student visualise and learn the subject out of the classroom, and to learn that the theory is really applied in the everyday practice to almost anything we see", "It has made us see that what we learn in the classroom can be applied to the reality", "It has given us a more concrete vision of the concepts seen in the classroom".

As it has already been said, the evaluation of the project given in 1999 showed that the structures closer to those examined in the course had been the most effective ones to the attainment of the project's objectives; because of it, in 2000 it was decided to ask the students to analyse structures closer to the ones they see in the classes. Probably this is the reason behind the increase from 18% to 37% in the number of students who pointed out the link of theory with practice as one of the project's major strengths, as they had now been more able to identify in the real world the mathematical models they had examined in the course.

The second strength most mentioned by the students – by 26% of them – was the stimulus the project had given to the observation of the structures around us. They wrote: "It

has made us pay attention to the structures of everyday life, whose behaviour we had not cared about before the project", "It has made me pay much more attention to the structures of any objects", "With this project I started to better observe structures to which I had not given importance before", "From now on I observe structures in a different way and I end up by noticing structures whose importance I had not known before", "It has made us open our eyes to what is around us", "Now I am accustomed to look at structures with more critical eyes", "We have started to look at structures and objects in a different way".

The fact that the project has made them observe structures in a more critical way and made them see how they work was pointed out by 20% of the students as one of the project's major strengths: "It has made us 'stop' and see how structures work", "It has promoted the interaction students-world and a better comprehension of the behaviour of common structures", "It has developed in us the curiosity to know how real structures work", "It has developed our interest in knowing how forces travel through the different structures, and consequently we have started to look at things in a different way".

The three weaknesses most pointed out by the students were: lack of enough knowledge to analyse the behaviour of the structures (22% of the students), lack of a better orientation about what they should do (13% of the students) and too little weight given to the project in the final mark of the course (5% of the students).

Although it had been better explained what it was expected that the students should do, and in spite of having been organised a meeting of the students with the professors in the middle of the term so that they could pose their doubts and questions to the professors of the course, it could be seen that these measures had not been sufficient to solve the weak points of the project.

Once again, these weaknesses have not prevented the project from being very successful, and its goals were achieved. The students did very good projects, some of them of truly exceptional quality.

It was then decided to repeat the project in 2001, with minor alterations introduced as a result of the evaluation of the project of 2000.

THE PROJECT GIVEN IN 2001

As the evaluations of the projects given in 1999 and 2000 had shown that the more effective analyses had been those of civil engineering structures similar to the ones the students examine during the course, it was decided to ask only analyses of such structures in the project given in 2001. It was also decided to further reduce the number of structures from 8 to 6.

The structures the students were asked to analyse in the present semester are:

- A construction in which there is a cantilever beam;
- A construction in which there is a simply supported beam;
- A footbridge or a bridge with lateral trusses;
- A structure with a large span;
- A structure buried in the ground;
- A structure in which there is at least one arch.

In addition to the information given about the project in 2000, in 2001 it was also explained how the professors will evaluate it, so that the students could have an even better idea of what they should do.

The items that will be evaluated in the correction of the project are:

1. It will be verified if the structures analysed really correspond to the six categories of structures that should be examined;
2. The photographs will be evaluated according to their capacity of showing the structures and their details well;
3. It will be verified if the answers to the first four questions posed are adequate;
4. In the evaluation of the other three questions, it will be verified the effort made by the students in trying to understand the structures and their behaviour;
5. The photographic quality of the photographs will be evaluated;
6. The quality of the presentation of the technical report will be evaluated.

As there are 180 students in the civil engineering course of Escola Politécnica da Universidade de São Paulo, they are divided into four classes of 45 students each, each of these classes having its own professor. The list of items above is the same the professors use when they evaluate the project, and it was prepared so that its correction by four different professors could be done in a uniform way.

As the students of 2000 still found that it was lacking a better orientation during the execution of the project, in 2001 more meetings of the with students with the professors will take place, so that they can have all their doubts and questions about the project answered during its execution.

The complete text of the project given in 2001 (in Portuguese) can be found in the site of the course PEF-2200 "Introduction to mechanics of structures". For those who would like to see this full text, the home page address of the course's site is: http://www.lmc.ep.usp.br/people/hlinde/Pef-2200/HOME.htm. After having entered the site, the button "Projeto" shall be clicked. The photographs which illustrate the text of this project are from projects done in 1999.

CONCLUSIONS

The project of observation of everyday life structures was proposed to the students of the first course of mechanics of structures especially aiming at:

- Stimulating the students to observe the constructions around them and to identify their structures;

- Stimulating the students to try to understand how structures work;
- Making the students see that the mathematicals models examined in the course are indeed behind the structures of the real world.

By feeling the importance structures have to mankind, by seeing how they work and by seeing that the theory they have in the course is indeed behind the real structures, it was expected that the students would be more interested and more enthusiastic about the study of mechanics of structures.

The project was given for the first time in 1999 and repeated in 2000. The evaluation of these experiences showed that its objectives were really attained, and that the students who did it now see the structures with different eyes and are indeed more interested in studying them.

The project of 2000 was modified so that the shortcomings verified in 1999 could be overcome. The project now in course in 2001 was modified once again so that the problems still found in 2000 could be solved. The evaluation of the project at end of this semester will give new information on how to improve the next version of the project.

It has been verified that the structures more efficient to the attainment of the objectives of the project are those similar to the ones the students examine in the course. It has also been verified that a good and thorough explanation of what it is expected the students should do and a close orientation of its execution by the professors of the course are very important for the success of the project.

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