# Designing Indicators to Measure the Quality of Engineering Courses: The Case of Escola Politécnica da Universidade de São Paulo

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*Abstract* - **The teachers of engineering courses in Brazilian public schools are recruited and selected mainly in function of their capacity to produce research. Escola Politécnica da Universidade de São Paulo (Polytechnic School of the University of São Paulo) is not an exception to the rule and most of its professors do not have a didactic and pedagogic background. Escola Politécnica da USP has about 500 teachers with broad and diversified ideas and values concerning the validity of the actions to be implemented in education, but few of them have the pedagogical training that might help them in the conduction of teaching. The Undergraduate Commission does not succeed in valuing attitudes and practices only by imposing guidelines in regulations or recommendations. The existence of a study group on the teaching of engineering might motivate and foster the adherence of a larger number of professors to capacitation in teaching technology, in pedagogy and in learning psychology. It is always fundamental to discuss a systematic assessment of the courses to allow the Board of any institution to act so as to correct deficiencies and to promote initiatives for improving quality. The need to establish indicators is evident and this paper discusses their definition and the implementation tools to generate and evaluate them.**

*Keywords:* Engineering education, Didactic and pedagogic Training, Evaluation, Indicators

## INTRODUCTION

The engineering course at Polytechnic Scholl at University of Sao Paulo (Epusp) is assessed in different ways and some different results have been presented. Despite the reflexes of the success achieved by many of its alumni, in the opinion of many of its teachers, Polytechnic Scholl has presented signs that not everything is going so well. What can actually be observed is a great uncertainty concerning the quality and the adequacy of its teaching before the new scenarios of job markets internationalization and of the necessary competences.

Perhaps especially for being concerned with maintaining the excellence of undergraduate teaching, translated in the different existing classifications, either the ones organized by written media organizations, or those ones disseminated by the official higher education assessment organizations, the leaderships of Polytechnic Scholl at University of Sao Paulo have manifested a permanent concern in improving the course.

The change in the curricular structure itself which occurred in 1999, having even altered the way of getting engaged in the engineering habilitation, is a sample of this attempt to maintain the course at Polytechnic Scholl as an acknowledged reference.

Therefore, since 1999, the student is introduced in the Engineering career through the entrance exam (*vestibular*). At the end of the first year, the student chooses a great area: Civil, Mechanics, Chemical or Electric according to his performance in the entrance exam as well as his performance in the disciplines taken at Epusp. At the end of the second year, the student chooses either a habilitation, or a sub-habilitation or an emphasis according to his performance in the disciplines taken at Epusp. Although the Engineering final groups are divided into 17: Environmental, Civil, Computer (cooperative), Electric with emphasis on Computer and Digital Systems, Electric with emphasis on Automation and Control, Electric with emphasis on Power and Automation, Electric with emphasis on Electronic Systems, Electric with emphasis on Telecommunications, Mechanics, Mechanics sub-habilitation Automation and Mechanical Systems (Mechatronics), Naval, Production, Mine, Petroleum, Metallurgy, Materials, Chemical (cooperative), the degrees granted by Epusp are those of Civil engineer, Environmental engineer, Computer engineer, Electric engineer, Mechanical engineer, Naval engineer, Metallurgical engineer, Mine engineer, Petroleum engineer, Materials engineer, Chemical engineer, Production engineer. However, has this change brought about the wondered benefits?

Since there are relatively few studies [9], [7] on what happened after the implementation of the modifications, it is essential to count on a body of teachers who researches and helps the managing groups by Epusp, such as the

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Undergraduate Commission to continuously verify the validity of what has been carried out.

Polytechnic Scholl counts on about 500 teachers with values and broad diversified ideas concerning the validity of the actions to be implemented in education, but few of them count on the pedagogical formation that might help them in the conduction of teaching. The Undergraduate Commission itself does not succeed in valuing attitudes and practices only by imposing guidelines in regulations or recommendations. The existence of a study group on teaching of engineering might motivate and foster the adherence of a larger number of teachers to be able in teaching technology, in education pedagogy and in learning psychology.

## ENGINEERING EDUCATION STUDY GROUP

In order to justify the existence of a study group, one can list some out of a number of questions made concerning the engineering course at Polytechnic Scholl.

In the current Polytechnic Scholl scenario it is important to know how can one place its engineering course in relation to the others. The comparison can be made with the other engineering schools in Brazil or even those abroad. However, it's a good new if there are enough data for this comparison.

It is important to stress that it is not simple to indicate important parameters for establishing comparisons among courses that meet people with different talents, backgrounds and purposes, even within the same area of knowledge.

In the case of the Engineering courses, it can be stated that the students entering Epusp are well prepared to participate in a selective process like the entrance exam promoted by Fuvest, but we don't know if the students are actually prepared to take Epusp courses. We don't have data about the profile of the students entering Epusp. There is a belief that most of the students come from wealthy families and that they studied at elite schools. This could be considered an advantage for that kind of students.

We want to know what are the competences of the entering students and the graduating at Epusp. The Epusp disciplines were structured to develop the values and the abilities necessitated for the XXI century engineer (NAKAO, 2000). But have the goals been achieved?

The entering students are not certain of their option concerning the desired option within engineering. We want to know what happens if they are frustrated if they not enter in the first the desired option.

Following a world trend that shows a smaller interest for the engineering schools, has the number of candidates for the vacancies at the Epusp Engineering courses decreased. Its important to revert that situation.

In 2003, there were about 3 million students enrolled in higher education courses in Brazil, in the 12,155 courses of 1,391 universities, university centers, integrated higher education schools, higher education schools, schools, institutes and technological education centers. What do these numbers mean?

Indicators could be chosen to establish a relationship among the quality of the course, the students' learning, and the teachers' teaching.

These indicators could be the class attendance rates, the percentage of approval in the disciplines and the dropping out rates, or are they not representative and do not reflect a dissatisfaction with the course?

How many students complete the course in the ideal five-year period is an important indicator to be considered.

When the cost of an engineering course is presented or the number of students failing a discipline is registered, it should be kept in mind that society pays for the free tuition at a State university like University of São Paulo. Therefore, if there are track corrections that can optimize learning and decrease the failure rates in the disciplines, they ought to be conducted with the pertinent criteria and care, and must be urgent. Can one imagine a private sector enterprise (even being a university) failing to assess its costs and not adopting corrective measures?

It is observed that there are problems with motivation, with the background and with the career.

In the congresses promoted by the Brazilian Association of Engineering Teaching (Abenge) a series of suggestions for measures have been presented to improve the engineering courses. It is important that these suggestions will be knowed by all teachers.

The implementation at the undergraduate teaching of Polytechnic Scholl, from the deficiencies pointed out in the studies and surveys conducted at the time by Polytechnic Scholl centennial in 1993, could improve the course. The new curricular structure implemented in 1999 and denominated EC-2 complies with the curricular guidelines of engineering teaching. Indicators can be used to measure the satisfaction with what was done. The validity of the follow-ups conducted could be registered. The methodology of directly interfering in the processes could validate the result of the research.

Since 1993, there has been an evolution in the school management, in the facilities provided to both students and teachers, in the teaching methodologies and learning and in the assessments. Updating courses were offered to the teaching staff, as well as seminars for increasing the value of undergraduate teaching, workshops for presenting research lines and there is project Poli 2015 in course. The result of this process colud be measured and there are still necessary and urgent to do interventions and to evaluate the impact of this new practice.

## Group Formation

In 2003, in its 110th anniversary, Polytechnic Scholl was engaged in a project named Poli 2015 with the purpose of getting organized to keep playing an important role in society. Although it happens to be a global program, only the aspect related to undergraduate teaching will be commented on, since it is the scope of this work.

In a plenary session with guests representing some of the entities related to Engineering, as well as students and teachers, a text was elaborated to provide an overview of what was to be expected from Epusp for the year 2015: "Poli 2015 will be a national and international reference in university teaching, research and extension. It will be committed with sustainable development in the social, economic and environmental spheres. It will count on a

flexible and integrated management. The Poli 2015 engineer will have a comprehensive background, both systemic and analytical, founded on solid knowledge of the basic sciences for Engineering, with an attitude for continuing learning. The engineer will be competent in human relationship and in communication. He/she will present ethical posture as well as cultural and social commitment with Brazil" [5].

These issues have always been treated by the members of the Undergraduate Commission, of the Didactic Guidance Commissions coordinating the courses of the different habilitations, of the Basic Core Commission coordinating the first two years of the engineering course, of the cooperative courses Coordination's and by some teachers who also made undergraduate teaching their research theme.

There was, however, the need to organize the knowledge acquired through the experiences and to direct the energy of the different groups in order to attain the common goal of improving teaching.

Therefore, the Engineering Education Study Group emerged from the meetings of the Teaching Group within the Poli 2015 project. The people participating in the meetings, who built the projects related to teaching for the strategic planning felt the need to establish a body committed with the suggestions and that could provide foundations for the actions that the Epusp Board deemed necessary to implement.

The problems related to teaching and learning processes are always present in the discussions involving teachers and pedagogical coordinators. The causes pointed out and the strategies suggested as a solution undergo individual and collective pedagogical attitudes which, even not being immediately implemented, modify the environment and alter the conditions in which each hypothesis is assessed.

## ACTIONS FOR THE GROUP

A group as the one suggested can maintain a minimal cohesion so that the other activities of the teaching staff do not make teachers set this concern with education aside.

It is important to emphasize that the emergence of the group was the natural path from the researches conducted by Epusp teaching staff. The discussion on the teaching and learning process, the modifications and adaptations of the curricular project, the establishment and the implementation of indicators to aid the course management are some of the propositions for the Engineering Education Study Group.

### Broadening the discussion on the teaching and learning process

According to [11] learning is the process by means one acquires information, abilities, attitudes, competences and values from the contact with the environment and with other people. It is different from innate factors and, according to Vygotsky, especially because of its emphasis on the socio-historical processes, includes the interdependence of those involved in the process. [11] prefers to use the word *aprendizado*, which is less common than *aprendizagem* (both meaning *learning* in English) to help recall that the concept has a more comprehensive meaning, involving social interaction, as Vygotsky utilizes the Russian term *obuchenie* which means something like the teaching-learning process, including the one who learns, the one who teaches and the relationship among these people.

### The meaning of mistake

Understanding is determined by the ability with which one manages to form concepts and build up an internal model that comes closer to reality. Hence, from this point of view, when someone fails to understand the questions, the instructions or explanations presented by another person, this could be attributed mostly to the lack of ability of the one who communicates, at a level that is not suitable to that one the other person is able to operate, and less to the deficiencies of the person receiving the question, instruction or the explanation. One cannot make the mistake of attributing mistakes to incapacity, for they depend on their present levels of thought and processing.

It is known that even the culture one lives in may influence information processing as in knowledge acquisition. According to [4], the left hemisphere of the human brain predominantly processes rational, direct, logical, mathematical and objective information, whereas the right hemisphere processes the qualitative, intuitive, visual, artistic and subjective information. And, therefore, when one observes the higher right-answer rates of the Chinese in answers to more intuitive questions on the structural behavior in a research between American and Chinese students, this was credited to the fact that, in the East, graphic signs are used for writing; in the West, the engineering teaching is distinguished by direct, objective, scientific rationing.

The students of the engineering schools in Brazil, at first, are ready for the cognitive development that the tradition and the history of teaching consider to be adequate. This way, the Engineering Education Study Group may help reminding the teacher that a mistake made by these students is simply a sign of the effort to find the right answer according to their cognitive structure.

If the answers are not those ones expected, it is important to verify whether they are not in accordance with the way the student is able to process and, mainly, whether the learning material was adequately presented to that level.

If the opportunities of conceptualizing at a higher level than the adequate are not fully utilized, this should not be interpreted as lack of interest, for instance. At no time should the student be made confused or feel guilty if the failure lies in the learning material and on the student's understanding level.

At all levels, the teacher should take into account how the student processes the information and deals with it. Mistakes occur because either the main elements have not been correctly interpreted or information previously received has been retrieved and applied incorrectly.

Therefore, mistakes should be investigated at the point in which they were originated and not globally, at the end of a process. Mistakes provide signs of the deficiencies to be corrected. They provide clues about what is wrong, both in the teaching and in the learning process, and the mistake is not always the responsibility of the student himself. The students' mistake, actually, teaches more to the attentive and differentiated teacher than the right answers do.

The Engineering Education Study Group may help the correct construction of these scenarios.

### Attaining requirements

Admitting that means of learning and progresses are different for each person, the responsibility of the teacher as the teaching and learning process manager emerges. He/she makes decisions during the classes which, supposedly, should promote progress, whenever possible, along each of the students' stages. This task includes the attainment of these requirements for continuity.

Certainly the intention is not to provide the teacher solely with the control of the process. However, as an active element is expected from the student, the sole purpose of the person who teaches should not be the presentation of content or the promotion of training for repeating the explanation.

Once again the question comes up: does the teacher at the engineering schools count on the adequate background for performing this role? At the moment, researchers on education, both national and international, have emphasized what has been denominated studies on the instructor's thought, that is, a reflexive approach on education. According to [1], considering that reflexion is a human characteristic, every teacher that proposes to be competent has to reflect on what he/she does. [14] is the predecessor of this pedagogical line and presents reflexion on action, reflexion about action and reflexion about the reflexion on the action. He stands out that reflexion on action occurs at the moment the lesson is taking place. They are the perceptions the teacher has, as a consequence of his/her knowledge from experience, and which allow modifying, introducing explanations, making small and opportune route corrections. Reflexion about the action occurs when the teacher reflects soon after finishing the class and along that same day, asking him/herself what did not go right and the reason for it, or even taking advantage of the satisfaction of what went right as a motivator factor. Reflexion about the reflexion on the action is deep, and implies a quest for awareness.

Therefore, the knowledge obtained should be taken into consideration based on what the teacher elaborates personally in terms of teaching practice and of the construction of this practice [10].

The Engineering Education Study Group can compile and disseminate these competences from the different successful teachers.

### Correcting teachers' faulty points

Some faulty points can be pointed out in the teaching background for the technological area, according to [12]: teaching based on knowledge already elaborated; great oscillation in the degrees of difficulty of the examples the teacher offers according to his/her preferences; courses with no link to everyday life; class centered only on the teacher's pace and speaking; atmosphere (teacher and colleague) which constrains the student; teaching centered on a goal, memorization and reproduction of repetitive tasks; compliance with the program and with the level of approach independently of the advancement made by students; veneration to precision; valorization of the product, forgetting about the process; works and requirements for individual performance.

These faulty points also identified by [3] are difficult of being corrected. There are structural factors, which are not under the teacher's control. However, if identified, the procedures leading to these faulty points should be avoided. Awareness of and reflexion on them will already help the teacher to also accept the fact that the student is failing to learn as part of the teacher's share of responsibility.

There are several reports of pedagogical trainings conducted in different ways. In prominence is the experience conducted at Universidade Federal de Juiz de Fora (UFJF) described by [13] when it offered a Workshop on Educational Means, whose goals were "to provide a basis for the psycho pedagogical foundation for the production of learning materials" and "to include the reflexion on the image and knowledge in the didactical approaches".

With the pedagogical courses the Engineering Education Study Group may propose (after studies) to be programmed for teachers, full advantage can be taken from offering different ways of developing motivation and the dissemination of knowledge, as suggested by [6].

### Expository or participative classes?

Personal characteristics end up defining preferences for different ways of learning and teaching.

In the research by [2], students reported what they understood as being the best teaching, the one in which the teacher presents the subject and conducts exercises (33%), the teacher presents the subject interacting with students (23%), the teacher programs activities (questions, problems, projects) to be conducted by students (21%), the teacher and students discuss the subject indicated to be previously studied (12%), the teacher presents the subject and the students attend the class, make notes and occasionally ask a question or intervenes (4%). This is a datum showing the need for diversifying strategies and may be disseminated by the Study Group to stimulate the quest for diversification.

## ESTABLISHING INDICATORS

It is always fundamental to discuss an assessment systematic of the courses that allows the Board of any institution to act so as to correct deficiencies and to promote initiatives for improving quality.

The need to establish indicators is evident; otherwise, how would it be possible to verify whether the undergraduate teaching at Polytechnic Scholl improved or gone worse with EC-2 - New Curricular Structure implemented in 1999. The most plausible idea is to justify any thesis by means of indicators. However, it was a very hard task since the simplest indicators (such as the rate of approval) could betray the validity of its reading for the unavailability of important data such as the number of missing students, the number of drop-outs, the gap between the preparation and the assessments, the difficulty of the assessments.

The research with the teachers responsible for the development of each discipline in each teaching term, on the difficulties presented by students in each group, on the level of questions in the assessments may collect some of the variables that could not fail to be considered if the focus

were the number of students approved, and if these data are not systematically available. The Undergraduate Commission of Polytechnic Scholl itself sought a definition of relevant indicators that could allow the assessment of the undergraduate courses and point out ways for the continuous improvement of the teaching quality. In 2004, a task force was established, and suggested the indicators. They are numbers that allow assessing whether the undergraduate course is satisfactorily meeting the expectations of Society, of the Institution, or even the students'. When this databank is available, it will be possible to check these expectations, how they are met and their evolution. These indicators, which were not implemented, should deserve the attention of the Engineering Education Study Group for the continuity that is deemed necessary.

Table 1. Indicators suggested: discipline and group

| INDICATORS |
|---|
| DISCIPLINE |
| Ideal number of places[2] |
| Necessary number of places[3] |
| Maximum number of places[4] |
| Number of places offered to students from other courses[5] |
| Number of places offered to special students /the elderly[6] |
| Number of students enrolled per discipline |
| Percentage of occupation[7] |
| Percentage of students enrolled for the 1st time |
| Percentage of students enrolled for the 2nd time |
| Percentage of students enrolled for the third or more times |
| Percentage of students' approvals in the 1st assessment |
| Percentage of students' failures in the 1st assessment due to marks and absence |
| Percentage of students' failures in the 1st assessment due to marks |
| Percentage of students' failures in the 1st assessment due to absence |
| Percentage of students' approvals in the 2nd assessment |
| Total percentage of students' approvals |
| Total percentage of students' failures |
| Percentage of average attendance to classes |
| Average of marks attained by the ones who took the discipline[8] |
| |
| **GROUP[9]** |
| Percentage of students with no dependence (ideal curriculum) |
| Average of marks attained by students in each teaching period[10] |
| General average of students up to the present semester[11] |
| List of students with qualitative information |
| Evasion/transference |

Table 2. Indicators suggested: cycle

| **INDICATORS** |
|---|
| **CYCLE** (Evolution of the groups/historical vision of the whole) |
| **POLI[12]** |
| Percentage of students in the group who graduated |
| Average time of permanence of those who graduated |
| Percentage of students who graduate in 5 years |
| Percentage of students who graduate in 5.5 years |
| Percentage of students who graduate in 6 years |
| Percentage of students who graduate in 6.5 years |
| Percentage of students who graduate in 7 years |
| Percentage of students who graduate in 7.5 years |
| Percentage of students who graduate in 8 years |
| Percentage of students who graduate in 8.5 years |
| Percentage of students who graduate in 9 years or more |
| Average number of failures per teaching term (per group) |
| Number of students in article 76 I[13] |
| Percentage of these that graduate |
| Number of students in article 76 II[14] |
| Average number of semesters of students in article 76 II |
| Percentage of these that graduate |
| Number of students in article 80[15] |
| Percentage of these that graduate |
| Number of students in article 75[16] |
| Number of places |
| Relationship candidate/place (entrance exam, GA, habilitation/emphasis). |
| Number of students enrolled (per round) |
| Evasion rate (per Fuvest round)[17] |
| Distribution of students (per age, sex, region – capital, hinterland, State) |
| Number of students (Basic Core, GA, habilitation/emphasis) |
| Number of students with a dependence in each discipline |
| Interruptions (percentage, average time, reasons) |
| Total number of drop-outs of the course |
| Average of time for concluding the course |

## REAL DATA MEASURED

The project to obtain the indicators proposed is quite hard and takes a lot of time because Brazilian engineering schools have no experience with those kinds of indicators. Table 3 and figure 1 shows some preliminary data of Polytechnic School at USP.

Table 3. New students of year (i-5) and engineers of year (i) (courses semester)

| year | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|
| Entering students | 720 | 720 | 720 | 720 | 720 | 720 |
| Engineers Graduated | 576 | 559 | 568 | 571 | 518 | 556 |
| Evasion/Retention | 12,4% | 22,4% | 21,1% | 20,7% | 28,1% | 22,8% |

[2] Number those who would be enrolled for the 1st time, in the ideal semester
[3] Ideal + total number of externally transferred + total of those who owe (in conditions, who should have already taken the discipline).
[4] Number defined by the available resources (professors, infrastructure).
[5] Understanding the course as that identified with the Júpiter code (USP control system).
[6] Ratio between number of students enrolled and the ideal number of places.
[7] In the discipline itself or in an equivalent one, it is necessary to use the Intranet filter (Epusp internal access system).
[8] History of the group.
[9] It is necessary to use the Intranet filter.
[10] More than 9 years taken, excluding the fully interrupted terms.
[11] Application to restitute the place.
[12] Data available in the educational Support section of Epusp.
[13] The USP Jupiter warns. Less than 20% approval in the past 4 terms taken.
[14] More than 9 years taken, excluding the fully interrupted terms.
[15] Application to restitute the place.
[16] Disconnected by administrative action (automatically by the system): for not having enrolled for three 3 consecutive teaching terms, for failing due to absence in the 1st and 2nd Semesters of the starting year, for having zero credits approved in 4 consecutive semesters, for simultaneously enrolling at another public school- state or federal.
[17] 1st round, 2nd round, 3rd round, confirmation of enrollment, 4th and other rounds.

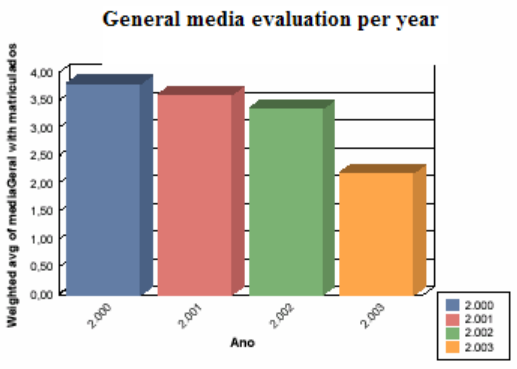


Figure 1
General media evaluation of the discipline MAP2121 – Numerical Methods

The relation between the candidates of entering and the vacancies at Polytechnic School are in media 10 to 14, compared with law and medicine is quite inferior.

The indicator that show the total disciplines course evaluation media of the students is between 5,3 and 6,6 in the years 1998 and 1999.

The average time of permanence is are between 5,8 and 6,4 in the years 1998 to 2003, while the normal expected are 5 years.

The percentage of students who graduate in 5 years are between 35 a 48% in the years 1998 to 2003

The total number of drop-outs of the course in the years 1999 and 2004 with the New Curricular Structure dropped from 87 to 12 students.

## FINAL CONSIDERATIONS

The establishment of Engineering Education Study Group had as main goals:

- Developing integration and synergy among the participants by promoting meetings and gatherings for exchanging experiences;
- Developing didactic training and pedagogical coursesfor the teaching staff using national and international research material[15], [16], [17] and [18];
- Proposing and implementing managing tools for the teaching and learning process based on the profile of the engineer expected to be formed, defined by a set of competences, abilities, attitudes and contents and in historical indicators aiming at well defined goals.

The Engineering Education Study Group initially proposed a series of activities to attain these goals:

- Implementation of system for organizing lectures, system for promoting courses and systems for organizing and promoting training workshops and didactic experience workshops;
- Promotion of training in the use of tools for aiding teaching (WEBCT, Moodle, Col and similar ones);
- Project and implementation of infrastructure for producing didactic material;
- Establishment of a service of “didactic consultancy”;
- Proposition and implementation of a financing system for education research projects and a virtual library on engineering teaching;
- Implementation and maintenance of an indicator system available for consultations by all the Epusp teaching staff;
- Proposition, implementation and maintenance of an assessment system for disciplines and courses;
- Proposition and implementation a system for stimulating the conduction of teaching at Epusp and a historic date bank of the interest of teaching;
- Implementation of a system to identify and to disseminate events of interest of researchers on engineering teaching and a system to identify and to disseminate call for works;
- Implementation of a Website; of Follow-up Reports; of Information Bulletins; of Dissemination Periodical.

It is expected that, with the establishment of this group, the teaching and learning process may achieve its true value.

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