

NEW TEACHING DESIGNS APPLIED IN ENGINEERING SCHOOLS: AN EMPIRICAL CASE STUDY ON NON TECHNICAL SUBJECTS

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ABSTRACT

Brazilian public universities, in particular, engineering schools, have been founded inspired by European models: students following a learning process in a passive mode, where knowledge is transferred from professors in a one oriented way. The aim of this paper is to discuss about pros and cons of experimental methods on non technical subjects taught in engineering practices, once the approach normally adopted in these situations differ from engineering courses logic, where praxis is at stake. To achieve that, an empirical case study is done, at Polytechnic School of University of Sao Paulo, using a classroom experiment in economics science. The experimentation dealt with Competitive Equilibrium, one of the most central concepts in microeconomics. The results indicates that this is an efficient method based on satisfaction and academic score indicators which shows stronger integration of students on Managerial courses, requirement that has been highlighted in the last years. This learning proposal appears to encourage proactive behaviour from students, building their own knowledge. Moreover, this case study helped to evaluate assumptions of neoclassical economics on the presented topic (Competitive Equilibrium) and point out aspects that cannot be directly related to the neoclassical approach but to other economic theories. In this case, the linkage between different economics approaches could be widely explored. Nevertheless, some weaknesses must be mentioned as for a natural resistance to change must be faced. Going further in this trade-off appears to be the questions that researchers on design to engineering education will face and this paper explores.

Keywords: Design to engineering education; new teaching designs; learning proposal

1 INTRODUCTION

Brazilian public universities, in particular, engineering schools, have been founded inspired by European models, including the Portuguese model, since higher education has its roots in the imperial period, as well as the French and the German model ([1], [2]). In all of these models students follow a learning process in a passive mode, also called “chalk and talk”, where knowledge is transferred from professors in a one oriented way. This models is more linked with Socratic methods, instead of scholastics ones. This fact is also evidenced on the research conducted by Michael Watts [3], in which the "chalk and talk" style still predominates in courses related to economics, the author emphasizes that other teaching methods have been employed with increasing importance.

In this line, the Brazilian university model has also been questioned. This phenomenon may be clearly noticed at Polytechnic School of University of Sao Paulo, one of the biggest and better evaluated universities in Latin America, according to different international rankings, such as Times Higher Education and QS ranking. Recently, this traditional engineering school revisited the curriculum inspired by the motto “greater flexibility in the careers” and a new curriculum system was proposed to the engineering students who will be free to choose part of their courses.

It is undisputed that the engineering education is confronted by the challenges of globalization, inseparable phenomenon of recent decades. By observing the practices adopted by universities with high quality standard, it is punctuated [4] the need for inclusion of managerial disciplines in the curriculum of engineering courses. In this way, students gain a greater understanding could incorporate problems linked to the characteristic engineering projects, developing industry related

skills [5]. In the Brazilian context, this outlook is not different. In the top five engineering schools in Brazil, in all their courses, managerial disciplines such as introductory economics and principles of management are offered.

Although concepts of economics are universal, their approach depends on the context in which they are discussed. It is punctuated [6] the difference in teaching economics to business students and engineering students, as for the differences in mathematics teaching in these two contexts [7].

Regarding the teaching of the discipline of economics, teaching methods have been widely discussed, especially with regard to the use of resources which aim to achieve that students are actively involved in the learning process ([8], [9], [10], and [11]). A more active teaching system is widely discussed in the scientific literature, such as economics experiments, games or other interactive activities. Virtual activities are as well discussed ([8], [9], [10], [11]).

Taking into account these considerations, a question arises about the efficiency of experimental methods. Although there are many studies reporting the experience using innovative methods ([8], [9], [10], [11]), few approach the efficiency of these new methods. According to research carried out in the ISI Web of Science only twenty articles with topics on "efficiency" and "teaching methods" were found.

Although the pertinence and relevance of this matter, this paper is not concerned with strong considerations on pedagogical aspects. The focus is on new teaching designs applied in engineering courses. The aim is to discuss about pros and cons of experimental methods on non technical subjects taught in engineering practices, once the approach normally adopted in these situations differ from engineering courses logic, where praxis is at stake.

To achieve that, an empirical case study is conducted, at Polytechnic School of University of Sao Paulo, using a classroom experiment in economics science. The experiment dealt with Competitive Equilibrium, one of the most central concepts in microeconomics.

This article is structured in five sections. Section 1 presents the context and purpose of the research. In section 2, the theoretical background of the research is presented, focusing the theory that is the basis of the experiment. Section 3 presents the details of the experimental method used in the case study. Section 4 presents and discusses the main findings of the research. Section 5 provides the main findings of the research, followed by the interpretation of the main results. And finally the contribution to the field of research studied, as well as the limitations of this research.

2 THEORETICAL BACKGROUND

To understand Competitive Equilibrium, is vital to introduce what is behind the traditional economics theory. With the aim of understating the logic adopted in experimental method, in this session, this theme is briefly discussed. A special attention is given to the assumptions of this theory. This will be significantly important to evaluate if the experimental method adopted is efficient or not in keeping this assumptions.

The firm from the perspective of traditional economics theory is understood as a "black box". In this sense, the firm is perceived as just a production function and it is neglected the relation inside and outside firm, its origin and why still exists or not. Taking this in mind the economics theory develops the concept of competitive market, as a kind of market structure. According to Mankiw [12] competitive market is a "market with many buyers and sellers trading identical products so that each buyer and seller is a price taker".

Perfect information of all economic agents, large number of small firms, firms can free entry and exit, and homogenous product characterize the competitive market according to the traditional economic theory. In this structure, the agents are not able to influence price or quantity of market, which implies that they are price takers. Besides, the agents' revenue is proportional to the amount of output produced and, in order to maximize profit, a firm chooses a quantity of output such that marginal revenue equals marginal cost. Consequently, the supply curve is the firm's marginal cost curve. This happen because of the large number of agents and the difficulty to organize themselves in order to interfere in the market.

According to Demsetz [13] the marginal product value of one input is a function of only one controllable variable, that is the quantity of inputs. In this case, elements such as price, technology and

work quality does not affect productivity. The quantity is the only variable considered in the manager decisions.

3 EXPERIMENTAL METHOD

The case study procedure was conducted following Ruffle’s recommendations [14]. A total number of 56 chemical engineering students, who had never had a formal contact with economics concepts, took part in the classroom experiment performed in one of the “Introduction to Economics” lectures.

Due to human resources and physical location constraints, two different blocks of students underwent the experimentation simultaneously in the same room but effort was made to avoid any communication between them.

Each block was further split up into two different groups of the same size, one representing the buyers and the other, the sellers. All students were tagged in a manner that sellers could visibly be distinguished from buyers. The tagging done, the experiment was able to be further carried out.

From this point on, the experimentation was run in rounds. In each round, buyers and sellers were physically separated and a single card was given to each student containing a value which represented his/her utility. A buyer could only negotiate one single unit of some sort of product with a seller, who could in turn sell his single unit of the product. Thus, the cards that sellers and buyers received had different meanings: for buyers, the value represented the maximum amount of money they could spend on a product, while for the sellers, the number defined the production cost of his product and they could only sell his unit of production for a value greater than that displayed on the card.

The students were informed not to tell his/her colleagues about the values received and could only start the negotiation after a pre-defined command. Negotiation occurred in a pit market and the round could last no more than a pre-established period of time.

Ended the round, sellers and buyer who had agreed upon a price should inform the supervisors about the accorded value. Those who didn’t make a deal should also report the instructors. All the cards should be returned to the instructors and mixed up in order not to give the same buyer or seller the same card every round. Profit for every participant involved in a negotiation was calculated in every round: for buyers it was the difference between his/her amount of money and that agreed while for sellers it was the difference between the agreed value and the production cost. Profit, participants’ ID and agreed price were recorded in an Excel spreadsheet before the beginning of a new round.

4 RESULTS AND ANALYSIS

The analysis proposed in this article goes in two different axis. The first one focus on the didactical aspects, whereas the second one will regard the economics learning results. Two questions about the former axis will be discussed: satisfaction perceived and alleged by the students and resources deployed with the teaching method applied in the experiment. The later axis, in turn, concerns two other questions: the retain efficiency of learning economics concepts and the capability of experimental methods to treat these economic concepts.

Normally, the use of different teaching methods is evaluated by the students’ satisfaction service. Adopting this same approach, it was measured the students’ satisfaction through five Likert based questions during different moments in the course. In particular for the proposal of this article, it was surveyed the satisfaction one class before in which was employed the traditional method of solving exercises and surveyed again after the experiment conducted in the classroom. The evolution of the results is summarized on Table 1. The total of ten questionnaires, filled by five people each, was collected.

Table 1. Results of the satisfaction survey with students

Item asked to students	Before Experiment	Post Experiment	After Experiment
Scope of the exercised contents	4.25	3.50	4.09
Opportunity to review the concepts studied in lecture	4.15	3.40	3.92
Development of team activity	4.06	3.90	3.82
Temporal extent of activity	3.40	3.10	3.62
Dynamics of activity	3.40	4.30	3.32

According to results show on Table 1, it is undeniable that difference can be noticed. Statistics tests goes in the same direction revealing significant differences between the 'traditional activities' and experiment. By one hand, the proxies that measure dynamics of activity have a improvement. By the other hand, students are very clear with their unhappiness with the time expended by this activity when compared to traditional ones. Reinforcing the results, is important to mention that the standard deviation is significantly high. The variance coefficient is impressive 0.49, showing inconsistent and no uniform results.

The results observed on satisfaction are consistent with the findings that are likely to be found in the literature on the subject: students that seek more dynamic and interactive methods. However these results abetting a given data revealed by this research. Students are reluctant or even resistant to proposed changes. This can be evidenced by observing the qualitative assessments made at the end of the experiment, where they were questioned about the ability of the experiment on students' learning process. Results can also be noted that the first and second proxies in Table 1.

Among the 5 proxis adopted, only the criteria related to dynamics increased with experimental method activity. Regarding the other four measures, the results go against this line. It is possible observe a generated decrease in all these values. The stability of these figure may be noticed when the results from the first traditional activity was applied (before the experiment) with the results from the traditional activity after the experiment.

An important aspect is usually ignored: the need for additional resources in terms of materials and people. During the experiment were there the professor, assistant professor and three guests, thus overcoming the resources expended in a traditional classroom. Besides human resources, it's important to include material resources just for this experience, more than 300 printed pages and cards were consumed, plus technological appliances. Even these methods bring benefits to the students, it's relevant to highlight the reality in different Brazilian universities it's not the same from the University of São Paulo, which counts with highest university budget in Brazil. Hence, adopting this different approach implies an additional challenge: capture the resources needed.

When asked about the effectiveness of an educational method, one should not focus only on the aspects already discussed. One must keep in mind that the educational approach aims to enhance the education of students. Given this caveat, it is also crucial to note is after the experiment students were able to absorb the concepts that were being addressed by this method. In this case, as outlined in the theoretical background, competitive balance was the concept behind the experiment. To assess the level of understanding of students in the final assessment they were asked, in a very simple and direct way about the experiment. Precisely the following research was called: "The experiment conducted in the classroom had a well-defined goal. What was the point of it? Which concept (s) was (were) tested? How it was possible to check if the goal has been reached? What the preliminary results indicated? What factors could have led to different results from those that were expected?" The correction of this question followed the following rule: each correct statement about the experiment the student received the score of 0.1, with a maximum score of 1.0. The correction was performed by the assistant professor and reviewed by the teacher. A total of 58 took the test and all were present on the day of the experiment. It is worth mentioning that the adoption of this mean was motivated by the seriousness with which students perform a test.

The results indicate a deficiency in the capacity to absorb the contents treated there, with a score of 0,27 (27%), with a standard deviation of 0,25, clearly shows this deficiency. The students had significant difficulty in understanding the theoretical foundations of the experiment, associating them with solids contents that had been explored in lectures, as well as interpreting the results that were submitted after the experiment session. A comparison with the overall average of the final test results confirms this finding. The overall performance was higher than the specific performance question about this experiment (48, 6%). It would still be possible to compare the result with the middle term test (65, 5%), the results of which were more significant than those obtained.

Moreover, it is interesting to analyze if the experimental method is actually able to test, via a practical approach, theoretical concepts. In this particular case, to test the operation of a market in perfect competition. It is known that experimental approaches have limitations such as the inability to reproduce real situations under which the theory speaks of. The experiment conducted in this study, as already highlighted, is about assumptions of neoclassical microeconomic theory. These assumptions define specific behaviours, whose disobedience may result in distortions in the expected results. This is a already much debated and questioned theory. Williansom [15] debates these assumptions by

inserting the variables of bounded rationality, imperfect information, uncertainty, and other variables that define transaction costs as defining elements of the behaviour of market players who were ignored by neoclassical theory. It is worth to question whether an experiment conducted in the classroom is able to discern specific aspects of a theory alone, disregarding the influence of other variables, already widely exploited in defining the behaviour of market actors. The intention here is to raise the discussion of the efficiency of the experimental method to study this specific topic, knowing that the result may be biased by a number of factors. In this specific case, the goal would be met if the experiment were able to isolate these variables, exactly fulfilling the assumptions of the theory underlying the experiment.

However, require the students explicitly or implicitly such an attitude is something significantly difficult, or even impossible, since we are dealing with students of a course in introductory economics. This difficulty can lead to a paradoxical situation where the results distorted by the failure of theoretical assumptions leads to confusion as to the students' understanding of concepts. In the specific case, variables that are widely exploited in heterodox theories of economics, as a previous relationship, uncertainty, friendship, incomplete information, were decisive for the result not reaching the walrasian equilibrium. Thus, students were faced with concepts that fled to what was being examined by the experiment. Clearly, more robust models of such experiments could isolate variables in a more particular way, but more sophisticated and expensive resources would be needed. Therefore, experimental methods, as the one adopted, not necessarily fulfil the objective of delineating, because of the significant difficulty of keeping under control variables that are unknown by the students themselves.

Last but not least, is valid to highlight a last finding observed through a qualitative analysis. The introduction of new methods, such as adopted, requires a change of attitude, a change of behaviour. To do so, a break with centuries-old tradition should be taken. Students pass from a passive mode to an active mode in, which can be considered, an abrupt way. It is necessary, therefore, an effort to track possible dispersions, riots, discouragement, disruptions or any other form of shambles. In a situation where an only teacher had just come into the existence of several regents. How to make everyone stay in harmony, is a considerable challenge.

5 CONCLUSION

Many challenges arise when changes in teaching methodology changes. This article aimed to discuss the efficiency of experimental methods in teaching introductory economics for engineers. The attempt was to approximate the teaching of non-technical disciplines to the reality and characteristics of this kind of audience. The main question was to precisely evaluate the efficiency of alternative methods, focusing on the experimental method to this profile of students.

The experiment replicated in this study addressed the concept of competitive equilibrium, a central concept in microeconomics study, grounded on a number of assumptions. To answer the question that was posed in this article, a case study was conducted with students in an engineering course at the University of Sao Paulo.

The efficiency in this study was analyzed in different perspectives and the results were not inspiring. The assessment, as perceived by the students, indicated that satisfaction, in terms of dynamics, had an increase, albeit small, in the levels earned. The results were consistent with the literature on the subject. However, when students were asked about coverage, capacity concept review, among other issues, the results were not satisfactory. In general, there was a reduction in the degree of satisfaction of these variables at the time of application of the experiment.

Moreover, analyzing the capacity of absorption of the contents by the students treated in the experiment, measured through official assessments applied to determine whether to approve or not the student in an activity that commonly that involves greater commitment and seriousness from the students, the result was clearly insignificant. With a level of achievement of 27%, this number is well below the yield constant in other reviews or even on total of their evaluation.

Other observations can be punctuated as for the significant need for additional resources, the involvement and collaboration of students and the clear violation of theoretical assumptions, something difficult to control in the conducted experiment. All these matters lead the validity and applicability of these methods, as they are currently applied at universities that aim to achieve higher parameters in terms of quality.

Clearly this study has its limitations, such as the restriction to a single case study and no further discussion of pedagogical issues. It is suggested expanding the study and developing additional proxies that measure the efficiency of these methods.

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REFERENCES

- [1] Favero M.L.A. University in Brazil: from its origins to university reform – 1968. *Educar*, 2006, 28, 17-36.
- [2] Paula M.F. Higher education in Brazil: concepts and influences. *Avaliação: Revista da Avaliação da Educação Superior*, 2009, 14(1), 71-84.
- [3] Watts M. and Schaur G. Teaching and Assessment Methods in Undergraduate Economics: A Fourth National Quinquennial Survey. *Journal of Economic Education*, 2011, 42(3), 294-309.
- [4] Cheah C.Y.J., Chen P. and Ting S.K. Globalization Challenges, Legacies, and Civil Engineering Curriculum Reform. *Journal of Professional Issues in Engineering Education and Practice*, 2005, 131(2), 105-110.
- [5] Arlett C., Lamb F., Dales R., Willis L. and Hurdle E. Meeting the needs of industry: the drivers for change in engineering education. *Engineering Education*, 2010, 5(2), 18-25.
- [6] Islam S. Teaching introductory economics to students of different majors. In *American Society of Business and Behavioural Sciences Annual Conference, ASBBS'18*, Vol. 18(1), Las Vegas, February 2011, pp.877-885.
- [7] Purvinis O. Mathematics for engineers and economists: similarities and differences. *European Journal of Engineering Education*, 2002, 27(3), 267-272.
- [8] Katz A. and Becker W.E. Technology and the teaching of economics to undergraduates. *Journal of Economic Education*, 1999, 30(3), 194-199.
- [9] Becker W.E. and Watts M. Teaching tools: teaching methods in undergraduate economic. *Economic Inquiry*, 1995, 33(4), 692-700.
- [10] Becker W.E. Teaching economics in the 21st century. *The Journal of Economic Perspective*, 2000, 14(1), 109-119.
- [11] Maier M.H., McGoldrick K. and Simkins, S. P. Starting point: pedagogic resources for teaching and learning economics. *Journal of Economic Education*, 2012, 43(2), 215-220.
- [12] Mankiw, N. *Introdução à Economia*. 2^a ed. São Paulo: Thompson, 2005.
- [13] Demsetz, H. *The economics of business firm: seven critical commentaries by Harold Demsetz*. Cambridge University Press, 1995, 191p.
- [14] Ruffle B.J. Competitive equilibrium and classroom pit markets. *Journal of Economic Education*, 2003, 34(2), 123-137.
- [15] Williamson, O. E. Prize Lecture: Transaction Cost Economics: The Natural Progression". Nobelprize.org. Nobel Media AB 2013. Web. 25 Feb 2014.