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Teaching circuit analysis and learning energy conservation

Ensinando análise de circuitos e aprendendo conservação de energia

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Abstract

In the learning process of circuit analysis, early in the electrical engineering course, some concepts are understood like tools to solve specific problems or typical questions on text books. However, when students are questioned about the utility of certain concept, or in which situation determined theory is applied, they are not sure about their answers. This is the result of some failures in the connection between theory and practice. The challenge in the current processes of teaching and learning concerns the integration of theory with practice while encouraging students through motivational situations. This paper proposes the application of a method for the teaching of circuit analysis contextualized by the rational use of energy, aiming to expand the perception of electrical engineering student with regard to what is taught.

Keywords: Circuit analysis, electrical engineering education, energy conservation, rational use of energy.

Resumo

No processo de aprendizagem da análise de circuitos, no início do curso de engenharia elétrica, alguns conceitos são entendidos como ferramentas para resolver problemas específicos ou questões presentes nos livros textos. Todavia, quando os estudantes são questionados sobre a utilidade de certo conceito ou em qual situação determinada teoria é aplicada, eles normalmente não tem certeza sobre suas respostas. Este é o resultado de algumas deficiências na conexão entre a teoria e a prática. O desafio neste processo de ensino e aprendizagem consiste na integração da teoria com a prática incentivando o estudante através de situações cotidianas. Este artigo propõe a

aplicação de um método de ensino, para a análise de circuitos, contextualizado pelo uso racional da energia, no qual se busca a expansão da percepção do estudante de engenharia elétrica com relação ao que é ensinado.

Palavras-chave: Análise de circuitos, educação em engenharia elétrica, conservação de energia, uso racional da energia.

Introduction

In the last years the students profile have changed significantly, mainly if considering the stimulus received, before to join to the college or university, at home or in high school. For the electric engineering courses, the question is more complex, because some students come from high school without any contact with activities associated to manual abilities and experiences in developing activities that need more concentration (TSIVIDIS, 2009). The educational systems in many countries have suffered changes with the intention to improve the teach-learning efficiency, but in some cases some adjusts are necessary, because the results have led a reduction in the interest for engineering (LOPES-MARTIN, 2010).

However, when the student is in an engineering course and assuming that it was a correct choice, the major challenge is attract its attention to the course. If considering the traditional way to teach the subjects, without establishing the clear relation among others subjects in the course, actual world, sustainability and, mainly, what is an engineer and its importance to the society, the situation become delicate.

Some articles have suggested alternative ways of teaching and learning, involving or not technology, however, they do not address the importance of the professor's didactic-pedagogic improvement. The enhancement of the teacher activity is a relevant element in the conducting of engineering course contents and, so far, there are several intervention strategies in both classroom and laboratory. This paper presents the contextualization of contents through energy conservation (DIAS; MATTOS; BALESTIERI, 2004) applied to circuit analysis in laboratory.

Traditional Circuit Analysis Teaching in Laboratory

The traditional circuit analysis teaching in laboratory is based on handouts which contain, mostly, a little theoretical introduction, materials and instruments, procedures and some questions about the experiments to be realized. The process is finished when the students deliver the report to the teacher at the end or in the next class. In this structure happens some drawbacks, eg, in the practical sessions do not investigate a practical circuit and its implications in the technological development, or yet, developing activities that do not establish relation with actual world (MAGDALENA et al., 2008).

This is a safe way to conduct experimental activities, which does not expose students to mistakes that can damage components and instruments and that is quite comfortable for the professor, because he just follow the script. In some cases, this situation is desirable, mainly when capital resources are limited and components can

not be purchased all the time, as well as the repair of equipments depends on the willingness of third parties.

However, if the script is restricted to the contents of the lecture, it will be only a confirmation activity of the theory, ie, failure in to increase awareness of the student. Thus, an activity that could contribute to the formation of the future engineer, it becomes boring (MONTES; CASTRO; RIVEROS, 2010). Sometimes, the difficult begins in the first circuit laboratory, when it involves dry instructions which served to teach measurement techniques and to verify the theory and the students starts to believe that engineering is boring (TSIVIDIS, 2009).

Another point is also relevant, but it is not a general rule: the traditional class is very attractive to professors without educational formation, which normally conduct their activities based on stimulus-response method; for example, when the content taught is only verified in the proof, without giving importance to the process learning. On the other hand, there are professors that carry out their educational activities with ease, as a consequence of their personal characteristics and/or by professional education. The first ones can be technocrats while the second ones are always concerned with didactic aspects and his classes are naturally interesting. In respect to the first ones will be required a greater commitment to understand what is education and how it is understood in the present concepts.

In classroom and laboratories, sometimes, it is probable to find professors developing their activities without pedagogical intention; they act as “knowledge transposers” and are not concerned with the understanding of teaching and learning processes and their challenges (SILVA, CECÍLIO, 2007). The importance to improve the skills in teaching engineering has led some educational organizations to create opportunities to the engineering professors to study the main concepts of pedagogy (FINK; AMBROSE; WHEELER, 2005; PINHO, 2008).

A traditional teaching is not completely bad and, therefore, it is not necessary to promote “a witch hunt”, belittling it; sometimes traditional teaching is necessary, the problem lies in applying always the same educational resource. When an educational referential takes into account (DIAS; MATTOS; BALESTIERI, 2004) the creativity process, technological applications and, mainly, the comprehension in how thinking of the current generation operates, the results in the classroom or laboratory are normally satisfactory.

Contextualization by the Rational Use of Energy

Firstly is necessary to understand what is contextualization in education and justify its use in circuit analysis. Contextualizing in education means using justifiable examples, based on cognitive science, which can foster learning. These examples are present in areas of interest of human society, for example, environment, information technology, social inclusion and rational use of energy. Such examples are known as transversal themes because they are present in various subjects, giving them an interdisciplinary characteristic (BRASIL, 1998).

The development of transversal themes in educational process can bring some advantages, among them the integration of subjects, the opportunity to put in practice what was taught in classroom or laboratory and the awareness enlargement about society issues.

The choice of rational use of energy as a transversal theme in circuit analysis classes is a natural consequence of applying energy balances to evaluate electric circuits. Nowadays, energy issues represent one of the most serious constraints to the humanity development and its use, correct or not, can be perceived in any place. This is an opportunity in learning circuit analysis taking into account how to save energy or using Ohm or Kirchhoff Laws when some electric appliance is repared at home, or when buying a new ear phone and want to find the correct impedance by using the Maximum Power Transfer Theorem and among other examples.

The next sub-itens describe an experimental activity carried out with a class of second year of electrical engineering at Univ Estadual Paulista (UNESP) - Campus Guaratinguetá, in São Paulo State – Brazil, which was submitted to the process of contextualizing the circuit analysis teaching through the rational use energy.

Raising Awareness about Importance of Circuit Analysis

At the beginning of academic year, it is done a presentation of Electric Circuit Laboratory (ECL) subject, in which will be developed the Circuit Analysis contents. In this moment it is explained the importance of having a good performance in this subject, because the whole electrical engineering course will depend on this dedication. Briefly it is shown the relationship of electric circuits analysis with electronic, control systems, power systems analysis, electrical machines, electrical installations and other subjects on the curricular grid. As a motivation to the students, some qualitative examples of each subject are presented.

In the next step, the subject rules are given and clarified to the students. They are made aware about the ECL objectives and about the choice of energy conservation as transversal theme. This initial discussion is very important (PLAZA; MEDRANO, 2007) because everybody knows exactly what will happen in laboratory activities and, mainly, how to proceed to achieve the goals: to learn Circuit Analysis and how to save energy.

After presenting the ECL subject, a discussion about electrical engineering activities, technological development, environmental impacts, energy conservation and education is initialized. In this final moment it is reinforced the importance of engineers in the society and the challenge they have in conducting the social, economic and environmental development on a sustainable basis (BRAUN, 2010).

Activities in Laboratory

The beginning of activities within a laboratory should be planned carefully in order to place the contents in sequence that promotes the teaching and learning. At this stage, the orientations about the experiment are addressed to a group of students, however, it can not forget that the process toward systematic knowledge is an individual achievement (DIAS; MATTOS; BALESTIERI, 2004). Hence, it is necessary an approach that allows to establish a direct relation with daily situations. For example, when

Maximum Power Transfer Theorem is taught, the students know how to calculate this condition; but if asking a practical application for that theorem, many of the students do not have an answer. After observing the students expressions, another question is given to them: When an mp3 player or similar device is in use, which one is the first accessory to be damaged? The answer is immediate: the earphone. The next question follows what are the criteria for buying another earphone? After this the Maximum Power Transfer Theorem application is discussed in a new perspective.

This contact with real-life promotes the interest in the subject (COSTA; HONKALA; LEHTOVUORI, 2007), because this approach is endowed with meaning for the student. This is a conceptual approach, using the oral communication supported by maieutics (the questions are aimed to an objective). There are others ways to achieve the students as, for example, discovering what there is inside the equipment in an initial activity (HOLDER, 2009).

Throughout the year, thirteen main topics are taught, which are subdivided into basic contents, such as Ohm's Law, Kirchhoff's Laws, Thèvenin and Norton Theorems, Maximum Power Transfer and among other issues, in direct and alternate current, and three-phase systems and introduction to magnetic circuits. These basic contents are contextualized on energy conservation, supplying elements that can help to explain the theory that was presented in classroom and motivating the activities in laboratory.

After these considerations, the students develop their experimental activities. At the end of the script there is a research involving the realized experience, applied to energy conservation. For example, in Ohm's Law topic the students must bring, in the next class, the research result about this situation: "The electric resistances are present in many applications and devices; for example, electric current limitation, electric power in thermal energy conversion, electronic components polarization and others. The electric current flow in a resistance depends on electric voltage presence. In this context, considering an electric faucet and a clothes iron, both with the same nominal power and supposing that these appliances operate by one hour, what can you say about their energy consumption and what would be the proposed strategies to promote the rational use of energy?".

The following are two other examples of research proposals:

- *Normally in homes, due to poorly elaborated electrical designs, there are an insufficient number of electrical outlets to the growing number of electrical equipment. To overcome this deficiency, the residents of these homes use the adapters with three outs to the outlets. Using Kirchhoff's Laws as a tool of analysis, what are the undesirable effects of using these adapters from the point of view of safety as the rational use of energy?*
- *Search on the importance of controlling the power factor in electrical installations from the point of view of the rational use of energy and write a summary of the information obtained.*

This methodology has been employed since 2006, however, in 2010 the procedures for the data acquisition about understanding on the rational use of energy were formalized, when Circuit Analysis is taught, since the performance of students in the experimental activities have always been satisfactory.

Assessment of teaching methodology: energy conservation concepts

Once established the rules and proceedings for the ECL, two assessments were conducted, one in the middle and the other at the end of the year, consisting of five questions and each issue addresses a topic related to energy use. The first question of the Assessment 1 provides a link to first question in Assessment 2, looking for identify the kind of trend in the answer in relation to question 1. With regard to the questions, these are divided into:

(1) Assessing the knowledge of issues related to energy;

Assessment 1: In 2000, the Earth population was 6 billion of inhabitants. Considering the energy consumption patterns of industrialized countries, mainly United States, is correct to affirm: (there are five alternatives, with one correct answer; note the limitation in natural resources)

Assessment 2: The preoccupation with social, political and economical consequences, associated to the limitations of energy supplies, they become discussion target when: (there are five alternatives, with one correct answer; note the impact of energy use in the economical model based on consumerism)

(2) Assessing the perception of information, relevant to energy use, in the media;

Assessment 1: In the text, "(…) the low price in energy market, which reached R$5.00 per Mw/h (…)", it can be stated that: (there are five alternatives, with one correct answer; note the wrong energy unit, the correct unit is MWh)

Assessment 2: In the text, "(…) the consumer should be able to choose between paying more for energy badly used or invest in energy efficiency". Considering the above, it can be stated that: (there are five alternatives, with one correct answer; note the behavioral aspects of people)

(3) Assessing the ability to operate numeric values in situations involving the use of energy;

Assessment 1: An iron ironing of 1000 W is used for thirty minutes and a shower of 2000 W is on for fifteen minutes. It can be stated that: (there are five alternatives, with one correct answer; note that with these information can not make a comparison on what equipment consumes more energy, because there are differences in their operation)

Assessment 2: A refrigerator of 300 W the compressor operates twenty minutes and is turned off for twenty minutes (thermostat control) operating cyclically over twenty-four hours. After performing cleaning (defrosting), the refrigerator operates ten hours during the twenty-four hours. Faced with such procedure, it can be stated that: (there are five alternatives, with one correct answer; the energy saved is 18 kWh per month)

(4) Assessing the perception with regard to the consequences of energy use in the natural cycles balance;

Assessment 1: With regard to the environment, to make better use of electrical equipment, it would be collaborating with: (there are five alternatives, with one correct answer; note the choice influence of people)

Assessment 2: In the text "(...) another advantage of the installation of a cogeneration unit, using natural gas, is that it does not pollute, because it makes full use of the heat in their production process (...)", can be stated: (there are five alternatives, with one correct answer; note that the pollution exists and the 2nd Thermodynamic Law is contradicted)

(5) *Assessing how to conduct the first actions for energy saving.*

Assessment 1: The use of vehicles with lower power is the only solution to fuel economy in urban centers. This statement is: (there are five alternatives, with one correct answer; note that there are other factors, eg, the way to drive a car)

Assessment 2: In current residences designs has grown the desire for installation of air conditioning. This fact is due to: (there are five alternatives, with one correct answer; note the unawareness of other means of obtaining thermal comfort)

In the Assessments 1 and 2, 49 and 44 students, respectively, were present. With the data collected it was plotted the Figure 1, in which it is possible to observe some peculiarities in relation to the percentage of correct answers:

- *In the situations that involve cognitive aspects in abstract terms (questions 1 and 4), possibly the domain about energy conservation failed, because energy is not a trivial concept, mainly when natural cycles (for example, carbon and water) are associated. The students need more experience and contact with the concepts present in the rational use of energy, because the approaches are multidisciplinary. A justification for this situation relates to cognitive dissonance, which allows to understand how a person can think one way and act another, or even contradict himself in situations where personal values about energy use are not well established; the energy education shows up as one of the main strategies to overcome cognitive dissonance in relation to energy conservation and environmental awareness (DIAS, 2003);*
- *On the other hand, situations that involve information, ability in operate numeric values and predisposition to action (questions 2, 3 and 5), the students got a better result, showing an advance in the understanding of content. These results reflect their present situation, since they are in an engineering course and, hence, it is natural to have ability with numbers. In relation to information and predisposition to action is something interesting, because the interrelation between these elements is a challenge to this students generation. The contextualization of teaching allowed working better in activities that require more patience and dedication.*

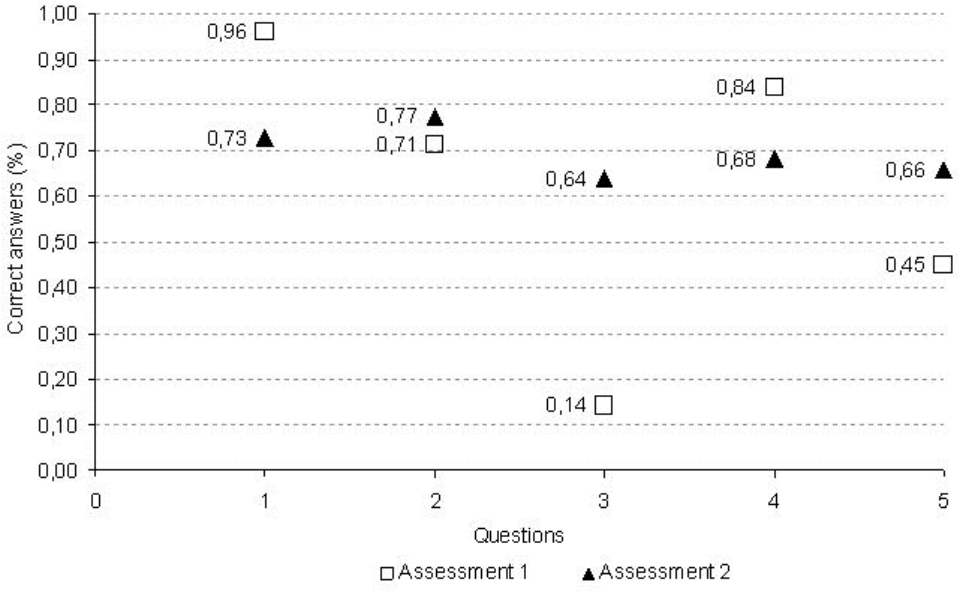

Figure 1. Performance evaluation on the energy use issue

The first analysis indicates the strengths and weaknesses in the teaching-learning process. The results show the points that need more attention, as the energy issues and multidisciplinary approach. However, it is necessary to assess if the students performance, in terms of knowledge about energy conservation, would have any improve. The histograms in the Figures 2 and 3 show some progress in relation to number of correct questions. It is observed that there was a shift from an intermediate amount of correct answers to a more satisfactory situation, with four and five hits. It means that occurred an improvement in the performance, because part of 46.9% of students that had three correct questions, in the assessment 1, shifted to four and five correct questions in the assessment 2.

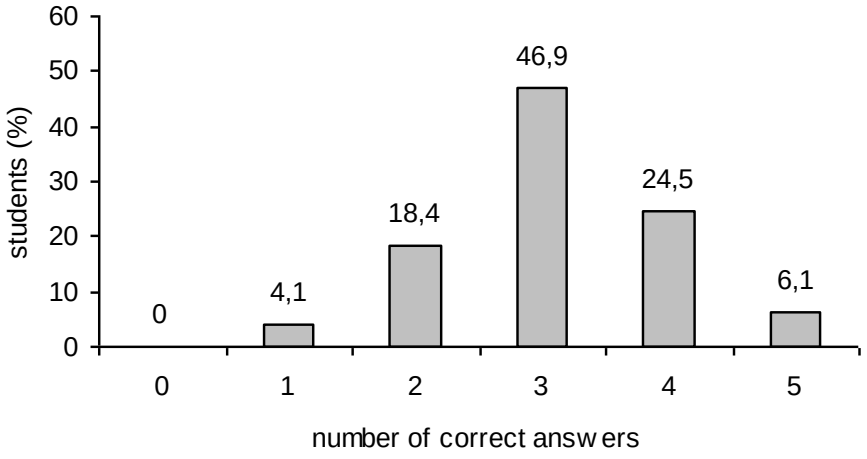

Figure 2. Performance in the first assessment

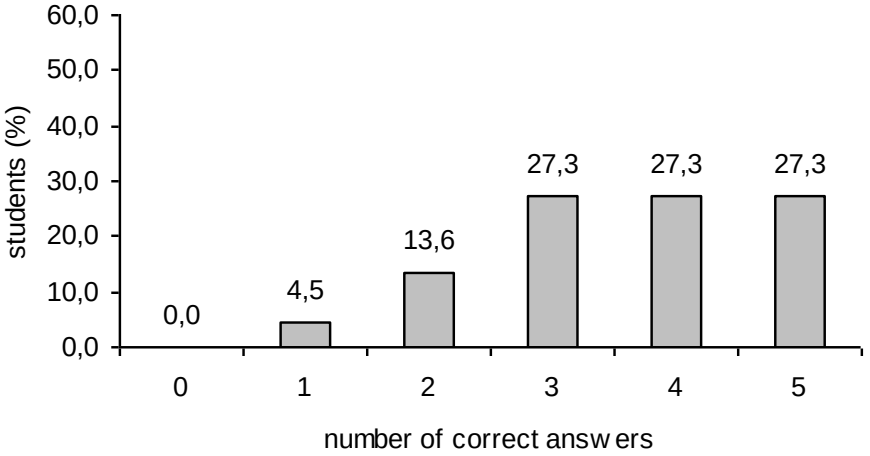

Figure 3. Performance in the second assessment

Results

The results obtained can be divided in two parts: the first one aimed to quantitative values, giving more visibility to performance of students and the second one is

concerned to educational aspects, requiring more attention in the teach-learning process.

When the positive results are observed in Figure 1, it means that the proceedings in education is giving opportunities in developing the cognitive, affective and psychomotor domain, because most students were not educated to physically interact with the real world, i.e., the skills to assemble, organize and repair were not well explored in their personal formation (TSIVIDIS, 2009). Through the contextualization of rational use of energy in teaching Circuit Analysis, it becomes possible to place students closer to energy issues. In this sense, their homes became a laboratory extension and they started paying more attention in things that using electrical energy.

Moreover, efforts to improve awareness of energy transformations and their impacts on the environment are needed. This is not a simple task, since it requires the establishment of an abstract concept, i.e., what energy is and how it relates to the environment in your processing chain (DIAS; MATTOS; BALESTIERI, 2004).

In relation to Figures 2 and 3, the evolution in the correct answers reflect the conceptual improvement of students inside the subject, but it is important to observe that the educational strategy always requires some adjusts, because the balance among professor, students and contents is dynamic. It is necessary to accompany the students performance and provide the best way in teaching (not only in classroom or in laboratory), considering the opportunities to put them in contact with the engineering area and with daily situations (for example, at home it is possible to learn many things related to energy conservation and circuit analysis).

Conclusion

Although there are difficulties in engineering education, there are several opportunities to learn something new. In this context, it is necessary to take into consideration that all involved are the result of modifications in generations and, therefore, it is a waste of time be remembering the past (nostalgia) or be saying that students no longer want to study. The challenge of engineering professor is understand how learning happens, looking for an educational reference for teaching better (action).

The circuit analysis teaching is facilitated by the contextualization based on energy conservation (or other transversal theme), because students have an opportunity to develop their skill considering the daily situation, when they study the contents. However, it is very important to identify the steps that did not provide satisfactory results and understand the cognitive, affective and psychomotor processes involved in order to accomplish the necessary and/or possible corrections.

This paper is a simple contribution to the engineering education, but it reports the necessity in changes paradigms in the teach-learning processes. The results are promising, mainly when students begin to understand and appreciate the engineering.

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References

BRASIL, MINISTÉRIO DA EDUCAÇÃO **Parâmetros curriculares nacionais para o ensino médio – PCNEM**. Brasília, Brasil: MEC — Ministério da Educação, 1998. (*in Portuguese*)

BRAUN, D. Teaching sustainability analysis. **IEEE Transactions on Education**, v.53, n.3, p.243-247. 2010.

COSTA, L. R. J.; HONKALA, M.; LEHTOVUORI, A. Applying the PBL approach to teach elementary circuit analysis. **IEEE Transactions on Education**, v.50, n.1, p.490-496. 2007.

Dias, R. A. **Desenvolvimento de um modelo educacional para a conservação de energia**. 2003. 130f. Tese (Doutorado em Engenharia Mecânica – Transmissão e Conversão de Energia) – Faculdade de Engenharia do Campus de Guaratinguetá, Universidade Estadual Paulista, Guaratinguetá. (*in Portuguese*)

DIAS, R. A.; MATTOS, C. R.; BALESTIERI, J. A. P. Energy education: breaking up the rational energy use barriers. **Energy Policy**, v.32, n.11, p.1339-1347. 2004.

FINK, L. D.; AMBROSE, S.; WHEELER, D. Becoming a professional engineering educator: a new role for a new era. **Journal of Engineering Education**, p.184-194. 2005.

HOLDER, M. E. Thevenin's Theorem and a black box. **IEEE Transactions on Education**, v.52, n.4, p.573-575. 2009.

LOPEZ-MARTIN, A. J. Attracting prospective engineering students. **IEEE Transactions on Education**, v.53, n.1, p.46-52. 2010.

MAGDALENA, Rafael et al. A teaching laboratory in analog electronics: changes to address the Bologna requirements. **IEEE Transactions on Education**, v. 51, n. 4, p.456-460. 2008.

MONTES, A. J. S.; CASTRO, H. A. B.; RIVEROS, J. A. H. How to motivate students is laboratory: a new approach for an electrical machines laboratory. **IEEE Transactions on Education**, v.53, n.3, p.490-496. 2010.

PINHO, S. Z. (coordinator) **Oficinas de estudos pedagógicos: reflexões sobre a prática do ensino superior**. São Paulo: Cultura Acadêmica. 2008. (*in Portuguese*)

PLAZA, I.; MEDRANO, T. C. Continuous improvement in electronic engineering education. **IEEE Transactions on Education**, v.50, n.3, p.259-265. 2007.

SILVA, L. P.; CECÍLIO, S. A mudança no modelo de ensino e de formação na engenharia. **Educação em Revista**, v.45, p.61-80. 2007.

TSIVIDIS, Y. Turning students on to circuits. **IEEE Circuits and Systems Magazine**, v.9, n.1, p.58-63. 2009.

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