LEARNING OBJECTS FOR TEACHING STATISTICS IN ENGINEERING COURSES

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In engineering, statistics has wide application in process planning and control, product development and production strategies. Thus, it is critical that engineering students have significant contact with statistics during their undergraduate studies. However, students often do not exercise in practice what would help them better understand the theory. In this sense, the creation, delivery and dissemination of learning objects can fill in some gaps that arise due to this situation. Learning objects are reusable digital resources that contain information for which meanings are produced in the process of knowledge construction and are important elements for the systems of teaching and learning that use the computer and that rely on information technology. They can be used both in distance learning and in the classroom. Thus, this paper is a survey of existing learning objects aimed at teaching engineering statistics, focusing mainly on statistical quality control, design of experiments and the Six Sigma methodology.

INTRODUCTION

Brazil's economic growth in recent years has brought with it a great demand for professionals in engineering. The expression "Blackout in Engineering" has started to be used due to concern over the possibility of a shortage of engineers for the realization of projects needed to support this growth. Even with the creation of new openings in engineering programs, there is the risk that the result is irrelevant in terms of graduates, as most of the entrants in these programs have gaps in basic education, one of the main causes of the difficulties in the progression of students in engineering programs. Students often repeat courses, especially in the core subjects, resulting in high dropout rates (Canto Filho, et al, 2012). Insufficient basic education - including deficiencies in the development of statistical thinking, important for the professional engineer - has an effect on subsequent academic results, not yielding the professional profile that is desired nowadays. In this sense, the traditional lecture style lessons, taught to a large number of students, may not be sufficient to improve this situation, and no longer fully meet the current educational needs. In this context, the use of Information and Communication Technologies (ICT) in education has expanded the range of possibilities for one who teaches - in pedagogical practice and initial and continuing education - and one who learns - with regard to the different ways with which they can interact with the content of school subjects. Learning environments, now developing characteristics from virtual environments, are no longer restricted to the boundaries of classrooms and schools. Developed with digital resources, learning objects have become a rich and efficient solution for creating and presenting content studied in all levels of education; learning objects can incorporate some practices of individual and group tutoring in order to get higher educational quality. So to improve teaching and meet the current educational needs of engineering students, the development of research and projects that provide meaningful, quality education in statistics is fundamental. Moreover, new information and communication technologies are increasingly present in everyday life in contemporary society, encouraging and enabling further use of software in teaching statistics.

Considering this development of learning objects in digital media, we propose in this paper a literature review on audiovisual learning objects (LOs) for the teaching of quality engineering, focusing on statistical quality control (SQC), design of experiments (DOE) and the Six Sigma methodology. Initially, this survey involves learning objects available in Portuguese, since the research is focused on teaching undergraduate courses in engineering in Brazil. However, because of the globalization of education and the shortage of material in Portuguese, we chose in the end to also use some objects in the English language that can serve as support for the development of LOs in Portuguese. Therefore, this review was aimed at contributing to the development and provision of audiovisual learning objects for teaching statistical methods in quality engineering courses.

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QUALITY ENGINEERING

In engineering, statistical methods have broad application in the creation, planning and control of processes and services. Therefore, statistics assists the engineer in the development of new products, new processes and systems, and contributes to the continuous improvement of existing ones. Specifically in quality engineering, statistics focuses on process and manufacturing control, analyzing variation and quality in products, seeking to track process stability. In this sense, one of the main applications refers to statistical quality control (SQC), which monitors variability using statistical control charts and the Six Sigma program, and which uses standardized procedures for data collection and statistical analysis, aimed at identifying, handling and eliminating sources of error in an attempt to improve quality and processes with an emphasis on reducing defects. In SQC, we study statistical process control (SPC), process capability analysis and studies of repeatability and reproducibility (R&R), important issues in the context of industrial statistics. Still in the area of SQC, this also includes the design of experiments (DOE), one of the tools of the DMAIC (Define, Measure, Analyze, Improve and Control) problem solving cycle of the Six Sigma quality management methodology. Thus, it is essential that students, mainly from industrial engineering programs, have more effective contact with these statistical methods during their undergraduate studies.

LEARNING OBJECTS

With the advancement of technology in education, there are more and more new resources aimed at improving the processes of teaching and learning. With this advance came learning objects, which are reusable digital resources stored in software repositories on the Internet where packages may be retrieved and installed on a computer. They can be animations, video, text, images and audio, among others, with applications in the teaching activities in the classroom and also in distance learning, aiming to support students in a particular area, and thereby facilitating their learning. According to Wiley (2002),

> Learning objects are elements of a new type of computer-based instruction, based on the object-oriented paradigm of computer science. [...] Additionally, learning objects are generally understood to be digital entities available through the Internet, so any number of people can access and use them simultaneously.

The learning objects that will be developed with the research presented here are "Open Educational Resources", that by the definition of UNESCO (2012), "are teaching, learning and research materials in any form or media, which are under the public domain, or are licensed openly, allowing them to be used or adapted by others". An educational object is a unit of independent learning that has its own content and is able to be reused in multiple instructional contexts. So it's an entity that combines its digital elements through a display. Thus, digital elements such as a picture, an audio file, a movie, an HTML topic, etc. do not necessarily constitute a learning object, however these elements can be combined with an educational purpose and this set of elements can prove to be an object to be used as an instructional resource (Machado, et al, 2006).

LEARNING OBJECTS IN TEACHING STATISTICS FOR ENGINEERING

In Brazil, the Ministry of Education (MEC) provides on its website a repository of learning objects encompassing digital content for the teaching of statistics in elementary school, high school and higher education. When conducting the research presented here, there were 123 learning objects available for engineering, and none were geared toward quality engineering. As for the study of probability and statistics for undergraduates there were 22 learning objects available covering various areas, encompassing animations, simulations and educational software. Most, however, are in English. Regarding the literature, for primary, secondary and technological teaching, we found some papers covering proposals or experiments with LOs, each with their own specificities. We include here some papers related to technological and undergraduate education.

Vasconcelos (2009) presents the learning object EstatísticaNet, designed and modeled to be used in mathematics because the school does not have a statistics course in its curriculum and the perceived need of the content in the technical and high school levels of an agricultural school. Fujii

and Silveira (2006) point out that different levels of adaptation can be achieved with the use of learning objects. In their work, the authors propose the application of adaptive content, made up of these objects, according to the knowledge level of the student. A prototype was developed that, besides being a supplementary learning resource for students, can help teachers in the development of their work in large classes and dealing with heterogeneous knowledge. For the authors, the prototype may become a tool to support the learning of statistics in undergraduate courses.

Machado *et al* (2006) discuss how statistical content construction can be accomplished via learning objects. The collaborative construction by expert groups or multidisciplinary groups is greatly facilitated, and the flexibility of the organization can be increased, enabling the learning process to be more adapted or customized for different strategies. The system proposed by the authors, aimed at teaching statistics, reflects what must be considered in the design and construction of learning objects. One should keep in mind the need to teach HOW and WHY, and encouraging the use of real data. The focus should be on the substance beyond the numbers, noting the context, relevant analysis and model adjustments, selecting real everyday problems that are relevant to the area of the student, and promoting discussion and critical thinking. The intense use of computers is encouraged.

With this vision, Machado *et al* (2006) propose using the Galileo System for Education Statistics (http://www.galileu.esalq.usp.br/) that provides an environment of quality web resources with interactive and free access for the learning of statistics. Basically, it consists of an interconnected library of learning objects with dynamic access whose purpose is statistics education. It includes biographies and entries in the form of hypertext, in addition to data sets, examples, activities, tutorials, statistical programs, presentations and applets. Some of the objectives of the proposed system include enabling the construction of objects for teaching and learning of statistics, and encouraging and enabling users to build learning objects within paradigms and standards for content and form previously discussed and established. They include the facilitation of access to objects through specific methods and directing the construction towards reusable learning objects using the concept as a criterion of demarcation. Thus, students and teachers are able to have access to view all content in the form of objects or in the combined form defined by the user. In this system, for applications in quality engineering, only materials aimed at the design of experiments are found.

In a thorough search on the Internet in Brazil, there were no LOs covering SQC, capacity analysis and R&R, which fully met the definition and objectives of learning objects. There were some courses or training offered, generally by consulting firms. We should highlight Portal Action (http://www.portalaction.com.br/), which despite having no educational purpose, features a well-designed and attractive format for students, and can be accessed free of charge. From the world of academia, there are handouts and presentations, but without judging the quality of the material, they do not necessarily constitute learning objects in the way specified by Wiley (2002). This is a promising scenario for the development and research of LOs.

SOME PROPOSALS

In view of the above, it is essential to invest in developing LOs for quality engineering education. The use of technology is crucial in order to succeed and so, statistical software is essential in this new trend in teaching statistics. Thus, one possibility is the use of free software, and R (R CORE TEAM, 2013) is a natural option. Some packages that extend R can serve as tools for the development of LOs. We can cite the following packages specifically for SQC at the undergraduate level: QCC (Scrucca, 2004), Six Sigma (Cano, Moguerza & Redchuk, 2012) and CEppt (Barros & Ferreira, 2012).

Another option is the qualityTools package (Roth, 2013), which was implemented for teaching and includes methods associated with DMAIC (Define, Measure, Analyze, Improve and Control) for the resolution of problems associated with the quality management cycle of the Six Sigma methodology. The use of these methods is illustrated with the aid of artificial data sets. This package can assist in systems analysis and measurement, as well as planning experiments. Similarly, the SixSigma package (Cano, Moguerza & Redchuk, 2012) covers functions for a more complete analysis, with process mapping, loss function analysis, Pareto analysis, control charts, process capacity and design of experiments. Thus, the latter two packages demand a closer look,

since they aim to achieve a complete cycle within the Six Sigma program, a part of quality engineering, which can subsequently be used not only with more rigor in academia, but also by small and medium businesses to improve industrial processes.

From the educational point of view, one proposal would be to produce small educational videos about the theoretical foundation and applications with R. Thus, there is a need to research and analyze the functions and R packages available for this purpose. As there are several packages and also different interfaces in R, research work is required for the analysis and selection of packages, functions and examples. These videos may be useful as supplementary material for extracurricular activities because they allow students to work in other environments beyond the school premises, performing more complex and complete analysis. In the case of the Brazilian reality, the development and dissemination of instructional material in the area of quality engineering is an alternative source of materials for the improvement of products and processes for small and medium enterprises, which often cannot acquire commercial software.

CONCLUSIONS

This article discussed a survey of existing LOs for teaching quality engineering, addressing SQC, DOE and Six Sigma in Brazil. The current reality, with few specific existing materials, sets up a scenario for research in this area. This way, it is possible to develop LOs with quality, greater range, application and effectiveness, providing undergraduate students in engineering resources to use R in the context of these applications. Also, it is possible to extend the capabilities developed in the form of open educational resources, in a wide range, allowing professionals and businessmen to have access as well.

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