

Using the Statistical Process Control to evaluate the learning process in Higher Education

Aplicación del Control Estadístico de Procesos para la evaluación de procesos de aprendizaje en la Educación Superior

DOI: 10.34140/bjbv3n5-017

Recebimento dos originais: 04/03/2021

Aceitação para publicação: 30/06/2021

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ABSTRACT

The purpose of this paper is to propose an approach for incorporating Statistical Process Control (SPC) charting technique to monitor and continuously improve the learning processes by monitoring the satisfaction of students who used an interactive computer-based learning material, which was produced to solve problems in the Operation Management course. By applying SPC methods, the authors examine the sources of process variation (common or special causes) and analyse the ability of teaching strategies to ensure the acquisition and development of the competencies and skills demanded in current university studies. A total of 184 students participated in the learning experience. The findings show that the learning process is under control and therefore the variation of process is due to common causes. However, the Capability Analysis carried out, reveals that process has not enough capacity to achieve the specifications required by the teachers involved in the educational project. This quantitative approach will not only allow self-assessment, but can be used for comparative purposes (other teaching strategies, colleges, etc.). Thus, the control charting is a complementary assessment technique that should be included within the current Quality and Learning Assurance Systems at higher education institutions.

Keywords: educational improvement, Higher Education, Statistical Process Control, service quality

RESUMEN

El objetivo de este trabajo es proponer un enfoque para incorporar las técnicas de los gráficos de Control Estadístico de Procesos (CEP) para el monitoreo y mejoramiento continuo de los procesos de aprendizaje a través de la monitorización de la satisfacción de los estudiantes que utilizaron un material de aprendizaje interactivo basado en computadora, que fue diseñado para resolver problemas en un curso de Investigación

de Operaciones. Mediante la aplicación del Control Estadístico de Procesos (CEP) los autores examinan las causas de variación del proceso (causas comunes o especiales) y analizan la capacidad de las estrategias de enseñanza para asegurar la adquisición y desarrollo de las competencias y habilidades demandadas en los estudios universitarios actuales. Un total de 184 estudiantes participaron en la experiencia de aprendizaje. Los hallazgos muestran que el proceso de aprendizaje está bajo control y, por lo tanto, la variación del proceso se debe a causas comunes. Sin embargo, el Análisis de Capacidad llevado a cabo, revela que el proceso no tiene la capacidad suficiente para cumplir con las especificaciones requeridas por los docentes involucrados en el proyecto educativo. Este enfoque cuantitativo no solo permitirá la autoevaluación, sino que se puede utilizar con fines comparativos (otras estrategias de enseñanza, universidades, etc.). Por lo tanto, los Gráficos de Control son una técnica de evaluación complementaria que debería incluirse dentro de los actuales Sistemas de Calidad y Aseguramiento del Aprendizaje.

Palabras clave: Mejoramiento educativo, Educación Superior, Control Estadístico de Procesos, calidad de los servicios

1 INTRODUCTION

The opportunities that Information Communication Technologies (ICT) offer in university classrooms and the possibilities of teaching in smaller groups of students have encouraged new teaching-learning approaches within the European Higher Education Area (EHEA). Among other aspects, this involves a change from a teaching-based focus to a learning-based focus as facilitated by ICT (European Commission, 2002), with new strategies, resources, and activities to promote students' meaningful learning.

In this context, the techno-pedagogical design becomes a reference point, which integrates two linked dimensions (Coll, 2008):

- Technological dimension. This involves the selection of suitable technological tools for the learning process (virtual platform, software applications, multimedia resources, technological tools, etc.) and analysing their possibilities and limitations.
- Pedagogical dimension. This includes the analysis of the students' profiles, the definition of objectives and training skills, the development and implementation of content, the planning of activities (with guidance and suggestions on the use of technological tools), and the development of a plan for the evaluation of processes and results.

Thus, the techno-pedagogical design becomes an integrated part of the technological and pedagogical elements, incorporating different tools and guidelines in order to show how to use them in the development of learning activities or e-activities (Barberá, 2004). In other words, instructional design is defined as “*systematic instructional planning including needs assessment, development, evaluation, implementation, and maintenance of materials and programs*” (Richey, Fields, & Foxon, 2001, p. 181).

The results of some attempts to integrate ICT in the development of learning (e-learning) have been published in different studies. They use as a main source of information the students' opinion about

the usefulness of the teaching tools, their motivation for learning, and their satisfaction level. In this context, and in relation to Business Administration studies, the use of these types of teaching resources has demonstrated many advantages over other traditional educational tools. Novo-Corti, Varela-Candamio, & Ramil-Diaz (2013) found that the use of a Mixed-Methods Assessment (online and traditional face-to-face teaching) provides numerous advantages to learners: it increases their participation and motivational level and improves their academic performance. Arenas-Marquez, Machuca, & Medina-Lopez (2012) described a computer-assisted learning (CAL) experience in operations management higher education that entailed the development of interactive learning software, its evaluation in an experimental environment, and the formal analysis of the teaching method's influence on student perceptions (adaptation to the rhythm of study, motivation, attention/concentration, interest in the subject matter, and the ability of the method to help students learn from their mistakes and know the level of their acquired knowledge). Alfalla-Luque, Medina-Lopez, & Arenas-Marquez (2011) analysed three educational environments (CAL, presentation seminar, and traditional distance teaching) with this goal in mind in order to determine their influence on such variables as motivation, perceived difficulty, understanding of the material, and perception of learning. Aranda, Dominguez, & Martinez (2010) analysed how the usage of simulation games can improve the university teaching/learning process in different branches of business administration studies. To assess the experience of a virtual learning environment among students studying courses in operations management and technical features which they encountered, Greasley, Bennett, & Greasley (2004) used a shortened version of the Approaches and Study Skills Inventory for Students (ASSIST). Other studies that demonstrated the contribution of instructional technology implementation to effective learning are Achcaoucaou, Guitart-Tarres, Miravittles-Matamoros, Nuñez-Carballosa, Bernardo, & Bikfalvi (2014), Castillo-Manzano, Castro-Nuño, Sanz Diaz, & Yniguez (2016), Gonzalez-Zamora (2006), Guitart, Nuñez, Miravittles, Bernardo, Cruz, & Achcaoucaou (2014), Rao (2015), Rubio-Hurtado, Garcia-Duran, & Millet (2010), Ruiz-Jimenez, Ceballos-Hernandez, Garcia-Gragera, & Chavez-Miranda (2010b), Sacristan-Diaz, Garrido-Vega, Luque-Alfalla, & Gonzalez-Zamora (2010), & Wild and Griggs (2002).

With regard to the effectiveness of the processes of integration of ICT in student learning, the majority of the previous studies were focused on educational outputs (e.g., graduation rates) and outcomes (e.g., final examination scores), rather than processes that create such outcomes (Grygoryev & Karapetrovic, 2005a). Based on the educational literature, the outcomes have been measured objectively through the learning score (Larson & Chung-Hsien, 2009; Marin-Garcia, Miralles-Insa, & Marin-Garcia, 2008; Summers, Waigandt, & Whittaker, 2005; Sun & Cheng, 2007) and subjectively through students' perception of the teaching-learning process, normally linked to aspects such as perceived learning, difficulty, utility, satisfaction, & motivation (Alfalla-Luque et al., 2011; Klein, Noe, & Wang, 2006; Larson & Chung-Hsien, 2009; Lopez-Perez, Perez-Lopez, & Rodríguez-Ariza, 2011; McCray, 2000;

Skylar, Higgins, Boone, & Jones, 2005; Sun & Cheng, 2007; Webb, Gill, & Poe, 2005).

For these reasons, it is necessary to study the quality of educational services from another perspective, focusing not only on the outputs of the processes, but also on the process itself, where ICT and interaction between teachers and students become one of the main sources of learning in classrooms. This framework requires the adoption and use of principles from Total Quality Management (TQM) as the pedagogical methodology and an improved framework in managing, scrutinizing, and enhancing the quality of teaching and learning practices in higher education. This approach allows us to identify possible causes of variability in these processes and analyse the ability of teaching strategies to ensure the acquisition and development of the competencies and skills demanded in current university studies.

Under these conditions, students are considered to be the users of a service and their satisfaction level will depend on parameters equivalent to those of any other service: the level of compliance with specifications, the presentation format, tangible aspects, etc. They are the arbitrators or judges who express satisfaction or dissatisfaction with the educational service. Also, the students determine if the process should be evaluated positively or negatively, depending on accumulated evidence at the end of their studies (Canton, Valle, & Arias, 2008).

Therefore, the search for total quality in the educational setting is no different from the industrial process and other services. Thus it is appropriate to also apply Quality Control tools and techniques, which aim to help organizations measure the quality of its services and design their processes in order to improve productivity and customer service.

The Statistical Process Control (SPC) focuses on measuring processes and the prevention of problems (Montgomery, 2001) and has been applied to process controls in many organizations (both industrial sectors and other services). It can also be used as a good alternative to control and improve educational processes and ensure the achievement of the learning objectives and the acquisition of competencies and skills which current university studies demand.

However, unlike the industrial sector where SPC was initially and traditionally applied, and other service sectors (banking, health, tourism, etc.) in which implementation has been extended more recently (MacCarthy & Wasusri, 2002; Sulek, 2004; Utley & May, 2009; Yang, Cheng, Hung, & Cheng, 2012), the literature review shows that there are few studies in the education sector that present such an approach. We have found no such work in Spain; the most relevant studies in this field were developed in the United States (Cadden, Driscoll, & Thompson, 2008; Ding, Wardell, & Verma, 2006; Jensen & Markland, 1996; Manguad, 2006; Marks & O'Connel, 2003), with marginal applications in other countries (e.g., Debnath & Shankar, 2014; Nikolaidis & Dimitriadis, 2014).

Likewise, is important to highlight the growing interest of the scientific community in introducing the application of the SPC to analyse the variability of the different processes in the educational field, as recent studies have shown (Nandedkar and Bathi, 2021; Daneshmandi, Noorossana and Farahbakhsh,

2020; Carlucci *et al.*, 2019; Bi, 2018; Milosavljevic *et al.*, 2018; Zolkepley, Djauhari and Salleh, 2018; Hrynkevych, 2017 y Djauhari, Sagadavan y Lee, 2017; Aldowaisan and Allahverdi, 2016).

We consider that all these reasons justify the need to investigate the impact of teaching resources and strategies on the teaching process from a quality management point of view. For the reasons stated above, it seems appropriate to adopt a new quality approach, which requires the use of quality control and management tools in order to assess teaching resources and strategies in the new higher education setting. The main objective of this paper is to determine whether the use of an instructional teaching resource is under statistical control. In order to achieve this goal, we applied the SPC charts. We analysed if the variability of the learning process was due to common causes or causes attributable to the process (equipment, planning, programming, etc.). For this, we adopted a quality approach by studying the level of satisfaction/dissatisfaction of students who used the interactive computer-based learning material, which was produced to solve problems in the Operation Management course.

Essentially, the control chart is a test of the hypothesis that the process is in a state of statistical control. A point plotted within the control limits is the equivalent of accepting the hypothesis of statistical control, and a point plotted outside the control limits is equivalent to rejecting the hypothesis of statistical control:

- H_0 : the learning process of students is in statistical control (process is influenced only by common cause variation).
- H_1 : the learning process of students is not in statistical control (process is influenced by one or more assignable causes).

Understanding the factors influencing the variability of students' learning provides the opportunity to explore which actions might be carried out to boost the utilization of the resource by university students, and therefore, helping them achieve their skills and grades.

The remainder of the paper proceeds as follows: the next section presents the study's sample, data, and methods. The third section discusses the results. We draw conclusions in the final section.

2 MATERIALS AND METHODS

PARTICIPANTS

The study took place among third-year students of the Business Management and Administration Degree in a Spanish public university. A total of 184 students participated in the learning experience. The students usually attended Operation Management practice sessions organized in eight small class groups (≤ 30 students) located at the University's computer classrooms.

Data was collected in May of 2019, with a total of 165 valid replies collected. This represents 63.7% of the students enrolled in the academic year under review.

INSTRUMENTS

To realize the goals of this study, we used a questionnaire to measure students' self-assessment of learning competencies and skills and students' perceptions of the usefulness of interactive learning resources. There were 70 male students (38.04%) and 114 female students (61.96%).

The questionnaire was adapted from a previous study Guitar et al., (2012), based on the guidelines about generic competencies of *Tuning Educational Structures in Europe II* (2005) and the methodology proposed by Rodriguez Alvarez, Figuera, & Rodriguez (2008) for self-assessment of learning skills.

The questionnaire had three major parts. The first section asked students to submit their own demographics and academic information (gender, grade, age, class group, etc.). The second section asked students to score the usefulness of interactive learning resources used in classes. This section consisted of 5 corresponding items ($\alpha = 0.828$). Each item was rated on a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. The higher a score, the more useful an interactive resource was perceived to be by the students. The third section of the questionnaire served to measure students' self-assessment of learning competencies and skills. This section consisted of 13 items ($\alpha = 0.745$) rated on a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. In order to elaborate the questionnaire, we followed the guidelines in the *White Book for the Bachelor's Degree in Economics and Science*, published by The National Agency for Quality Assessment and Accreditation (ANECA, 2005). The competencies and skills identified for our study were: spoken and written communication, research and information searches, analysis and synthesis, the ability to apply theoretical knowledge to practical situations, problem-solving, critical evaluation, IT skills (use of computer programmes, Internet, etc.), autonomy and responsibility, and continuous study skill.

Multidisciplinary experts (educational technology, statistics, etc.) and other instructors helped us review and refine the initial questionnaire. Additionally, a pilot test was carried out with a small number of students which allowed some details regarding the proposed scores to be clarified. The bibliographical review, the above-mentioned critical judgment of researchers and university lecturers, and the pilot test all supported the validity of the measurement instruments that were designed (Hoskisson, Hitt, Johnson, & Moesel, 1993; O'Leary-Kelly & Vokurka, 1998).

In order to collect the questionnaire data, we use an interactive response system through individual devices called clickers (Educlick). Unlike other possible options for completing the questionnaires (manually, via e-mail, etc.), this computerized system allowed us to get the information immediately and show results quickly (Chafer, 2009; Judson, 2002; Ruiz-Jimenez, Ceballos-Hernandez, & Garcia-Gragera, 2010a), as well as ensuring a higher response rate (in our case, 100% of students who attended each class group).

We distributed the questionnaires while students were engaged in classroom practices and using an educational resource, which was an interactive computer-based learning material used to solve

production and operations management problems. Its general features are shown in the next section.

INTERACTIVE COMPUTER-BASED LEARNING MATERIAL IN THE OPERATION MANAGEMENT COURSE: GENERAL FEATURES

To develop the learning instructional resource we followed the instructional design principles of the ADDIE model (Analysis-Design-Development-Implementation-Evaluation) (Sangrà, Guàrdia, Williams, & Schurm, 2004). It was designed to favour the learning process using a holistic view of the student's pedagogical needs.

In the analysis phase, we considered all the contextual aspects relating to the teaching of the subject. Analysis of the course program, planning and programming of the subject, and the availability of resources (time, material, computer, software, professors, etc.) were some of those aspects.

The design phase dealt with specific learning objectives, assessment instruments, exercises, content, subject matter analysis, lesson planning, and resource selection. This design proposal aimed to encourage autonomous learning, referring to learning as "how to correctly do an activity" (guided learning). This is intended:

- To help students understand the theoretical content previously explained in the classroom in order to properly assimilate the subject.
- To help students acquire other competencies and skills (transversal and specific) identified in our study subject, as reported above.

The development phase is where the professors create and assemble the content assets that were created in the design phase. To implement the instructional resource, we designed a protocol with the following steps:

1) The new resource was presented to students and they were informed about its applicability to the development of practical lectures (corresponding to 37.5% of the teaching received), the monitoring of which is detailed in the subject teaching guide.

2) The learning resource was made retrieved in the virtual campus (Moodle platform) well in advance of the lectures in order to synchronize theoretical and practical content.

3) The resource was used to solve exercises in practical sessions.

Finally, to achieve the objective of this study, we assessed the use of resources in the classroom, for both the professors and the students.

The interactive resource that was designed differs from the classic problem-solving resource because:

- It is not a written presentation of the texts printed in a book or other academic documents (dossiers, notes, etc.).
- It has an interactive design that enables autonomous study.

- A very flexible navigation system is provided for learning this content that enables users to have control over their learning sequences and so construct their own knowledge representations.
- The guidance systems also prevent students from getting lost and disoriented with regard to content explanation (information window, direct links to the different content, and provides a clear reference of what has been reviewed and what has not, etc.). It also includes the steps for the correct application of the software used in each study unit.
- The student plays an active and responsible role in the process of knowledge construction (constructive approach).
- It has been designed to allow independent learning and so can be used in both a distance learning environment and in a blended learning environment.
- It can be used to complement face-to-face class meetings. The benefits of both teaching methods could thus be taken advantage of to improve students' overall learning experiences.

Figure 1 displays a screenshot from a module on Material Requirements Planning (MRP). This topic is highly relevant in Operation Management subject programmes.

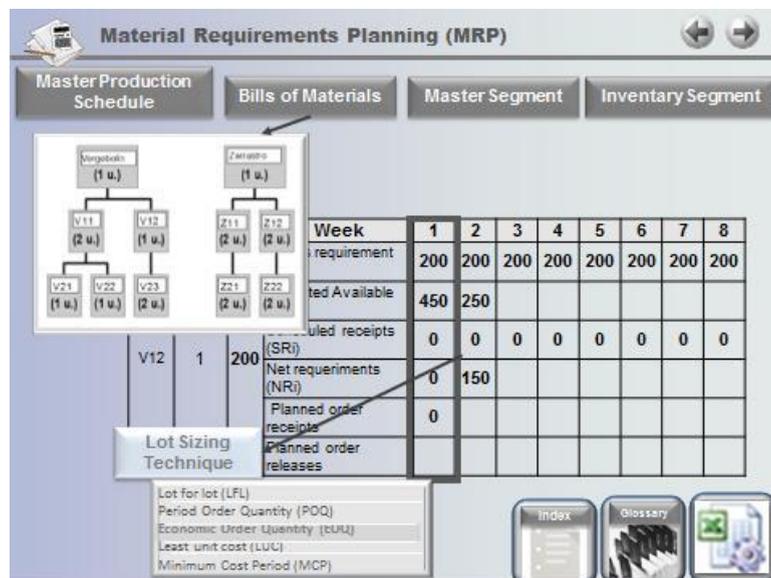


Figure 1. Screenshot for an Operation Management module

STATISTICAL METHODS

As far as data analysis is concerned, in order to firstly assess the computer-based learning proposal, we began conducting a descriptive study of the different variables of the questionnaire used for collecting data. Secondly, we applied the SPC to determine whether or not the learning process is stable (in statistical control). We used the SPC chart as a core tool, which is a graph used to study how a process changes over time, specifically the p-chart. Data was plotted in time order. A control chart always has a central line (LC) for the average, an upper line for the upper control limit (UCL) and a lower line for the lower control

limit (LCL). These lines were determined from historical data. By comparing current data to these lines, we could draw conclusions about whether the process variation was consistent (in control) or was unpredictable (out of control, affected by special causes of variation).

In education, “SPC charts can be used to indicate out-of-control conditions in teaching and learning processes, which instructors can then analyse and consequently improve knowledge transfer” (Grygoryev & Karapetrovic, 2005b). Thus, the instructor can monitor the learning process in an on-going way and can use SPC charts in order to seek the assignable causes for each out-of-control situation.

A logical sequence of stages has to be followed for its implementation, as can be seen in Figure 2, where we show the factors which should be considered when choosing a control chart for a given application. For the characteristic of quality that we want to control (student satisfaction), we used an attribute control chart, the p-chart (fraction nonconforming), which allowed us to control the proportion of students who were satisfied with the use and application of instructional resources for the development of classes in small groups (< 30 students).

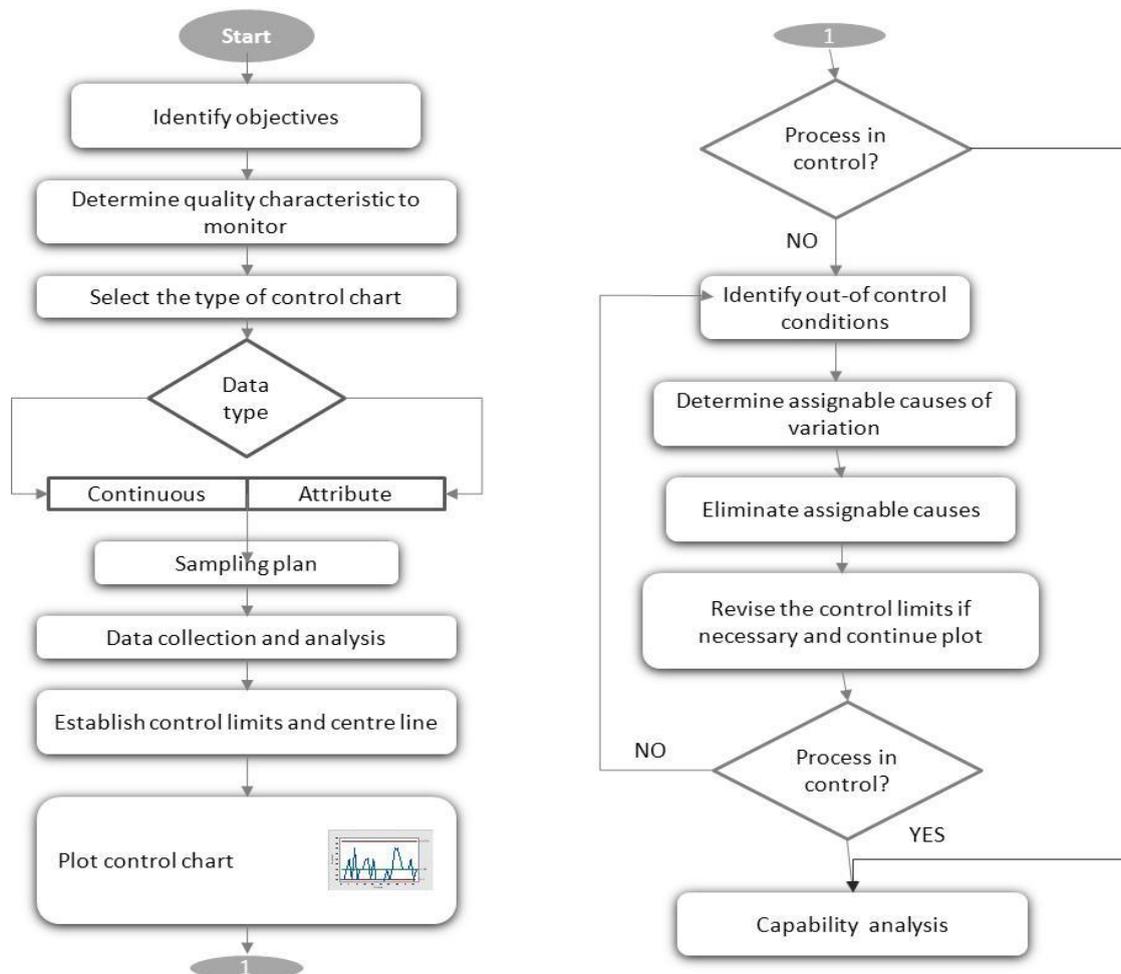


Figure 2. Application of quality control charts

The underlying statistical principles for a control chart for proportion nonconforming (p-chart) are based on the binomial distribution. Let us suppose that the learning process operates in a stable manner,

such that the probability that the students do not meet specifications is a constant (p).

To plot this chart, we observe subgroups (different class groups) of n units (students) over periods of time. We inspect (test) the n units in each subgroup and determine the number of these students that are nonconforming (d_i). We then calculate for each subgroup the fraction of nonconforming students in the subgroup (p_i):

$$p_i = d_i/n \quad (1)$$

Thus, if it is a random sample of n units (students) and d represents the number of nonconforming units (number of dissatisfied students), the probability that d take the values of 0, 1, 2, ... n , will be determined by the binomial distribution with parameters n and p [$d \sim B(n,p)$].

The statistical basis to define the control limits of this chart is common with other Shewhart charts. If the true fraction conforming p is known (or a standard value is given), then the centre line and control limits of the fraction nonconforming control chart are:

$$\begin{aligned} \text{UCL} &= p + k\sqrt{p(1-p)/n} \\ \text{CL} &= p \\ \text{LCL} &= p - k\sqrt{p(1-p)/n} \end{aligned} \quad (2)$$

where k = number of samples.

When the process fraction (proportion) p is not known, it must be estimated from the Retrieved data. This is accomplished by selecting m preliminary samples, each of size n . If there are d_i defectives in sample i , the fraction nonconforming in sample i is

$$\hat{p}_i = d_i/n, i = 1,2,3 \dots \dots m \quad (3)$$

and the average of these individual sample fractions is

$$\bar{p} = \sum_{i=1}^m d_i/mn = \sum_{i=1}^m \hat{p}_i/m \quad (4)$$

Thus, in general, as long as the points (p_i) plot within the control limits, the process is assumed to be in control, and no action is necessary. However, a point that plots outside of the control limits is interpreted as evidence that the process is out of control, and investigation and corrective action are required to find and eliminate the assignable cause or causes responsible for this behaviour. However, even if all the points plot inside the control limits, if they behave in a systematic or non-random manner, this is an indication that the process is out of control too.

3 RESULTS AND DISCUSSION

STUDENT PROFILE AND TEACHING CONTEXT

The number of students who completed the questionnaire was 184, which is the initial sample of our research. They are the students who regularly attended practical sessions in small groups (< 30 students) and represents 71% of the students enrolled in the academic year of our study.

Approximately 85% of the students are between 20 and 25 years old. Female students predominate in the sample (61.96% of total the sample).

The average frequency of attendance at theoretical sessions in large groups in the academic year under review is 67.49%

On the other hand, approximately, 30% of students are repeaters, so the students who have passed practical sessions in the academic year under study represent 70% of the sample. In the group of repeaters, the largest share is of students that have completed practical sessions two or three times (20.65% and 7.6% of the total, respectively).

For groups of students, except one, the percentage of students that made the practical sessions for the first time is more than 50% of students in each group, and it is higher than the average of the total study sample (69.79%)

Finally, it should be noted that students usually attend the same class group.

TEACHING RESOURCE ASSESSMENT

In general, the students were satisfied with the instructional resource. Approximately 60% of respondents agreed that the resource is suitable and useful for learning theoretical knowledge. 64.48% of them were satisfied with the Retrieved resources to develop classes in small groups properly. And finally, as a result of the above, and as expected, 75.28% of students believed it is suitable to extend this type of learning resource to other subjects of the degree.

Regarding the assessment of the competencies listed in the third section of the questionnaire, the results of the descriptive analysis (see Table 1), show that the highest scores in the assessment of competencies and skills by students are the ability to work in an autonomous and continuous mode. This promotes the development of other positively valued skills (e.g., capacity for analysis and synthesis and ability to detect and solve problems).

Table 1. Assessment of the students' skills ($n=165$)

Skills	Average ¹	Standard deviation
Autonomy and responsibility	4.08	0.74
Continuous study	3.67	1.13
Ability to detect problems	3.64	1.18
Capacity for analysis and synthesis	3.61	1.01
Capacity for critique and evaluation	3.45	0.97

¹Based on a 5-point Likert scale: 1 strongly disagree, 2 disagree, 3 neutral, 4 agree and 5 strongly agree

AN SPC APPLICATION

To assess students' satisfaction with the teaching resource we utilized the p-chart for 8 samples which had variable sizes (n = number of students that usually attend practical sessions in small class groups; $9 \leq n_i \leq 30$). Furthermore, for comparative purposes, we changed the sampling plan, selecting a larger sample ($k = 30$) with a constant size ($n = 5$).

The criteria used to determine the proportion of satisfied students with the resource was based on the response scale of the questionnaire items: a student was considered to be satisfied with the resource if he answered "agree" (4) or "strongly agree" (5); otherwise, we considered that the student was dissatisfied with the teaching tool if their response fell between the values (1) to (3).

Table 2 presents the proportion of students dissatisfied with the teaching resource (p_i) for each class group.

Table 2. Dissatisfied students per group ($n= 165$)

Class groups	No. students (n_i)	Dissatisfied students	p_i
1	27	7	0.26
2	21	4	0.19
3	17	6	0.35
4	22	2	0.09
5	9	1	0.11
6	20	2	0.10
7	30	11	0.37
8	19	1	0.05

First, before applying the SPC p-chart, we performed a goodness of fit test to determine whether our data followed a binomial distribution since, as it was mentioned before, this distribution is the statistical basis for the p-chart. To do this we carried out a diagnostic test of binomial probability using

Minitab™.

A graph of the results of the binomial diagnosis test and the p control chart are shown in Figure 3.

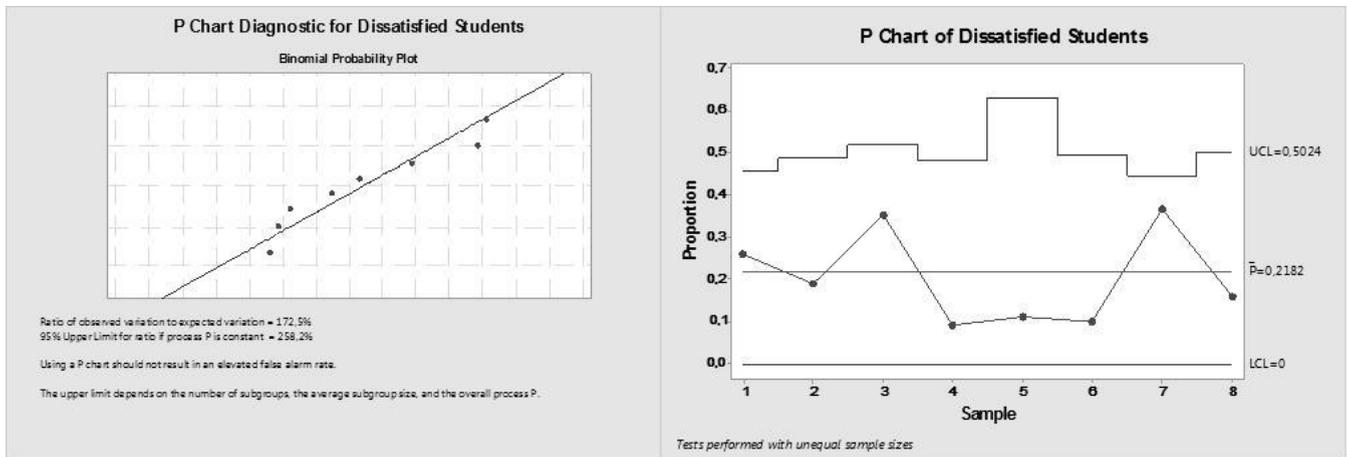


Figure 3. p control chart ($k =$ number group, $n =$ students in each group)

The obtained results verify that the process is under control, and therefore the null hypothesis of research (H_0) is true, because it holds that:

$$p_i \in \left[p \pm k \sqrt{p(1-p)/n_i} \right]$$

For the alternative sampling plan proposed (30 samples of 5 students), the results are shown in Figure 4.

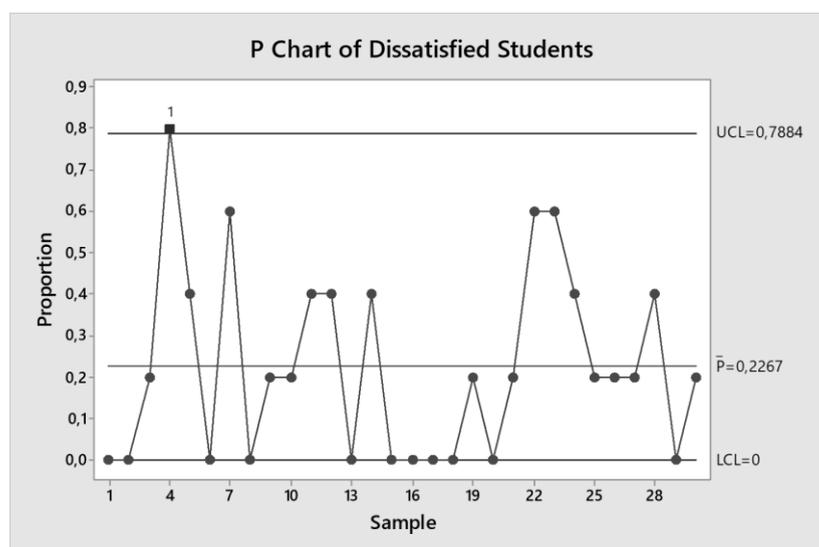


Figure 4. p control chart ($k = 30$, $n = 5$)

In this case, the proportion of dissatisfied students in sample 4 ($p_4 = 0.8$) is above the UCL

(0.7884); therefore, the process is out of statistical control and the null hypothesis is rejected. It would therefore be necessary to identify the cause attributable to the process, remove the sample, and draw the chart again for the rest of the samples ($n = 29$) (see Figure 5).

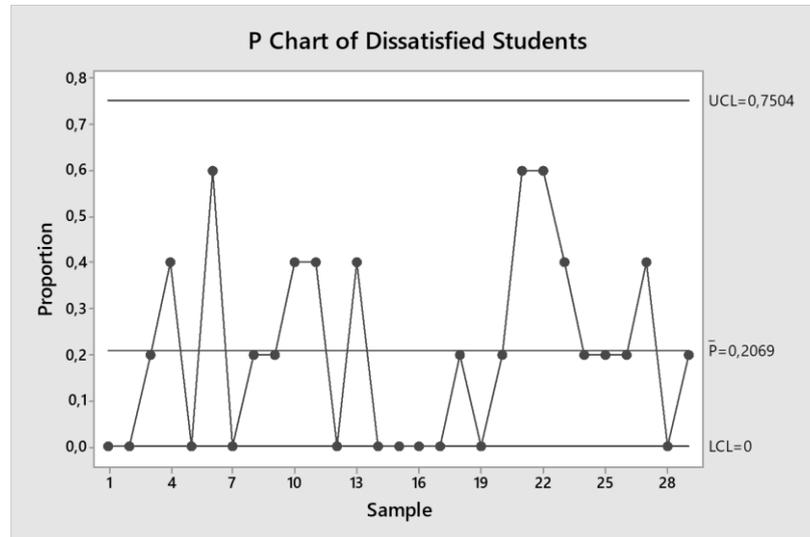


Figure 5. p control chart ($k = 29$, $n = 5$)

The new results show that the process is under statistical control, because all samples are within the new control interval [LCL (0), UCL (0.7504)], smaller than the previous one. These limits, in principle, could serve as a reference for subsequent sampling and monitoring of the learning process.

The average proportion of dissatisfied students when the process is under control is slightly lower in this case (20.7%) than in the first case analysed (22.6%).

In order to complete the study of the learning process under analysis through the SPC framework, we performed a corresponding Capability Analysis. Usually, the capability of a process is determined by comparing the width of the process spread to the width of the specification spread, which defines the maximum amount of variation allowed, based on customer requirements.

Although there are several alternatives proposed by various authors to measure process capability with attribute data (Correa, 2003; Cuatrecasas, 2005; Hsieh & Tong, 2006; Kumar, Crocker, & Chitra, 2006), to continue our analysis we followed the method recommended by the Minitab statistical software. This process comes from the binomial distribution and establishes a parts per million (PPM) index which indicates the number of nonconforming parts in the process and a sigma process level (Z), which describes the capability of a binary process (one process in which products or services are judged to be either defective or not defective) (Schmidt & Lausbyn, 1997).

The results are shown in Figure 6, for a target of 40% of dissatisfied students ($k=29$, $n=5$).

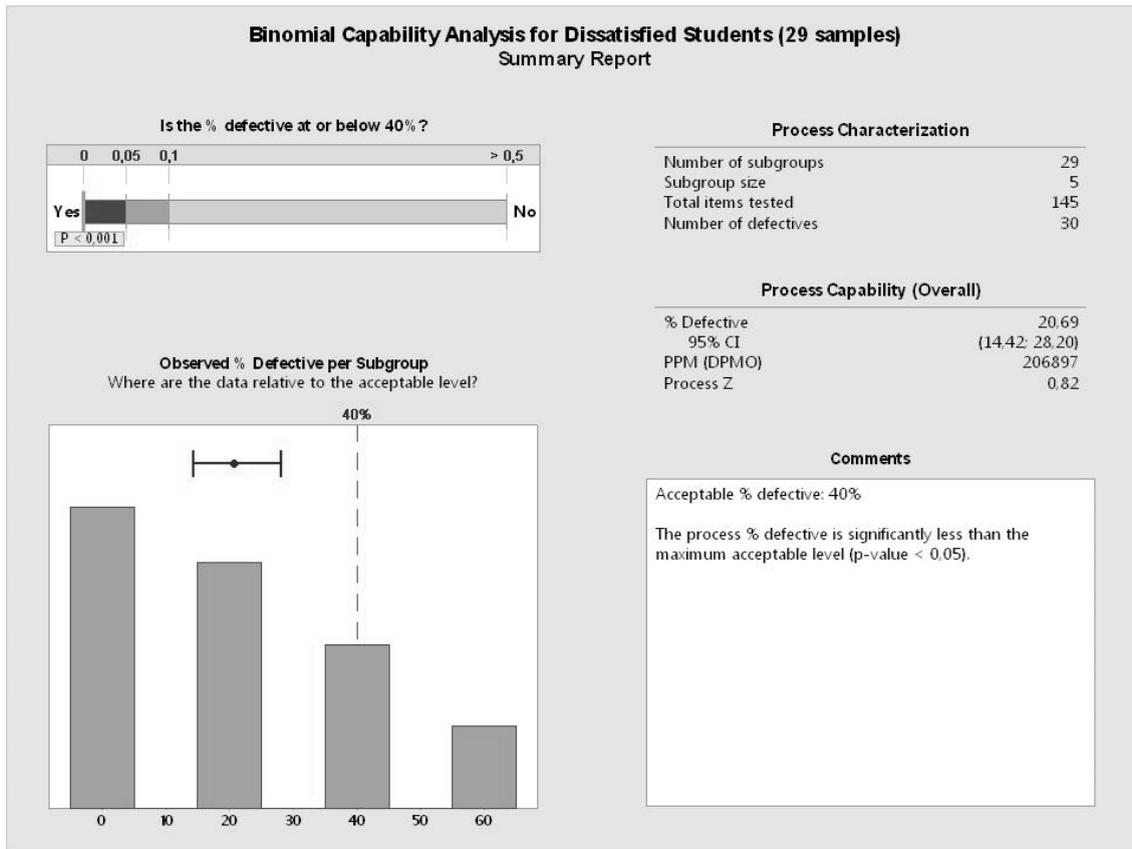


Figure 6. Capability analysis ($k= 29, n = 5$)

The capacity report provided by Minitab for a weak target (a proportion 40% of dissatisfied students is allowed) and a high level of satisfaction (students who scored 4 or 5), shows a Z value of 0.82 (< 1). This indicates that despite being under control, the process is not able to fully meet the specifications required by the teachers participating in the project.

The results show that although, for the level of requirements set by the professors, the students' satisfaction level is acceptable, in order to increase the performance of the resource in the learning process, and therefore achieving the goals of the lesson, teachers involved in the project should review the instructional model in its different stages, and search for possible assignable causes of the learning process. The teacher team should check those issues not only directly involved in teaching (group and lessons planning, synchronization of theoretical and practical lessons, etc.), but also issues regarding the centre where the subject is taught (curriculum planning and programming, availability and suitability of computer-equipment resources, classrooms, etc.).

4 CONCLUSIONS

The implementation of SPC to evaluate teaching strategies as presented in this paper provides a practical, systematic, and structured approach to evaluating different educational processes. Further, it is a different approach to the ones usually applied in the education sector. The approach presented and applied in this study may provide relevant information to stakeholders about the management and control

of the quality of learning processes and other educational services under a proactive approach for continuous improvement. Moreover, this approach is useful to detect possible assignable causes of variability in processes, and measure the ability of teaching strategies to ensure the acquisition and development of various skills and competencies demanded by current university curricula. Furthermore, the application of these techniques, will not only allow self-assessment, but can be used for comparative purposes (with other teaching strategies, other colleges, etc.).

Thus, the proposal made in this study may contribute to a shift in the evaluation of educational processes in general and specifically in teaching strategies, such as the one presented in this paper. The application of this important management tool should become a routine method in learning processes and educational services.

Although this work is based on a technique with inherent limitations linked to both the methodology and selection of data sources, it is considered to be a first step and could be a reference point for further analysis and improvements.

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