

Active learning in Operations Management: interactive multimedia software for teaching JIT/Lean Production

Carmen Medina-López, Rafaela Alfalla-Luque, Francisco Arenas-Márquez
Universidad de Sevilla (SPAIN)

Received December 2010

Accepted March 2011

Abstract:

Purpose: Information & Communication Technologies (ICT) can be a fundamental aid for the design of new teaching methods that better adapt to the framework of the European Higher Education Area. In this context, this study aims to develop and assess a complex and truly interactive ICT-based teaching tool for instruction in OM.

Design/methodology/approach: A multimedia application for Just-in-Time (JIT) / Lean Production has been conceived, designed and assessed. A constructivist focus was followed in its conception and design to encourage active and flexible learning adapted to each individual's own requirements. Using empirical research the tool has been assessed by students and compared to the traditional teaching methods.

Findings: The interactive multimedia application has been clearly valued for the way it conveys information and for its usability, for the way the application is structured and the improvements to students' understanding of the knowledge. Students are also in favour of ICT being incorporated into teaching over more traditional methods. The assessment took students' gender and the average overall mark on their academic records as control variables but, broadly-speaking, no significant differences were found.

Research limitations/implications: The study was carried out in a controlled environment and not in the normal on-site university teaching process. Conclusions could be extended to OM and other related subjects, especially if they make use of similar tools to the one described in this paper.

Practical implications: This study provides a contribution that allows reflections to be made on the design of specific software for OM and students' perceptions when using it.

Originality/value: Through this paper we contribute to an improvement in learning methods in general and to higher education in OM in particular.

Keywords: teaching, operations management, multimedia educational software, just-in-time, lean production

1 Introduction

European higher education is increasingly becoming immersed in two realities that will without doubt have a bearing on its future over the coming decades. On the one hand, the impact that Information & Communication Technologies (ICT) are having on teaching methodology, the way teaching processes are conducted, and the fashion in which teachers relate to students. On the other hand, the legal framework that regulates university education in Europe is in the process of adapting to the European Higher Education Area (EHEA), instigated by the European Union. The Sorbonne (1998), Bologna (1999), Prague (2001), Berlin (2003), Bergen (2005), London (2007) & Leuven (2009) declarations, all agree on the need to harmonise higher education in Europe. This harmonisation requires significant changes to be made to the university system including the need to adapt teaching methodologies to the new challenges that are being faced. For example, the European Credit Transfer System (ECTS) is bringing about a decrease in the number of on-site class hours, which is affecting the teaching methodology to be used. This teaching philosophy is aimed at greater student autonomy and means a change from a teaching-based to a learning-based focus facilitated by the new technologies (European Commission, 2002). In other respects, there is also a

patent need to respond to a growing demand for lifelong learning and distance learning. Going hand-in-hand with this is the need to cater for new student profiles, with a wide range of motivations, ages, interests and spaces.

In these circumstances, we consider the development of new learning tools which incorporate the advantages provided by ICT to be an appropriate response to this need. ICT are having a clear effect on teaching-learning models, considerably broadening the possibilities of further education to the extent that it becomes, in practical terms, permanent education. They are thus also having a strong impact on the teaching methodology, the teaching/learning process linkage and on the relationship between instructors and students. ICT-based learning tools are becoming very powerful tools for conveying information as they are significantly changing communication between the actors in the teaching-learning process. Institutions responsible for further education are well-aware of this phenomenon (NCET (National Council for Educational Technologies of UK) (1994), European Commission (1996), AACSB (American Assembly of Collegiate Schools of Business) (1997) and UNESCO (Andresen & Brink, 2002)). The interest shown by the European Union in the latest Framework Programmes is a faithful reflection of the importance that its member States are affording the study, promotion and incorporation of the new technologies in Higher Education. Therefore, continuing along the lines of earlier initiatives, the Fifth European Community Framework Programme covering Research, Technological Development and Demonstration Activities (1998-2002) proposed, Information Society Technologies (IST) and a range of lines of action related to the use of ICT in teaching environments among its priority topics. These lines included the “development of tools, open platforms, advanced personalised-teaching systems and large-scale experiments to achieve the flexible university of the future”. Meanwhile IST continued to be a priority topic in the 6th Framework Programme with one of its prime objectives being the eEurope Action Plan. This initiative gave great importance to the “effective application of ICT in education and permanent learning” For this reason the eLearning Programme (2004-2006) was also adopted with one of its basic lines being “to develop virtual university campuses”. The Seventh Framework Programme (2007-2013) also provides for research initiatives in this same line in its “ICT Work Programme 2011-2012”. This is divided into eight Challenges that are considered to be of strategic interest for European society, one of which focuses on the use of the ICT in teaching both in educational institutions, including

universities, and in the workplace (Challenge 8 - ICT for Learning and Access to Cultural Resources). One of the aspects included is the promotion of projects linked to developing tools that enable creative, non-linear learning, and the use of ICT for continuous training and the creation of new learning models on the basis of these technologies.

The ICT are therefore a recognised lynchpin for aiding the design of new teaching methods that better adapt to the European Higher Education Area (EHEA) framework and that facilitate quality on-site and distance training. In the area that concerns us here, Operations Management (OM), the use of ICT is both highly applicable and also has a huge potential for motivating the student (Krajewski, 1998) and improving the teaching-learning process (Barron & Orwig, 1995). And OM is one of the business areas that best adapts to computer-assisted teaching (Coye & Stonebraker, 1994). Despite this, Business Administration (BA) Higher Education has responded slowly and timidly to these new requirements. In the second half of the nineteen-nineties, the Association to Advance Collegiate Schools of Business signalled the slowness with which business schools in the United States were adapting their teaching methodologies to rapid ICT development (AACSB, 1997). In later studies, Pfeffer and Fong (2002) and Richardson (2003) stated that the programmes for the subjects and the teaching methods used for teaching them had not changed substantially to adapt to new demands. Likewise, they are a very useful tool in engineering. Shannon (1994) concluded that in the engineering disciplines much is to be gained through the ability to animate when presenting explanations of how and why something works. Meanwhile Rothberg, Lamb and Wallace (2001) determined that engineering academics have a strong belief that computer aided learning helps engineering education.

In this line it should be pointed out that the Operations area has generally been slow to incorporate innovative teaching methods. For example, when focusing upon the use of multimedia applications for educational use in OM -the object of this study- it can be seen that they have received little attention in studies in the literature (New, 2003). As the analysis in the following section will show, when computers are used in this discipline, they tend to be used for experimenting with games or simulations. Nevertheless, the opportunities that multimedia technologies provide can have important implications for training in OM (New, 2003). They have been acclaimed as a key technological development for education since they first

appeared in the nineteen-eighties (Gunasekaran & Love, 1999; New, 2003). It is for this reason that this paper focuses on the conception, design and assessment of an interactive multimedia application that makes use of the ICT to improve training in OM.

The paper is organised as follows. Section 2 reviews previous studies and sets out the research objectives. Section 3 describes the methodology employed. This is followed by the results of the study. Finally, the main conclusions are presented.

2 Literature review and research objectives

As pointed out above, OM does not seem to be a pioneering area in the generalised use of the most innovative teaching methods (Alfalla-Luque & Machuca, 2003; Alfalla-Luque, Arenas-Márquez & Medina-López, 2001; Arbaugh, Desai, Rau, & Sridhar, 2010; Carraway & Freeland, 1989; Goffin, 1998; Hammond, Hartman, & Brown, 1996; Raiszadeh & Etkin, 1989). This is why the need to incorporate the use of the ICT into teaching the subject has been highlighted so often (Alfalla-Luque & Machuca, 2001; Alfalla-Luque & Machuca, 2003; Arbaugh et al., 2010; Hayes, 2000; Krajewski, 1998).

However, improved OM teaching is a topic that has traditionally concerned OM researchers. As far back as 1965 Cangelosi stated his concern for the use of management games that emphasised the Marketing function to the exclusion of the Production function. Since then, numerous experiences of implementing different teaching methods and tools in OM have appeared in the literature. Some studies describe specific experiences of simulation or business game software specially designed for the teaching of OM topics (e.g. Ammar & Wright, 2002; González, Machuca, & Ruiz, 2000; Holweg & Bicheno, 2002; Johnson & Drougas, 2002; Lewis & Maylor, 2007; Machuca & Barajas, 2004; McKone & Bozewicz, 2003; Rauch-Geelhaar, Jenke, & Thurnes, 2003; Tan, Tse, & Chung, 2010; Yazici, 2006). Other authors go beyond this and propose the utilisation in teaching contexts of the same OM software actually used in companies, with the aim of providing realistic training based on the activities undertaken in the Production function in real companies (e.g. Boykin & Martz, 2004; Laforge & Busing, 1998; Laforge & McNichols, 1989; Sweeney, Campbell, & Mundy, 2010). Other experiences demonstrate the use of the following, amongst other things: team projects (e.g. Ahire, 2001; Fish, 2008;

Satzler & Sheu, 2002; Yazici, 2004), manual games (e.g. Cox & Walter, 2005; Gattiker, 2003; Griffin, 1997; Polito, Kros, & Watson, 2004), virtual learning environments (e.g. Greasley, Bennett, & Greasley, 2004; Naslund, 2005; Walker, Gough, Bakker, Knight, & McBain, 2009), multimedia applications (e.g. Alfalla-Luque, Medina-López, & Arenas-Márquez, 2011; Balazinski & Przybylo, 2005; Ball & Thornbury, 2004); problem-based learning (e.g. Kanet & Barut, 2003; Mukherjee, 2002), case studies (e.g. Julien, Doutriaux, & Couillard, 1998; Morris, 1997) and immediate response systems (e.g. Yourstone, Kraye, & Albaum, 2008; Ruiz, Ceballos, García, & Chávez, 2010).

As can be seen, among the teaching-learning strategies analysed, the use of multimedia for educational ends in OM has received little attention in studies as, when the computer is put to use, the tendency is to experiment with games and simulations (New, 2003). It must be stressed that multimedia applications should not be limited to the mere transfer of the content of a classic book to a digital medium. Using this approach to deliver large volumes of text is inappropriate, as it will not stimulate the interest of the learner (Ball & Thornbury, 2004). Despite this, there are few experiences that go beyond digitising a text book and the ones that do exist tend to be somewhat underdeveloped. Balazinski and Przybylo (2005), for example, focus only on the development of multimedia animation (with and without interactivity).

Other more complete multimedia applications exist in other areas, such as that developed by Belton, Elder and Thornbury (1997) in the discipline of Operational Research /Management Science. Multimedia shows its evident potential in these other subjects. For example, Altherr, Wagner, Eckert and Jodl (2004) state that using multimedia for teaching physics phenomena can enable a vivid presentation, which facilitates examination and analysis of correlations. In addition, it is possible to present complicated content and simultaneously provide different levels of abstraction to help students gain a better understanding. The Operations area should also benefit from the use of multimedia technologies. However, given the lack of appropriate multimedia applications, its evident potential cannot be used. This is why these tools need to be conceived and developed as is being done in this paper, as a prior step to their being incorporated into the teaching process.

In other respects, the literature review reveals that the numerous teaching experiments that were analysed were not formally assessed from the student point-of-view. In other words, the experiment is described, simply, and, on occasion, commentaries that have been made informally by students are added as a complement (e.g. Ahire, 2001; Ammar & Wright, 2002; Balazinski & Przybylo, 2005; Griffin, 1997; Holweg & Bicheno, 2002; Yazici, 2006). The result is that calls have been made for empirical studies such as that presented here, that conduct a formal study of the proposed teaching methods.

It should be highlighted that several studies (Kadiyala & Crynes 2000; Smith & Ragan, 1992) find multimedia instruction both more effective and more efficient than conventional educational approaches. Van Dijk and Jochems (2002) state that changing a traditional teaching approach in lectures into an interactive lecturing experience is not only feasible but is also beneficial to the students. One of the questions to be evaluated in this study will therefore focus on a comparison of the teaching tool with the traditional teaching method.

Finally, Belton et al. (1997) conclude that a multimedia application, in conjunction with more traditional modes of teaching, has significant potential for improving the effectiveness of teaching and learning. In this same line, Ball and Thornbury (2004) show how learning can be enhanced with an appropriate combination of computer aided learning, lectures and tutorials. Given how important the implementation of these new teaching strategies is, it is interesting to have the student's opinion in this regard, which is why this will be done in this research.

As has been expressed above, there is a dearth of multimedia applications in OM and formal evaluations of them from the student's point-of-view (both of the tool itself, and also in comparison with other teaching methods). For this reason, the objective of this paper is the design, development and evaluation of an ICT-based interactive multimedia application for training in OM. This objective has been broken down into: a) Creating an ICT-based interactive multimedia application for training in OM; b) Evaluating the design and operation of the educational application from the student's point-of-view; c) Assessing traditional teaching methods (lectures) compared to more innovative methods, such as the one proposed here. It should be highlighted that the application has been assessed bearing in mind two control variables: students' gender and the average overall

mark on their academic records. The aim of this is to determine whether there are any differences on the basis of these variables.

The average overall mark on students' academic records is a variable that might impact on their perceptions of the teaching method, although this has not been detected in other studies that have addressed this. With regard to gender differentiation, evidence exists that suggests that men and women conceptualise and use the medium differently (Arbaugh, 2000). Previous studies of differences in communication patterns between men and women have found that men tend to communicate on the basis of social hierarchy and competition, whereas women tend to be more network-oriented and collaborative (Tannen, 1995). Some studies have found that while gender differences toward computer usage may exist among school age children, they tend to disappear once people are old enough to enter the workplace (Kraut, Sherlis, Mukhopadhyay, Manning, & Kiesler, 1996; Whitely, 1997). In other studies, such as Arbaugh (2000), no significant differences are detected between men and women in learning or exam performance. There therefore does not seem to be a clear pattern with respect to this variable.

3 Methodology

The interactive multimedia application was developed in our research group (GIDEAO) following the three characteristic phases of educational software development processes: conception, development and assessment (Benyon, Stone & Woodroffe, 1997; Cabero, 2001; Chapman, 1995; Koper, 1998; Shabajee, 1999). During the whole process, consideration was given to pedagogical aspects, aspects of the subject matter to be studied, and technical aspects relating to computer science. The group's prior experience of developing other ICT-based training tools, basically business simulators (González et al., 2000; Machuca & Barajas, 1997; Machuca, González, & Ruiz, 2003) was of great use in this respect.

During the conception phase the course teaching content, the user objective and the training strategy were determined. Similarly, the groundwork was done to enable the features and properties of the application to be established during the development stage. In the assessment stage the assessment was underpinned by the producer-expert-student triple perspective under the premise of not assessing a medium in isolation from its context (Squires & McDougall, 1996; Jones et al.,

1999; Cabero, 2001; Rogers & Newton, 2001; Hosie, Schibeci, & Backhaus, 2005). These views are complementary and this allows a full assessment to be made by all the actors involved and by the people who have some contribution to make to the teaching-learning process. The assessments made on the production and expert levels are formative assessments consisting of a systematic improvement process during the application's development. This has to be done considering both the technical and pedagogical features apart from the content. In other respects, assessment on the user level is framed within a summative type of assessment. This is done once the application has been finished and might imply actions for its improvement.

Consequently, two stages were required to achieve the goal that was set. The first of these allowed an interactive multimedia application for training in OM with a constructivist focus and that makes use of the ICT to be conceived, designed and assessed on the production and expert levels. The second consisted of assessing the application that was developed at the user level. This assessment focused on an analysis of the application's features (design and operation) and on a comparison with traditional on-site teaching (OST).

During this first conception, development and formative assessment stage, the conception phase began with the determination of the topic to be implemented as content of the application. A classic topic in the discipline was chosen, the Just in Time (JIT) / Lean Production philosophy, which is highly relevant both to business practice (Avella, Fernández, & Vázquez, 1999; Marvel & Standridge, 2009; Miller, Pawloski, & Standridge, 2010; Puvanasvaran, Megat, Hong, & Razali, 2009; Schonberger, 2007) and in OM subject programmes (Bradley & Willett, 2004; Goffin, 1998; Machuca & Alfalla-Luque, 2002 and 2003; Ozelkan & Galambosi, 2009; Slack, Lewis, & Bates, 2004).

Potential users of the application were also defined. From the point-of-view of the content the user had to have basic knowledge of Business Management but no more than what was required to begin the study of JIT/Lean Performance in any other way. It would therefore be appropriate for students in their last years of Business Administration (BA) or Industrial Engineering (IE) and also for professionals looking for training or to increase their knowledge in this area. From the point-of-view of the skills required, the application was designed in such a way

that the user did not need to have any prior experience of the computer to use it properly.

The design of a good educational interactive multimedia application requires appropriate knowledge of the users who are going to operate the application, setting out a teaching strategy that follows a student-centred learning focus, and the design of a suitable graphic interface that makes use of a suitable combination of media, with a greater degree of interactivity than other multimedia applications whose purpose is merely to provide information.

The training strategy or, in other words, the learning process that the user follows, has been based on the constructivist approach in an endeavour to achieve student self-learning. The constructivist approach places a very active role upon the student in the teaching-learning process (Lewis, 1999; Shuell, 1996). It assumes that the person is not only a processor of information, but also a constructor of this depending on his/her experience, previous knowledge, and attitudes towards the content, media, materials and messages with which s/he interacts (Cabero, 2001). For this focus to be achieved the system has to be provided with a navigation system that gives users freedom of movement, a tracking system that guides their study, and a self-assessment system that tells them what level of knowledge of the subject matter they have achieved. Alongside these elements visual and interactive teaching software is required to encourage active learning. An attractive visual interface is important for generating interest and initial motivation, whilst the need for interaction ensures the cognitive engagement necessary for learning (Belton et al., 1997). In this regard, interactivity plays a crucial role in knowledge acquisition and the development of new skills (Domagk, Schwartz, & Plass, 2010; Evans & Gibbons, 2007; Sims, 1997; Wang, Vaughn, & Liu, 2011). Learners take on more active roles and assume greater responsibility within their own learning process and are able to follow their own learning style.

The importance of the interface for an educational application comes from the fact that it is the element that links what one is trying to teach with the student. No matter how complex the programming of the application is, the user must perceive it to be clear, ordered, simple and with specific objectives. When these features are not present, the student becomes anxious and, as a result, his/her study performance in the subject decreases (Lynch & Horton, 2008). Any absence of a

consistent methodological basis in the development of this type of tool might result in a low-quality product, whatever the resources used to produce it. We have followed generally-acceptable recommendations, style-guides and usage norms within the field of Educational Technology and Human Computer Interaction for the design of the interface (e.g. Crowther, Keller, & Waddoups, 2004; Dumas & Redish, 1999; Kemp & Buckner, 1999; Kim, Douglas, Orkand, & Astion, 2001; Lockyer, Bennett, Agostinho, & Harper, 2008; Mayes & Fowler, 1999; Nielsen, 2000; Parlangeli, Marchigiani, & Bagnara, 1999; Rubin & Chisnell, 2008; Schneiderman & Plaisant, 2005; Tullis & Albert, 2008; Van den Akker, Gustafson, Branch, Nieveen, & Plomp, 1999).

With a view to giving the application added-value, it was designed not only to be used by the instructor in the classroom, but so that it also adapted to independent self-learning by the user. The characteristics of distance education teaching materials therefore also had to be taken into account. This would lend itself to an integrated and flexible learning environment that enables greater adaptation to students' varying timetables and rhythm of learning (Cornélis, Cochinaux, Garady, Ferrant, & Webb, 1997). This is why it was also appropriate to give the application other complementary elements apart from interactivity, a suitable selection of activities, a user-friendly and intuitive interface, and the above-mentioned navigation, tracking and self-assessment systems. An interactive glossary of concepts, with users being able to access key study content terminology, would help with the training and would make the learning process easier. A help module would provide basic information about the way that the application operated and tell the user which actions had to be carried out on any screen at any time. In other respects, a suitable entry module linked to the tracking system would allow users to organise their study and pick up working where they had previously left off in earlier sessions. In short, the aim was to develop a tool that would facilitate student training in the subject matter within a constructivist approach without attending normal on-site classes being essential. The implementation and detailed analysis of these elements in the application is presented in the following section, as it is one of the results of this research.

We developed the software using a variety of programming tools, although special mention should be made of the Adobe Authorware authoring tool, which is an object-oriented programming software highly-suited to creating attractive rich-

media and user-friendly e-learning applications. An idea of the effort that went into its programming can be provided by the 6,800 plus objects that can be found in the current version of the application.

In-process versions of the application were assessed at the production and expert levels concurrently with the development phase. Assessment at the production level was done as the application was being developed. The objectives that had been set in the blueprint were periodically compared with the results that had been achieved thus far. This enabled continuous improvement. The expert assessment, meanwhile, was done by instructors (industrial engineers and BA graduates) with wide experience in the teaching of Operations Management and by experts in Educational Technology. The application that was developed was submitted to critical judgement. Their comments and suggestions were analyzed and the necessary changes were introduced to improve the application. Once this process was finalised, the application was obtained that would be assessed by the students and so begins the second phase of this study.

An empirical research was designed to assess the application at the user level with a group of students using the educational application to study with. A population of 256 students who complied with two conditions was selected for this study: they had to be enrolled in at least half of the credits for the third year on the University of Seville BA degree and not to have taken the OM subjects in the fourth and fifth years of the syllabus. This profile ensured a degree of homogeneity in their basic knowledge and eliminated any bias there might have been if they had studied JIT/Lean Production previously. Of these a representative sample of 68 students was chosen stratified by proportional affixation according to their average overall marks in their student records using a simple random sample process and setting a maximum allowed error of 0.1 and an a level of confidence of 95%. In all there were 29 male students (42.64%) and 39 female students (57.35%) in the sample. Distribution by gender was tested to ensure that the proportions were the same as for the population. Average overall marks on their student records were calculated on a base of four points, one being the pass mark, two 'good', three 'excellent' and four 'with distinction' The result was weighted on the basis of the number of credits already obtained. The average student record mark for the chosen sample ranged between 1 and 2.06, and the mean average was 1.29 with a typical deviation of 0.227. Using this variable the students were divided into two groups on the basis of

the median (1.24). Group 1 was made up of the 34 students with an average mark that was under the median and group 2 of the remaining 34 students.

The students spent a number of sessions with the multimedia applications in the computer room and 25 hours of on-site classes in morning and afternoon groups to facilitate participation and to enable the available computers to be properly managed. The teacher figure was omitted so that students could carry out self-learning although the teacher was present simply as an organiser and to deal with any technical problems. For this reason, in general terms the method used is referred to as computer-assisted distance learning (CADL).

A questionnaire was drawn up to assess the teaching tool that provided for any significant issues highlighted by the designers and experts in assessment processes within the field of Educational Technology (Amorós & Rodríguez, 1999; Arias, González, Navaridas, & Santiago, 2003; Bou, 1997; Cabero & Duarte, 1999; Cabero, 2001; Catenazzi & Sommaruga, 1999; Collaud, Gurtner, & Coen, 2000; Draper et al., 1994; Hosie et al., 2005; Le Roy, 2001; Leacock & Nesbit, 2007; Marquès, 2000; Martínez et al., 2002; SEDISI, 2000; Squires & McDougall, 1997). The final questionnaire was divided into two parts. The first part included application design and operation and these questions were scored by the students on a scale from 1 (strongly disagree) to 5 (strongly agree).

In the second part of the questionnaire the students had to compare the teaching tool that they used (CADL) with traditional on-site teaching (OST). For this a scale was used from 1 (CADL much less than OST) to 5 (CADL more than OST) with 3 equalling parity between the two teaching methods. A last question asked students' their opinions on whether they considered it to be appropriate to change from the traditional on-site teaching system to a mixed system where off-site credits were covered by teaching materials based on information and communication technologies (ICT). Learners rated this statement on a scale of 1 (strongly disagree) to 5 (strongly agree). The question was put to the students in pre- and post-tests. It could thus be seen whether their taking part in the teaching experiment had led to a change in opinion.

The original questionnaire was subjected to a fine tuning and debugging process with OM lecturers, Educational Technology experts and students which resulted in a final version. The items eventually included in the questionnaire are presented in

Tables 1 to 7 and Table 10. In our opinion, the bibliographical review, the above-mentioned critical judgement of researchers and university lecturers and the pilot test all support the validity of the measurement instruments that were designed (Hoskisson, Hitt, Johnson, & Moesel, 1993; O'Leary-Kelly & Vokurka, 1998).

A descriptive analysis was done using the data from the first part of the questionnaire (Tables 1 to 7) and the independent-samples t-Student test was used to determine whether any significant differences between the two groups were established by the control variables (gender and an average overall academic record mark) (Tables 8 and 9). The Levene statistic was used to determine whether there was any homoscedasticity. The one sample t-Student test (Table 10) and the paired-samples t-Student test were applied to the data obtained from the second part of the questionnaire, the latter to compare the results of the question asked in the pre- and post-tests (Table 11). All the analyses have been done at the 95% confidence level.

4 Results

Given the objective of the study, this section has been duly divided into three subsections. In the first, the interactive application is explained. The second and the third present the assessment done at user level providing the results of both the analysis of the application design and operation and those related to the use of the software as a teaching instrument compared to traditional on-site teaching (lectures).

4.1 The multimedia application

The educational application that was developed came under a teaching strategy that pursued a constructivist focus and independent and autonomous learning. This is why it featured elements that enabled active learning and its use outside the classroom as an off-site teaching tool. The application that has been developed made use of the ICT, with special emphasis placed on multimedia and interactivity. This is not a question of transferring traditional learning systems (e.g., a book) to the new format as used by ICT, but an attempt to exploit the potential for these to do more things and to do them better. In this way we have facilitated and fostered self-learning and open learning in such a way that users can conduct their learning without any limitations of space or time.

B4. Elements of JIT/ Lean U2. SMED (Single Minute Exchange of Die)

2. Phases to improve setup times (2/5)

1st Phase 1: Distinguish between internal and external steps

- ✓ It is necessary to conduct a full study of the processes and times currently used for setup activities.
- ✓ A distinction must be made between the following concepts:

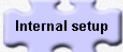

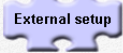

		step that can be performed while the operation is running.
		step that must be performed while the machine or operation is stopped.

Figure 1. "Example of interaction".

The design of any application with the features of the one described herein is decidedly influenced by the teaching content which in our case is related to JIT/Lean Production. Given the marked theoretical character of this, it has been essential to undertake considerable synthesising and structuring in order to achieve a training process in keeping with the previously specified strategy. The best media and formats for each concept being taught or example given (texts, photographs, graphics, animations, videos and narrations) (Figure 1) were carefully selected in each case. A range of different kinds of exercises and types of interaction were also designed to allow users to be an active part in the construction of their own knowledge: multiple choice self-assessment tests, interactive exercises with help messages when mistakes were made, links to a glossary of concepts and other sections of the application, etc.

The course content has been divided into six subject blocks (B1 to B6) (Figure 2). The first of these (B1) reviews the basic preliminary concepts required to be able to adequately study JIT/Lean Production. To be specific, a unit has been designed to describe the production planning, programming and control process. Block 2 (B2) is devoted to a description of the origins and development of JIT/Lean Production. The third block (B3) sets out the basics that underpin JIT/Lean Production. Block 4 (B4) goes into each of the tools that JIT/Lean Production uses to achieve its aims in detail. In short, it examines the elements that are required to adapt the production subsystem to the JIT/Lean approach: (SMED, standardisation of operations, shojinka, soikufu, jidoka, etc.), the need for level production and the expansion of JIT/Lean to include customers and suppliers. The fifth block (B5) analyses the process of incorporating JIT/Lean Production into a business. Finally, the sixth block (B6) compares JIT to MRP systems. Each of these blocks is sub-

divided into subject units, each with its own entity. These subject units represent the basic unit of learning, and are organised in such a way as to present the fundamental content that the student must learn. From our point-of-view, this facilitates a progressive study of the contents when the student follows the logical, recommended order.

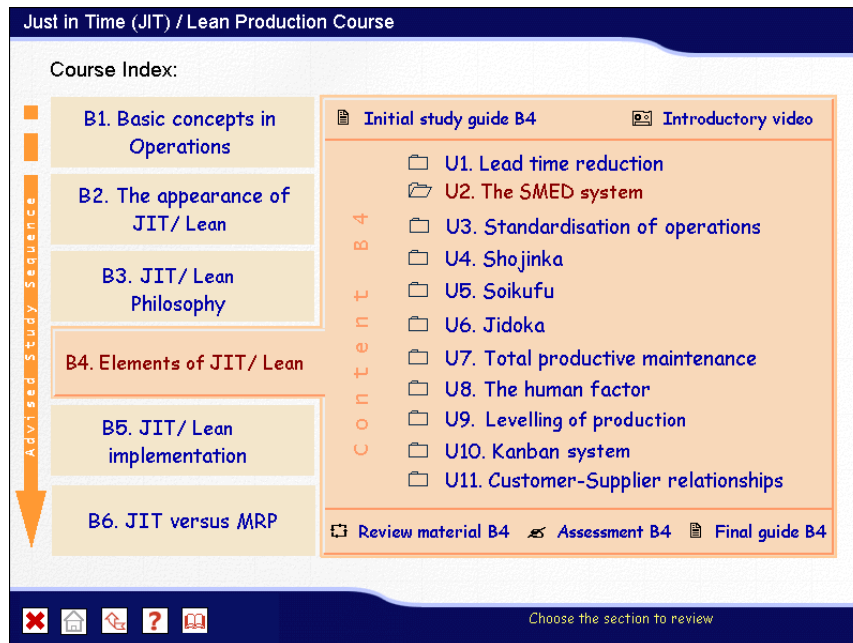


Figure 2. "Main or Blocks Screen".

To complete the educational organisation of the course, each of the blocks and units includes five elements to help with learning (Figure 2, Figure 3):

- *Initial study guide*. This presents the learning objectives for the subject as well as indicating the units or blocks that should have been learnt before attempting the study of a unit or block.
- *Introductory Video or Reading*. In some blocks and units an element called Introductory Video or Reading is included that gives advice on pre-reading or for watching a video of a real case.
- *Review Material*. Material that the user can use to review the content of the reference unit or block (readings, exercises, bibliographic references, etc.)

- *Self-Assessment Module.* A test with a time-limit to assess the user on the material that has been studied. Users can evaluate the degree of knowledge that they have gained and learn from their mistakes (at the end of the test a review of same with explanatory remarks can be accessed). As the test is being done, the application randomly chooses and orders the multiple-choice questions and exercises included from a database with a large number of questions. The answers to the questions are also placed in a random order each time an assessment test is generated. An attempt is thus made to prevent the trial and error that occurs when the user repeats self-assessment tests again and again. This is all to the benefit of the user who can do the test a greater number of times without it becoming repetitive
- *Final study guide.* This includes a summary of the results achieved in the self-assessment module. Depending upon the user's results, an indication is given of whether it is suitable for him/her to move on or to review the current element.

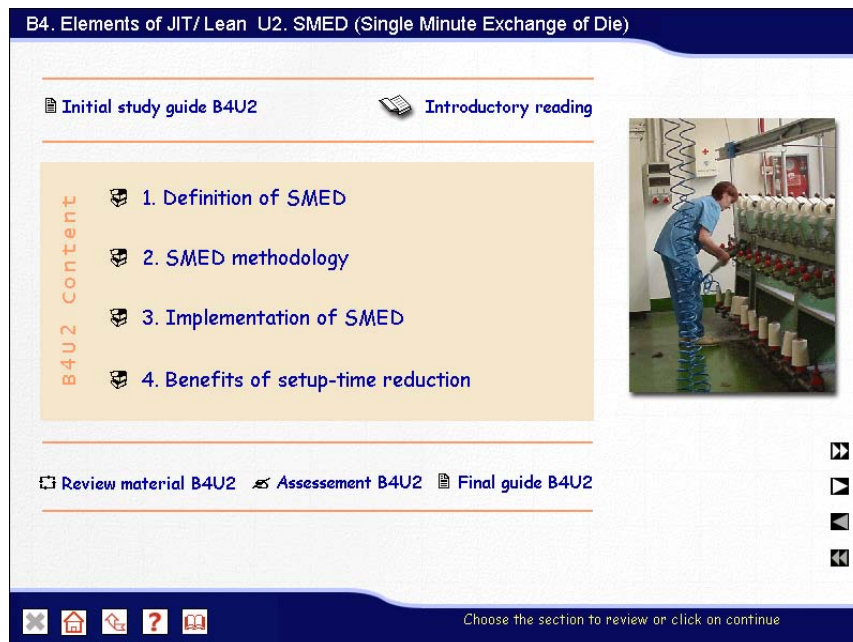


Figure 3. "Index screen for Block 4 Unit 2: SMED (Single Minute Exchange of Die)".

Having described the way the content and the elements that include blocks and units are organised, we now move on to an analysis of the remainder of the

application's features. Specifically, we focus on the design and implementation of the interface, interactivity, the tracking system, the navigation system, the glossary and the help module. Finally these elements are set within the framework of the application structure.

We have tried to achieve a user-friendly, easily operated and intuitive interface which does not require the student to have previous experience with computers and which enables all the effort to be focused on the purely cognitive tasks. There is an all-too-frequent temptation to transfer material from print copy to the digital format without giving thought to the possibilities ICT provide for better transferring knowledge and fostering and developing the student's skills; we avoided this temptation. The design has therefore attempted to provide a suitable balance of on-screen media at any given time, in order to avoid saturation and the presence of non-essential information.

Continual interactivity has been sought with the application that enables learning to be more flexible and better adapted to the personal requirements of the student. Interactions are designed to support different levels of learning from the simple stimulus-response to higher level problem solving. Individual students must be able to build their own content structure making their choices on the basis of their work rhythm and requirements. To this end, we have opted for giving the user free-navigational reign, with every block or unit being accessible at all times. The content has also been divided into a number of different concepts which are then presented in the format that is most appropriate for the information to be transmitted (texts, graphics, videos, animation, etc.). To progress in their learning users easily interact with the application through links connecting a range of elements and icons representing the different actions (Figure 4). These icons do not change throughout, which means users soon learn how to operate the application.

As the application demands interaction with users for them to progress in their learning, they find themselves compelled to take part in active learning (e.g. the solving of an exercise or the watching of a video). Figure 1 shows an example in which the user must find the correct definitions of two concepts.

B4. Elements of Jit / Lean U3. Standardisation of operations

2. Standardisation of operations: an easy example

Six operations are carried out (O_i) to obtain product W with each operation taking 1 minute to be completed. There are currently two workers assigned to this line: Kevin carries out operations 1, 5 and 6 (Kevin's operations route) and Nick 2, 3 and 4 (Nick's operations route)

In action ...

Start
Minute 1
Minute 2
Minute 3
End

Raw material

Product W

Deposit point O1

Deposit point O4

Kevin

Nick

At minute 2:
Kevin carries out operation 5 with the product in course located at deposit point O4
Nick moves on to operation 3

Legend

Question 1 **Question 2** **Question 3**

Every how many minutes does a finished W product come off this line? 3 6 9

Study the way the line works and then answer the questions.
To move on, click on 'Advance'

Figure 4. "Example of interaction".

The study guide has been devised on the basis of the Tracking System. This is a programmed internal structure that allows all a user's activity to be tracked. Its main objective is to guide users in the study of the course on the basis of the actions that they have carried out. The application therefore identifies what users have done up to any given point in time. The users then receive information about what they should do, what concepts they should study, what they have made mistakes in and why, etc. All the information and suggestions that the application makes to the user are given interactively thanks to the data that the tracking system collects. The guide function described exists across the whole application. It is therefore found in a variety of elements, such as content screens, the Initial and Final Study Guides, the Instructions Area in the Help Module, the Entry Module and the Navigation System.

Another vital element in the design that affects the application's teaching content is the Navigation System. This allows the user to access the different concepts, units and blocks found in the application. In developing it we aim to support a range of learning styles, giving students a wider choice in the way in which they explore the material. As we have already stated, the user can navigate with total freedom. Users are responsible for organising their study, and it is therefore of prime importance that the navigation system allows users to find their way round the

application easily. This is facilitated by the inclusion in the software of a number of different navigational tools:

- *Navigation Map*, with two types of screen: the main, or blocks screen (Figure 2), which is a first level navigation map, and index screens for the subject units, which are second level navigation maps (Figure 3). As a recommendation, the application indicates at all times the path that should be followed. As they move around these screens users know where they are, where they have been, which units or blocks they have passed successfully, and where it is recommended that they should go next. This is all done by programmed colour coding using information provided by the Tracking Module. Blue indicates that the element has not been visited and green that the corresponding self-assessment test has been done successfully.
- *Permanent Buttons*. These facilitate transfer between the different levels of the course structure and afford access to other available tools. They are always visible in the bottom left hand area of the screen, though not always available.

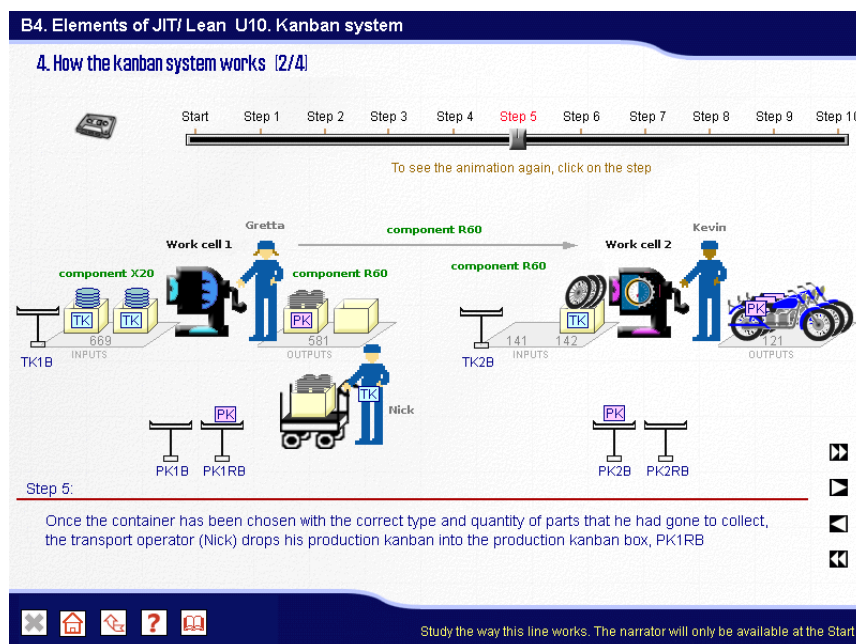


Figure 5. "Example of content screen".

- *Navigation Buttons.* These are found on content screens and allow the user to move through a concept (it may be explained over a number of different screens), or from one concept to another. They can be found in the bottom right hand area of the screen (Figure 5).

An interactive Glossary of Concepts has also been created to supplement the course content by providing definitions for all JIT/Lean Production-related OM concepts (Figure 6). These are explained using the resources that are considered most suitable in each case (text, images, graphics, etc.). It can be accessed by clicking on the permanent glossary button and it includes a search facility to find the desired concept. There is a second more dynamic system that uses hyperlinks to take you straight to the glossary when clicked on. The user can navigate around the glossary or jump back to the application to discover more about the different concepts. This encourages active and independent learning and facilitates a kind of study that caters for different learning styles.

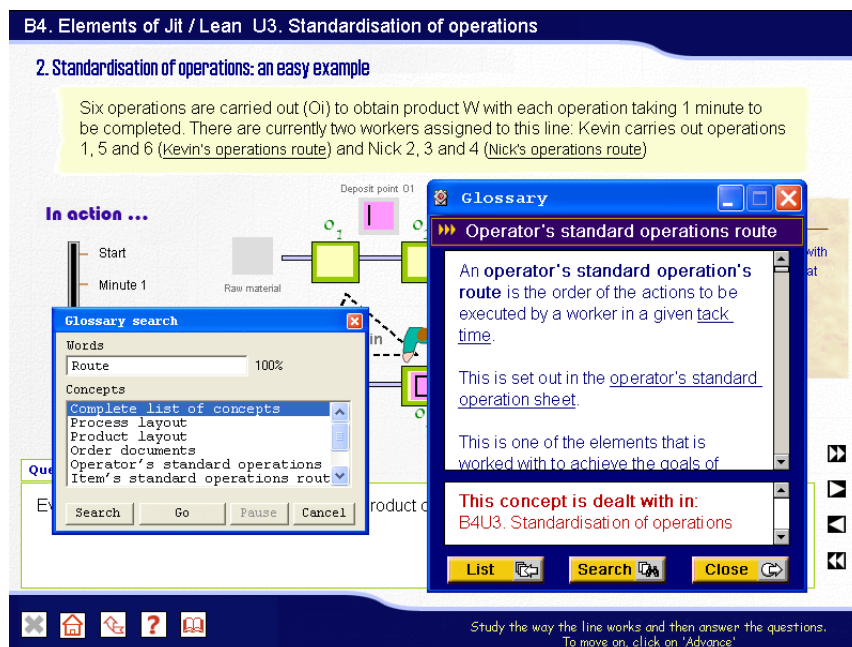


Figure 6. "Glossary of Concepts with search tool activated".

A *Help Module* has been created to make it easier to use the course. It contains two elements: a) a series of screens accessible by a permanent button which displays an explanation of how to operate the application; b) a small Instructions Area always present in the bottom right horizontal part of every screen which

indicates actions that can be taken at any given time (Figure 2). The instructions area uses the information fed to it by the Tracking System.

Finally, Figure 7 shows the global structure devised for the application. It shows how the Entry Module provides access to both the Help Module (which can only be exited by returning to the point of entry) and the Exit Module, where the application can be closed down or the user can return to the Entry Module. The Entry Module allows access to the teaching content via the Navigation map; this allows users to return to a previously-recorded study session and to pick up where they left off thanks to the information recorded by the Tracking System. The Help Module, the Glossary of Concepts and the Navigation System are accessible at all times (implicit in the diagram in Figure 7), which allows the user to move from one element to another. Also accessible from the Navigation Map is the Exit Module, which allows the user to either close the application down or return to the Navigation Map. The only element that does not appear in the diagram as described is the Tracking System. This is because it is an internal programming component which helps the rest of the elements that the application is made up of to operate correctly, and which is visible through these.

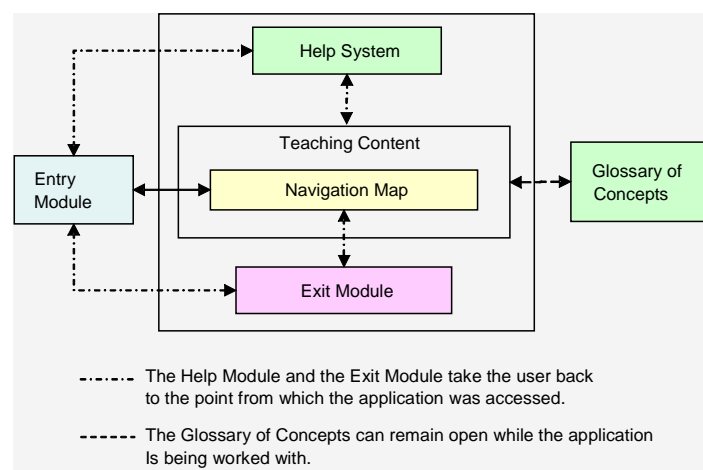


Figure 7. "Diagram of the structure of the application".

4.2 Multimedia application assessment

This section presents the results of the assessment of the application's design and operation at user level. To be more specific, the main elements described in the previous section (interface, interactivity and tracking system, navigation system,

self-assessment module, glossary of concepts, and help module), are analysed and the effect of the application's design on the concepts explained being understood. Finally, two control variables were considered with a view to finding out whether there were differences in the assessment depending on gender and average overall academic record mark.

Beginning with the interface-related items (Table 1) the degree of general satisfaction was very high. Students scored the visual environment (4.6), the screen structures (4.5), the way the buttons and content were laid out on-screen (4.5), the amount of on-screen text (4.5) and the size (4.6) and type of font (4.4) all very positively. Users therefore clearly confirm that the application is user-friendly, easily operated, has an intuitive interface and does not require previous experience with computers. This has a direct effect on the learning process. Students therefore do not encounter any problems with the operation of the application and can focus all their effort on learning the content that the application conveys to them

INTERFACE	Ave.	Typ. Dev.	Var. Coef.	Mode	Min.	Max.
The application is easy to use	4.324	0.837	0.193	5	2	5
The application does not require any previous computer experience to be used properly	4.209	1.108	0.263	5	1	5
The audiovisual environment is clear and the operating patterns remain constant leading to simple and intuitive operation	4.627	0.546	0.118	5	3	5
The buttons are designed in such a way that the user can quickly become familiar with the environment	4.515	0.658	0.146	5	2	5
The screens are well-structured and their design is clear, aesthetic and attractive	4.515	0.611	0.135	5	3	5
The screens allow the gist to be quickly seen	4.294	0.882	0.205	5	2	5
The amount of on-screen text is not excessive (not overwhelming and does not cause rejection or tiredness, etc.)	4.544	0.742	0.163	5	1	5
The size of the font is suitable	4.574	0.654	0.143	5	2	5
The types of font used make the text easy to read	4.441	0.720	0.162	5	2	5
A suitable combination of colours is used in the application	4.353	0.641	0.147	4	3	5
AVERAGE	4.439	0.740	0.167			

Table 1. "Assessment of interface".

The constructivist approach encourages continuous user-application interaction. This favours active learning which means that students must get involved in their own learning process through their actions. For this the design of a tracking system is required to guide and direct study. Table 2 presents the items that score

interactivity and the tracking system. The level of satisfaction can be seen to be quite high on average for the information that the application provides about mistakes that are made and the help for solving them satisfactorily (4.3). Users similarly state that they know what options they have for interacting with the application at all times (4.3), being able to pick up their study where they had left off (4.3) and knowing how their learning is progressing (4.0). This is all achieved thanks to the way information is dealt with by the Tracking System and conveyed to the user via the application screens. Students are engaging in an active rather than a passive learning process as they are continually channelled towards interacting with the application.

Although the scores received by the usefulness of the initial and final study guides are not low (over 3.2), they are rated lower than other elements. This might be due to the fact that their role in this module is to summarise students' progress and suggest concepts that they should study. If students are studying continually over a short period of time, as was the case in the experiment, users remember how they are advancing and do not need any help. The usefulness of these guides therefore decreases as users remember how they are getting on and do not need any aid. We believe that as study slows down over time the usefulness of these guides will increase as they summarise information about students' progress.

INTERACTIVITY and TRACKING SYSTEM	Ave.	Typ. Dev.	Var. Coef.	Mode	Min.	Max.
Users know what options they have for interacting with the application at all times	4.284	0.813	0.190	5	2	5
The application provides information about mistakes made and helps to solve them	4.343	0.863	0.199	5	1	5
The application lets me pick up studying where I had left off earlier	4.284	0.934	0.218	5	1	5
The application shows the user's study progress adequately	4.000	0.921	0.230	4	1	5
The initial study guide is useful for learning	3.235	1.024	0.316	4	1	5
The final study guide is useful for learning	3.294	1.052	0.319	4	1	5
AVERAGE	3.907	0.934	0.239			

Table 2. "Assessment of interactivity and Tracking System".

The Navigation System conditions and characterises the way in which the application is worked with. The system continually feeds off information provided by the Tracking System. The items used to assess the navigation system (Table 3) can be split into two groups. Firstly, the first three items in Table 3 show that users value positively the freedom for organising their own study that the application

affords them (3.8), the lack of issues with finding their way around the application (4.6) and the ease with which they can situate themselves in the application and access the available features (4.5). Secondly, the remaining items score the usefulness for learning the navigation system's three basic elements and the ease of use of two of them. The feature that the students find most useful is the navigation buttons (4.1), which may be due to the fact that they are the quickest means of accessing the application content following the recommended order of study. What stands out in other respects is the ease of use of both the navigation (4.7) and the permanent buttons (4.6).

The Navigation System has therefore enabled users to work simply and easily, making their way through the application without getting lost. It has also enabled them to do the learning activities by helping them access the information that they needed easily and quickly. These results corroborate the effectiveness of the efforts made to ensure that students can easily find their way around the application and centre their efforts on the content (rather than on operating the tool). This data also supports the initial goal of favouring a constructivist approach to content learning providing a learning model that is flexible and adapts to each student's individual study rhythm.

NAVIGATION SYSTEM	Ave.	Typ. Dev.	Var. Coef.	Mode	Min.	Max.
The application enables users freedom for organising their study	3.809	1.136	0.298	4	1	5
I had no problems finding my way around the application	4.642	0.883	0.190	5	1	5
Users always know "where they are" and can move forward and back and easily access the application's features	4.463	0.659	0.148	5	3	5
The block and unit indexes are useful for learning (indicating elements visited)	3.500	0.889	0.254	4	1	5
The navigation buttons are useful for learning	4.132	0.913	0.221	4	1	5
The permanent buttons are useful for learning	3.485	1.058	0.304	4	1	5
The navigation buttons are easy to use	4.662	0.822	0.176	5	1	5
The permanent buttons are easy to use	4.603	0.883	0.192	5	1	5
AVERAGE	4.162	0.905	0.218			

Table 3. "Assessment of Navigation System".

The Self-Assessment Module is a key element in the active learning environment that has been developed. It enables users to know the level of knowledge that they have acquired by indicating the mistakes that they have made and helping them to correct them. In this respect, as can be seen in Table 4, students recognise the

great usefulness of the self-assessment module (4.5) and consider it easy to use (4.6). In our opinion, the high score given to the usefulness of this element is due to the features included in its design: random selection and ordering of questions drawn from a broad database and random ordering of possible answers. This enables the user to do the self-assessment tests a greater number of times as training tools.

SELF-ASSESSMENT MODULE	Ave.	Typ. Dev.	Var. Coef.	Mode	Min.	Max.
The self-assessment module is easy to use	4.632	0.929	0.201	5	1	5
The self-assessment module is useful for learning	4.544	0.700	0.154	5	1	5
AVERAGE	4.588	0.815	0.178			

Table 4. "Assessment of Self-Assessment Module".

Another tool that seeks to complement the course content is the interactive Glossary of Concepts. Users score this element positively. They afford it a high degree of usefulness for learning (3.8) and also agree that it is easy to use (4.6) (Table 5). The Glossary's design also allows the user to navigate and study the different concepts and analyse how these are interrelated. It therefore encourages active and independent learning and supports different learning styles.

GLOSSARY OF CONCEPTS	Ave.	Typ. Dev.	Var. Coef.	Mode	Min.	Max.
The Glossary of Concepts is easy to use	4.574	0.951	0.208	5	1	5
The Glossary of Concepts is useful for learning	3.824	1.269	0.332	5	1	5
AVERAGE	4.199	1.110	0.264			

Table 5. "Assessment of Glossary of Concepts".

Table 6 presents the application's help module items that were scored. Students consider the application's operating instructions to be clear and adequate (4.7). This is in line with the high score seen for aspects of the interface and it also reinforces the consideration that the application is intuitive and easy to use. This could be the reason that leads them to consider the instructions window accessory to the application and giving it a lower score (3.1) than other elements.

HELP MODULE	Ave.	Typ. Dev.	Var. Coef.	Mode	Min.	Max.
The operating instructions are clear and adequate	4.687	0.499	0.106	5	3	5
The instructions window is useful for learning	3.088	1.290	0.418	4	1	5
MEDIA	3.887	0.894	0.230			

Table 6. "Assessment of Help Module".

One interesting issue was to analyse whether the different resources and media were designed in such a way that they favoured the understanding of the concepts that they were explaining. The items that score this issue (Table 7) could be divided into two groups. The first group would include those linked to application design and the use of the media favouring understanding and learning (first five items in Table 7). These items received high scores, above 4.3 in every case. The high degree of agreement (4.4) with the item "the use of different audiovisual elements does not disrupt learning, but stimulates interest and facilitates learning" stands out. This score is especially important as when different multimedia resources are used there is a risk of using the media to such an extent that they eclipse the content.

The second group in Table 7 would include the remaining eight items which analyse the extent to which each of the media used helps the understanding of the concepts that they specifically explain. In general terms the scores given to the resources are very good. We therefore believe that it has been confirmed that the media used in the application have been suitably designed and favour the understanding of the concepts that they explain. Notwithstanding, it is interesting to highlight the fact that the traditional media are the most highly valued (over 4.2), i.e., the exercises, the text that and the static graphics. This is probably due to the fact that these are the types of resources that students are most familiar with for study. They are followed in scoring-terms by the animations and moving graphics (4.1). Other media, such as narrators, reading texts, photos and videos have received lower scores but over 3.4 in all cases. This is probably due to the fact that a degree of effort is required to relate them to the concepts. It is therefore necessary to work further on these other media in order that students might benefit from their potential to the greatest extent.

UNDERSTANDING OF THE CONCEPTS	Ave.	Typ. Dev.	Var. Coef.	Mode	Min.	Max.
The application does not include any elements that are too quick and make understanding of the concepts difficult	4.426	0.654	0.148	5	2	5
The use of a range of audiovisual elements does not disrupt learning but, rather, stimulates interest and facilitates understanding	4.388	0.834	0.190	5	1	5
The application helps mistakes to be understood	4.358	0.753	0.173	5	2	5
The explanations and comments provided by the application while exercises are being done and when they have been completed have helped me with my learning	4.328	0.766	0.177	4	1	5
The screens provide a sufficient amount of information for them to be understood properly	4.324	0.818	0.189	5	1	5
The exercises help the concept that they are explaining to be understood	4.627	0.546	0.118	5	3	5
The text helps the concept that it is explaining to be understood	4.567	0.557	0.122	5	3	5
The static graphics help the concept that they are explaining to be understood	4.209	0.640	0.152	4	2	5
The animations and moving graphics help the concept that they are explaining to be understood	4.090	0.933	0.228	5	2	5
The narrators help the concept that they are explaining to be understood	3.672	0.860	0.234	4	2	5
The reading texts help the concept that they are explaining to be understood	3.552	1.019	0.287	4	1	5
The photographs help the concept that they are explaining to be understood	3.507	0.943	0.269	4	1	5
The videos help the concept that they are explaining to be understood	3.388	1.058	0.312	4	1	5
AVERAGE	4.111	0.799	0.194			

Table 7. "Assessment of Understanding of Concepts".

Once the different aspects of application design and operation and their effect on understanding the concepts were analysed we moved on to testing whether there were any differences in the scores given by students according to two variables, gender and average overall academic record mark.

The independent-samples t-Student test procedure was used to test whether there were any differences in the scores given to the application on the basis of students' gender. Levene's statistic was used to test for homoscedasticity. Table 8 presents the corresponding t statistic depending on whether equality of variance was assumed or not.

In general terms it can be stated that there are no significant differences in the scoring given by males and females. Significant differences can only be seen for 4 specific items referring to the interface, the self-assessment module and understanding of the concepts (Table 8). It is the males who give lower scores in all cases. These items specifically refer to the structure of the screens, button

design, the usefulness of the self-assessment module for learning and the help that narrators provide for understanding the concept. The small number of significant differences found does not allow it to be stated in general terms that there are gender-related differences in perception.

	Gender	Ave.	Typ. Dev.	Levene		T-Student	
				F	Sig.	t	Sig.
INTERFACE							
Screens are well-structured with a design that is clear, aesthetic and attractive	M	4.207	0.675	5.151*	0.027	-3.728*	0.001
	F	4.744	0.442				
The buttons are designed in such a way that they enable the user to quickly become familiar with the environment	M	4.276	0.797	8.043*	0.006	-2.510*	0.016
	F	4.692	0.468				
SELF-ASSESSMENT MODULE							
The self-assessment module is useful for learning	M	4.345	0.857	3.431	0.068	-2.072*	0.042
	F	4.692	0.521				
UNDERSTANDING OF CONCEPTS							
The narrators help the concept that they are explaining to be understood	M	3.414	0.907	2.547	0.115	-2.207*	0.031
	F	3.868	0.777				

* $p < 0.05$

Table 8. "Independent-Samples t-Student test according to gender".

	AM	Ave.	Typ. Dev.	Levene		T-Student	
				F	Sig.	t	Sig.
INTERFACE							
No previous experience of using computers is required for the correct use of the application	< 1.24	4.485	0.939	1.296	0.259	-2.056*	0.044
	≥ 1.24	3.941	1.204				
INTERACTIVITY							
Students know what options they have at their disposal for interacting with the application at all times	< 1.24	4.485	0.712	0.498	0.483	-2.044*	0.045
	≥ 1.24	4.088	0.865				
UNDERSTANDING OF CONCEPTS							
The reading texts help the concept that they are explaining to be understood	< 1.24	3.794	0.977	0.606	0.439	-2.017*	0.048
	≥ 1.24	3.303	1.015				

* $p < 0.05$

Table 9. "Independent-samples t-Student test according to AM".

When the second control variable is included, the average marks on students' academic records (AM), the sample was divided into two groups depending on whether their AM was lower (group 1) or higher or equal to (group 2) the median (1.24). When the independent-samples t-Student test was applied significant differences were only found for the score given to three of the items included (Table 9). In this case it is the students with worse academic records who give the better scores. They specifically perceive a lesser need for prior experience with computers, a greater knowledge of the options that they have at their disposal for interacting with the application and greater help from the reading texts for understanding the concepts that they explain. Given the small number of

significant differences that were found it cannot be stated that different scores have been given to the application on the basis of AM.

4.3 Comparison of teaching methods

This section presents the results of the comparison of the educational application used as a teaching instrument (CADL) and traditional on-site teaching (OST). As has been stated, a scale of 1 (CADL much less than OST) to 5 (CADL much more than OST) was used to score the items with 3 equalling parity between the two teaching methods. A one sample t-Student test with a test value equal to 3 was used for each of the aspects to see whether the methods were considered to be similar or not.

CADL compared to OST	Ave.	Typ. Dev.	Var. coef.	One sample t- Student test (test value = 3)				
				t	Sig.	Ave. Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Time required for study	2.059	0.912	0.443	-8.507	0.000	-0.9412	-1.162	-0.720
Effort required for study	2.353	0.958	0.407	-5.568	0.000	-0.6471	-0.879	-0.415
Improves student study performance (reduces failure rate)	3.522	0.927	0.263	4.613	0.000	0.5224	0.296	0.749
Helps students to learn from their mistakes	3.735	1.087	0.291	5.576	0.000	0.7353	0.472	0.999
Allows students to know what their level of acquired learning is	4.029	1.119	0.278	7.584	0.000	1.0294	0.758	1.300
Motivates users to study	3.559	0.887	0.249	5.193	0.000	0.5588	0.344	0.774
Arouses students' interest in the subject matter	3.529	0.938	0.266	4.655	0.000	0.5294	0.302	0.756
Maintains students' interest in the subject matter	3.471	0.969	0.279	4.004	0.000	0.4706	0.236	0.705
Maintains students' attention/concentration in the subject matter	3.588	1.040	0.290	4.664	0.000	0.5882	0.336	0.840
Adapts to your own rhythm of study	3.750	1.070	0.285	5.778	0.000	0.7500	0.491	1.009
Makes it easy to combine study with having a job	4.162	1.217	0.292	7.872	0.000	1.1618	0.867	1.456

Table 10. "CADL compared to OST: One sample t-Student test".

The results are presented in Table 10. The average scores of all the questions that were asked are significantly different from the score of 3, which means that there is no parity between the two methods. When the scores are analysed to see

whether they are above or below 3 it can be seen that CADL receives better scores than OST in all the aspects under study. Specifically, learners state that less time is required to study with CADL (2.1) and less time is required in order to learn (2.4) than with OST. The students also consider that CADL improves student performance (3.5), helps students to learn better from the mistakes that they make (3.7), allows them to know better what their level of acquired learning is (4.0), motivates them more to study (3.6), arouses and maintains their interest in the subject matter (3.5), maintains their attention/concentration on the subject matter better (3.6) and adapts better to users' needs both with regard to their rhythm of study (3.8) and when they need to combine their studies with having a job (4.2).

An independent-samples t-Student test was used to analyse whether any gender-based differences existed in the scoring of the items. Significant differences were only found for the "Makes it easy to combine study with having a job" item ($t: -2.343$; sig. 0.023). To be specific, females score this item significantly higher (4.5) than males (3.8). Both genders are therefore concluded to value CADL more although females consider the method has a greater capacity for enabling study to be combined with work activity than males. This result may be due to the greater awareness of females of the need to reconcile a career with other activities that have to be performed, including training.

In other respects, the two groups established on the basis of the median were considered to analyse the influence of the AM on the comparison of methods. The independent-samples t-Student test was applied without any significant differences being identified in the scoring of each item.

It can therefore once again be stated that in general terms no significant differences have been found in the scoring as far as either of the control variables are concerned.

Finally, students were requested to score the following statement on a scale from 1 (strongly disagree) to 5 (strongly agree): "I believe it would be suitable to change the current on-site teaching system for my university studies to a mixed system in which off-site credits are covered by information and communication (ICT)-based teaching material". This question was posed both at the beginning and the end of the teaching experiment. As can be seen in Table 11, students quite agree with this

statement before studying using the application that was developed (3.5). Once the experiment had been completed their degree of agreement had risen slightly (3.6). However, when the paired-samples t-Student test with 95% confidence ($t = -0.731$; $p\text{-level} = 0.467$) was applied, no significant differences were found between the two observations. This leads us to believe that the experience responded to students' initial expectations and reaffirmed the opinion that they had at the beginning.

	Pre test		Post test	
	Ave.	Typ. Dev.	Ave.	Typ. Dev.
I believe it would be suitable to change the current on-site teaching system for my university studies to a mixed system in which off-site credits are covered by information and communication (ICT)-based teaching material	3.515	1.1928	3.621	1.1867

Table 11. "Pre- and post-test"

A dual analysis was carried out to discover whether the two control variables, gender and AM, have any influence on this issue. Firstly, using the independent-samples t-Student test it was confirmed that there are no significant gender-based differences in the responses given at the beginning and end of the experiment. The same was true when the users were divided on the basis of their AM. When the paired-samples t-Student test was applied to compare initial and final responses, it was also confirmed that there are no significant differences according to either gender or AM. The control variables therefore had no significant influence on users' opinions on this question.

5 Conclusions

Today's society is calling for methods and instruments that enable continuous, flexible and quality training. In this context, the ICT in general, and multimedia applications in particular, open up a whole field of possibilities in the world of university training that OM teachers cannot ignore. Despite this, it has been seen that only patchy use is being made of interactive multimedia software in the discipline. This led us to design, develop and assess (from the triple producer-expert-student perspective) an application for training in OM. We have specifically focused on a topic of great academic and professional relevance, the JIT / Lean Production philosophy.

Using a constructivist approach that encourages active learning adapted to the needs of each individual student, a very practical and interactive explanation of the concepts being taught was sought underpinned by the use of a range of media and copious exercises that both enabled the most common questions to be answered and assisted the learning process. The use of a consistent methodological base for conceiving and producing the software and the analysis of the scores awarded by students who worked with it confirm its technical, operational and pedagogical effectiveness in general terms.

The results obtained from the analysis of the application show some very positive scores were given to its design and operation. With regard to the interface, students showed a very high degree of satisfaction with its various structure-related aspects and the format in which information is presented, and also with the layout of on-screen content. These results would seem to confirm that the interface design is homogeneous, attractive and suitable for preventing user eye fatigue and loss of concentration when studying. The student scores also show that the software is very easy to use and does not require any prior computer training. Students also considered that the application's work environment was very clear with consistent operational patterns and that it was simple and intuitive to use. In addition to the ease of use of the application we add the high degree of positional awareness shown when navigating through the various modules and content it can be concluded that users' control over the software was very high, which enabled them to focus all their efforts on the learning tasks.

Student perceptions also indicate that the design of the application and the different media used favour understanding and the learning of the concepts that are being explained and stimulate interest in the subject matter. These scores are especially relevant when it is borne in mind that one problem that is traditionally attributed to OM subjects is, precisely, a lack of understanding of the concepts (Johnson & Drougas, 2002; Yazici, 2006, Fish, 2008). It can therefore be concluded that both the application that was designed and the teaching methodology that underlies it contribute to avoiding one of the main difficulties attributed to the discipline.

With regard to the constructivist approach that guided software design, the description that was given and the analysis of the results obtained in the empirical

research both show a range of elements that corroborate that it was effectively applied. Firstly, the software has a marked interactive character and also possesses a tracking system that enables users to situate themselves in the study of the content on the basis of their actions. Consequently, alternative paths of study are suggested which allow users to progress through the content depending on each individual's training needs. The students stated that they knew the options that they had for interacting with the application at all times and, broadly-speaking, expressed a high degree of satisfaction with aspects of the tracking system (help and information provided on mistakes they made, the possibility of picking up their session where they had previously left off, the opportunity to know how their learning was progressing, etc.). To this must be added the wide range of ways to access the information and knowledge building offered by the navigation system, which was scored very positively. Finally, students perceived that the software allowed them a very high degree of freedom for organising their study, which supports our goal of providing a flexible learning model that moulds itself to the demands and requirements of individual users. All the above leads us to conclude that the application enables the effectiveness of the learning process to be improved by promoting active learning that can be adapted to different learning rhythms and styles. This is in keeping with Belton et al. (1997) and Cairncross and Manion (2001) who stated that the learning process improves when active learning is encouraged through interactivity, when there are navigation systems that allow the user to control the information and develop different learning styles, or when users are given the opportunity to learn in their own time and at their own pace.

The application's ease of use, the high degree of satisfaction with its interface, its marked interactive character, the flexibility with which it adapts to different learning styles and its ability to facilitate understanding of the concepts and user self-assessment confirm its potential as a self-learning tool. Therefore, apart from its use in the classroom, the tool could also be of great use for carrying out off-site training activities. The software that was designed could be used in conjunction with some of the many tools provided by the ICT for these off-site activities, such as online communication and virtual platforms that facilitate work and interaction between teachers and students. These tools could complement the advantages provided by the multimedia application and further improve student scores on their learning process.

When we focus on the comparison of the teaching method followed by the users of the software (CADL) and traditional on-site teaching (OST), student scores show a clear preference towards studying using the interactive multimedia application. These scores were significantly in favour of CADL in all the aspects provided for: help for learning from mistakes made, information about the acquired level of learning, the perceived study efficiency (time, effort and performance), psycho-pedagogical aspects (motivation, interest in the subject matter and attention / concentration), adaptation to rhythm of study and the suitability of the method when studies are combined with some work activity. This last aspect leads us to also consider the usefulness and suitability of the software for permanent education environments, which are, precisely, one of the European Union's main lines of interest in the field of training.

The results for the scores given for the implementation of a mixed teaching system with off-site credits covered by the ICT demonstrate that students are well predisposed towards it initially and that continues to be the case after their learning experience with the multimedia software. Studying using the application can be concluded to correspond to students' expectations regarding this mixed teaching system's potential. In other respects, the fact that the average degree of acceptance did not improve significantly after the experience might reflect the importance that students still afford the traditional on-site teaching that they know and with which they are familiar. In effect, despite the fact that students state a preference for the CADL that they experienced over OST, it is understandable that they might still be reticent about a more intensive use of the methodology in their university studies as a whole and, especially, that they still value a teacher being present in the classroom however satisfactory their study has been using the interactive multimedia software.

In other respects, when analysed the results show that it can be concluded that no significant differences can be found between the groups formed on the basis of the two control variables used in the research (AM and gender) except with for some occasional points. As indicated in the foregoing, no previous studies were found on AM having any influence on students' perceptions of the teaching method, which means that these results cannot be compared to similar experiences. Meanwhile, the lack of significant differences between the scores given by females and males is in line with what Kraut et al. (1996) and Whitely (1997) suggested. They only

detected gender differences associated with the use of computers in school age children, but not in people in older age-groups. It is also in line with Arbaugh (2000), who did not find any significant differences between males and females in the variables that were analysed. However, wider-ranging research in this field seems to be required to examine any influence that this variable might have and to detect any behaviour patterns, should there be any.

The characteristics of this study lead us to some considerations. It should be borne in mind that the study was carried out in a controlled environment and not in the normal on-site university teaching process of an OM subject. Although this could be seen as a limitation, it in fact reinforces the assessment results by introducing a greater degree of experimental rigour, as the avoidance of disrupting variables that might affect the conducting of the experiment was being sought (students who do not attend all the classes, number of hours devoted to study, monitoring of teaching materials used in the research, etc.). The results obtained direct us to ways in which the research can be developed in the future. These could focus on its use and analysis when incorporated into on-site teaching through suitable learning strategies to include it in the regular teaching of the subject. In this new context, the figure of the teacher as a coordinator of the teaching-learning process will mean the tool can be used in new ways.

The methodology used for the design of the software and the main conclusions drawn from the analysis of the results of this study show the clear potential of multimedia application use in OM training. In our opinion, these advantages could be extended to other related subjects, especially those linked to Industrial Organisation and Business Management if they make use of similar tools to the one described in this paper.

To conclude, it should be highlighted that the literature review has clearly shown that there are very few papers that examine the use of interactive multimedia software in the area of OM. Similarly, teaching studies done in the discipline are not usually formally assessed from the student perspective. In this regard, this study provides a contribution that allows reflections to be made on the design of specific software for OM and students' perceptions when using it. In this way we hope to make advances in this line of research.

References

AACSB (1997). AACSB report on teachers and problems related to teaching in Higher Business Administration Schools (1995-96). *AEDEM News*, 6.

Ahire, S.L. (2001). Linking Operations Management students directly to the real world. *Interfaces*, 31(5), 104-120.

[doi:10.1287/inte.31.5.104.9653](https://doi.org/10.1287/inte.31.5.104.9653)

Alfalla-Luque, R. & Machuca, J.A.D. (2001). Estudio empírico sobre los métodos docentes y de evaluación en la enseñanza de la Dirección y Gestión de la Producción/Operaciones en la Universidad española. *Revista Europea de Dirección y Economía de la Empresa*, 10 (3), 75-96.

Alfalla-Luque, R. & Machuca, J.A.D. (2003). An empirical study of POM teaching in Spanish universities (II): Faculty profile, teaching and assessment methods. *International Journal of Operations and Productions Management*, 23 (4), 375-400.

[doi:10.1108/01443570310467311](https://doi.org/10.1108/01443570310467311)

Alfalla-Luque, R., Arenas-Márquez, F.J. & Medina-López, C. (2001). La aplicación de las TIC a la enseñanza universitaria y su empleo en la formación en Dirección de la Producción/Operaciones. *PixelBIT. Revista de Medios y Educación*, 16 (enero), 61-75.

Alfalla-Luque, R., Medina-López, C. & Arenas-Márquez, F.J. (2011). Mejorando la formación en Dirección de Operaciones: la visión del estudiante y su respuesta ante diferentes metodologías docentes. *Cuadernos de Economía y Dirección de la Empresa*, 46 (in press).

Altherr, S., Wagner, A., Eckert, B. & Jodl, HJ. (2004). Multimedia material for teaching physics. *European Journal of Physics*, 73 (1), 7-14.

[doi:10.1088/0143-0807/25/1/002](https://doi.org/10.1088/0143-0807/25/1/002)

Ammar, S. & Wright, R. (2002). A demonstration of push/pull assembly line. *Informations Transactions on Education*, 2 (3), 1-8.

Amorós, L. & Rodríguez, M.T. (1999). Descripción de un instrumento de evaluación para multimedia didáctico. In Cabero, J. (Coord). EDUTEC. *Nuevas Tecnologías en la formación flexible y a distancia*. Sevilla, Spain: Secretariado de Recursos Audiovisuales y Nuevas Tecnologías de la Universidad de Sevilla.

Andresen, B.B. & van den Brink, K. (2002). *Multimedia in Education: Specialised Training Course*. UNESCO Institute for Information Technologies in Education. Retrieved November 10th, 2010, from <http://unesdoc.unesco.org/images/0012/001293/129390eo.pdf>

Arbaugh, J.B. (2000) Participation in an Internet-Based MBA Course. An Exploratory Study of the Effects of Gender on Student Learning and Class. *Management Learning*, 31 (4), 503-519.

[doi:10.1177/1350507600314006](https://doi.org/10.1177/1350507600314006)

Arbaugh, J.B., Desai, A., Rau, B. & Sridhar, B.S. (2010). A review of research on online and blended learning in the management disciplines: 1994–2009. *Organization Management Journal*, 7, 39–55.

[doi:10.1057/omj.2010.5](https://doi.org/10.1057/omj.2010.5)

Arias Oliva, M., González Menorca, L., Navaridas Nalda, F. & Santiago Campión, R. (2003). *Quality in elearning management education: a methodology to measure content quality*. Paper presented at the XVII Congreso Nacional y XIII Congreso Hispano-Francés AEDEM, Bordeaux, France.

Avella Camarero, L., Fernández Sánchez, E. & Vázquez Ordás, C.J. (1999). Análisis de las estrategias de fabricación como factor explicativo de la competitividad de la gran empresa industrial española. *Cuadernos de Economía y Dirección de la Empresa*, 4, 235-258.

Balazinski, M. & Przybylo, A. (2005). Teaching Manufacturing Processes Using Computer Animation. *Journal of Manufacturing Systems*, 24 (3), 237-243.

Ball, P. & Thornbury, H. (2004). A student Learning environment without the Overhead? Reviewing Cost and Benefits of CAL within a Manufacturing Course. *International Journal of Engineering Education*, 20 (5), 713-725.

Barron, A.E. & Orwig, G.W. (1995). *Multimedia Technologies for Training*. Englewood Cliffs, NJ: Prentice-Hall.

Belton, V., Elder, M. & Thornbury, H. (1997). Early Experiences of Mentoring: Design and use of Multimedia Materials for Teaching OR/MS. *Omega, Int. J. Mgmt Sci*, 25 (6), 659-676.

Benyon, D., Stone, D. & Woodroffe, M. (1997). Experience with developing multimedia courseware for the World Wide Web: the need for better tools and clear pedagogy. *International Journal of Human-Computer Studies*, 47, 197-218.
[doi:10.1006/ijhc.1997.0126](https://doi.org/10.1006/ijhc.1997.0126)

Bou Bouzá, G. (1997): *El guión multimedia*. Madrid, Spain: Ed. Anaya Multimedia.

Boykin, R. F. & Martz Jr., B. (2004). The integration of ERP into a logistics curriculum: applying a systems approach. *Journal of enterprise information management*, 17 (1), 45-55.
[doi:10.1108/09576050410510944](https://doi.org/10.1108/09576050410510944)

Bradley, J.R. & Willett, J. (2004). Cornell students participate in Lord Corporation's kaizen projects. *Interfaces*, 34 (6), 451-459.
[doi:10.1287/inte.1040.0103](https://doi.org/10.1287/inte.1040.0103)

Cabero Almenara, J. & Duarte Hueros, A. (1999). Evaluación de medios y materiales de enseñanza en soporte multimedia. *Píxel-Bit, Revista de Medios y Educación*, 13, 23-45.

Cabero Almenara, J. (2001). *Tecnología Educativa. Diseño y utilización de medios en la enseñanza* (262-264). Barcelona, Spain: Ed. Paidós.

Cairncross, S. & Mannion, M. (2001). Interactive Multimedia and Learning: Relizing the Benefits. *Innovations in Education and Teaching International*, 38 (2), 156-164.
[doi:10.1080/14703290110035428](https://doi.org/10.1080/14703290110035428)

Carraway, R.L. & Freeland, J.R. (1989). MBA training in Operations Management and Quantitative Methods. *Interfaces*, 19 (4), 75-88.
[doi:10.1287/inte.19.4.75](https://doi.org/10.1287/inte.19.4.75)

Catenazzi, N. & Sommaruga, L. (1999). The evaluation of the Hyper Apuntes interactive learning environment. *Computers and Education*, 32 (1), 35-49.
[doi:10.1016/S0360-1315\(98\)00039-6](https://doi.org/10.1016/S0360-1315(98)00039-6)

Chapman, B.L. (1995). Accelerating the design process: a tool for instructional designers. *Journal of Interactive Instruction Development*, 8 (2), 8-15.

Collaud, G., Gurtner, J.L. & Coen, P.F. (2000). Design and use of a hypermedia system at the University level. *Journal of Computer Assisted Learning*, 16 (2), 137-147.

Cornélis, F, Cochinaux, P., Garady, D., Ferrant, C. & Webb, M. (1997). *Investing in knowledge: the integration of technology in European education*. Brussels, Belgium: European Round Table of Industrialists.

Cox, J.F., & Walker, E.D. (2005). Increasing Student Interest and Comprehension of Production Planning and Control and Operations Performance Measurement Concepts Using a Production Line Game. *Journal of Management Education*, 29 (3), 489-511.

[doi:10.1177/1052562904271202](https://doi.org/10.1177/1052562904271202)

Coye, R.W. & Stonebraker, P.W. (1994). The effectiveness of personal computers in Operations Management Education. *International Journal of Production Management*, 14 (2), 35-46.

[doi:10.1108/01443579410072364](https://doi.org/10.1108/01443579410072364)

Crowther, M.S., Keller, C.C., & Waddoups, G.L. (2004). Improving the quality and effectiveness of computer-mediated instruction through usability evaluations. *British Journal of Educational Technology*, 35 (3), 289-303.

[doi:10.1111/j.0007-1013.2004.00390.x](https://doi.org/10.1111/j.0007-1013.2004.00390.x)

Domagk, S., Schwartz, R.N. & Plass, J.L. (2010). Interactivity in multimedia learning: An integrated model. *Computers in Human Behavior*. 26 (5), 1024-1033.

[doi:10.1016/j.chb.2010.03.003](https://doi.org/10.1016/j.chb.2010.03.003)

Draper, S.W., Brown, M.I., Edgerton, E., Henderson, F.P., Mcateer, E., Smith, E.D. & Watt, H.D. (1994). *Observing and measuring the performance of Educational*

Technology. Report by the University of Glasgow's institutional project TILT in the Teaching and Learning Technology Programme. Glasgow, UK.

Dumas, J.S. & Redish, J.C. (1999). *A Practical Guide to Usability Testing*. Intellect Books.

European Commission (1996). *Rapport de la Task force Logiciels éducatifs et Multimedia*. European Commission.

European Commission (2002). *European Union Policies and Strategic Change for eLearning in Universities*. Report of the HECTIC project, Brussels.

Evans, C. & Gibbons, N.J. (2007). The interactivity effect in multimedia learning. *Computers and Education*, 49 (4), 1147-1160.

[doi:10.1016/j.compedu.2006.01.008](https://doi.org/10.1016/j.compedu.2006.01.008)

Fish, L. (2008). Graduate student project: employer operations management analysis. *Journal of Education for Business*, September/October, 18-30.

[doi:10.3200/JOEB.84.1.18-30](https://doi.org/10.3200/JOEB.84.1.18-30)

Gattiker, T. F. (2003). P-Chart SPC card game: The case of the new supplier. *Decision sciences journal of innovative education*, 1 (2), 289-294.

[doi:10.1111/j.1540-4609.2003.00022.x](https://doi.org/10.1111/j.1540-4609.2003.00022.x)

Goffin, K. (1998). Operations Management Teaching on European MBA Programmes. *International Journal of Operations and Production Management*, 18 (5), 424-451.

[doi:10.1108/01443579810206118](https://doi.org/10.1108/01443579810206118)

González Zamora, M.M., Machuca, J.A.D. & Ruiz Del Castillo, J.C. (2000). SITMECOM 1.0. PC: a transparent-box multifunctional simulator of competing companies. *Simulation & Gaming*, 31 (2/June), 240-256.

Greasley, A., Bennett, D., & Greasley, K. (2004). A virtual learning environment for operations management: Assessing the student's perspective. *International Journal of Operations and Production Management*, 24 (9/10), 974-985.

[doi:10.1108/01443570410558030](https://doi.org/10.1108/01443570410558030)

Griffin, B. (1997). Using origami to teach production management. *Production and Inventory Management Journal*, 38 (2-Second Quarter), 1-6.

Gunasekaran, A. & Love, P. E. D. (1999). A review of multimedia technology in manufacturing. *Computers in Industry*, 38, 65-76.

[doi:10.1016/S0166-3615\(98\)00108-0](https://doi.org/10.1016/S0166-3615(98)00108-0)

Hammond, D. H., Hartman, S. J. & Brown, R. A. (1996). The match between undergraduate academic instruction and actual field practices in Production/Operations Management. *Journal of Education for Business*, 71 (5), 263-266.

[doi:10.1080/08832323.1996.10116795](https://doi.org/10.1080/08832323.1996.10116795)

Hayes, R.H. (2000). *Challenges posed to Operations Management by the New Economy*. Proceedings of the First World Conference on Operations and Production Management, Seville, Spain, 79-88.

Holweg, M. & Bicheno, J. (2002). Supply chain simulation - a tool for education, enhancement and endeavour. *Int. J. Production Economics*, 78, 163-175.

[doi:10.1016/S0925-5273\(00\)00171-7](https://doi.org/10.1016/S0925-5273(00)00171-7)

Hosie, P., Schibeci, R. & Backhaus, A. (2005). A framework and checklists for evaluating online learning in higher education. *Assessment & Evaluation in Higher Education*, 30 (5), 539-553.

[doi:10.1080/02602930500187097](https://doi.org/10.1080/02602930500187097)

Hoskisson, R.E., Hitt, M.E., Johnson, R.A. & Moesel, D.D. (1993). Construct Validity of an Objective (Entropy) Categorical Measure of Diversification Strategy. *Strategic Management Journal*, 14 (3), 215-235.

[doi:10.1002/smj.4250140305](https://doi.org/10.1002/smj.4250140305)

Johnson, A.C., & Drougas, A.M. (2002). Using Goldratt's game to introduce simulation in the introductory operation management course. *INFORMS Transactions on Education*, 3 (1), 20-33. Retrieved November 10th, 2010, from <http://www.informs.org/Pubs/ITE/Archive/Volume-3>

Jones, A., Scanlon, E., Tosunoglu, C., Morris, E., Ross, S., Butcher, P. & Greenberg, J. (1999). Contexts for evaluating educational software. *Interacting with*

computers, 11, 499-516.

[doi:10.1016/S0953-5438\(98\)00064-2](https://doi.org/10.1016/S0953-5438(98)00064-2)

Julien, F., Doutriaux, J. & Couillard, J. (1998). Teaching the Production/Operations Management Core Courses: Integrating Logistics Planning Activities. *Production and Operations Management*, 7 (2-Summer), 161-170.

Kadiyala, M. & Crynes, B.L. (2000). A review of literature on effectiveness of use of information technology in education. *Journal of Engg. Education*, 177-189.

Kanet, J. J. & Barut, M. (2003). Problem-based learning for production and operations management. *Decision sciences journal of innovative education*, 1 (1), 99-118.

[doi:10.1111/1540-5915.00007](https://doi.org/10.1111/1540-5915.00007)

Kemp, B. & Buckner, K. (1999). A taxonomy of design guidance for hypermedia design. *Interacting with Computers*, 12, 143-160.

[doi:10.1016/S0953-5438\(99\)00009-0](https://doi.org/10.1016/S0953-5438(99)00009-0)

Kim, S, Douglas, M.B., Orkand, A. & Astion, M.L. (2001). Design implications from a usability study of GramStain-Tutor. *British Journal of Educational Technology*, 32 (5), 595-605.

[doi:10.1111/1467-8535.00228](https://doi.org/10.1111/1467-8535.00228)

Koper, R. (1998). A method and tool for the design of educational multimedia material. *Journal of Computer Assisted Learning*, 14, 19-30.

[doi:10.1046/j.1365-2729.1998.1410019.x](https://doi.org/10.1046/j.1365-2729.1998.1410019.x)

Krajewski, L.J. (1998): Motivating students in the Operations Management class: challenges for the publishing industry. *Production and Operations Management*, 7 (2), 188-193.

Kraut, R., Sherlis, W., Mukhopadhyay, T., Manning, J. & Kiesler, S. (1996). The HomeNet Field Trial of Residential Internet Services. *Communications of the ACM*, 39 (12), 55-63.

[doi:10.1145/240483.240493](https://doi.org/10.1145/240483.240493)

LaForge, R.L. & Busing, M.E. (1998). The use of industrial software to create experiential learning activities in Operations Management courses. *Production and Operations Management*, 7 (3-Fall), 325-334.

LaForge, R.L. & McNichols, C.W. (1989). An Integrative, Experiential Approach to Production Management Education. *Decision Sciences*, 1, 198-207.

[doi:10.1111/j.1540-5915.1989.tb01407.x](https://doi.org/10.1111/j.1540-5915.1989.tb01407.x)

Le Roy, H. (2001). *Esquema de evaluación de software educativo*. Retrieved November 10th, 2010, from <http://www.hlrnet.com/evalsed.htm>

Leacock, T.L. & Nesbit, J.C. (2007). A framework for evaluating the quality of multimedia learning resources. *Educational Technology and Society*, 10 (2), 44-59.

Lewis, M.A., & Maylor H.R. (2007). Game playing and Operations Management education. *International Journal of Production Economics*, 105 (1), 134-149.

[doi:10.1016/j.ijpe.2006.02.009](https://doi.org/10.1016/j.ijpe.2006.02.009)

Lewis, R. (1999). The role of technology in learning: managing to achieve a vision. *British Journal of Educational Technology*, 30 (2), 141-150.

[doi:10.1111/1467-8535.00102](https://doi.org/10.1111/1467-8535.00102)

Lockyer, L., Bennett, S., Agostinho, S. & Harper, B. (2008). *Handbook of Research on Learning Design and Learning Objects: Issues, Applications, and Technologies*. Ed. Information Science Reference.

Lynch, P.J. & Horton, S. (2008). *Web Style Guide, 3rd Edition: Basic Design Principles for Creating Web Sites*. Yale University Press.

Machuca, J.A.D. & Alfalla-Luque, R. (2002). Un análisis de los programas docentes de Dirección de Producción/Operaciones en la Universidad Española: Un estudio empírico. *Cuadernos de Economía y Dirección de la Empresa*, 11, 149-185.

Machuca, J.A.D. & Alfalla-Luque, R. (2003). An empirical study of POM teaching in Spanish universities (I): Content of POM courses. *International Journal of Operations and Productions Management*, 23 (1), 15-43.

[doi:10.1108/01443570310453244](https://doi.org/10.1108/01443570310453244)

- Machuca, J.A.D. & Barajas, R.P. (1997). A computerized network version of the Beer Game via the Internet. *System Dynamics Review*, 13 (4), 323-340.
[doi:10.1002/\(SICI\)1099-1727\(199724\)13:4<323::AID-SDR135>3.0.CO;2-O](https://doi.org/10.1002/(SICI)1099-1727(199724)13:4<323::AID-SDR135>3.0.CO;2-O)
- Machuca, J.A.D. & Barajas, R.P.(2004). The impact of electronic data interchange on reducing bullwhip effect and supply chain inventory costs. *Transportation Research Part E*, 40, 209–228.
[doi:10.1016/j.tre.2003.08.001](https://doi.org/10.1016/j.tre.2003.08.001)
- Machuca, J.A.D., González Zamora, M.M., & Ruiz del Castillo, J.C. (2003). *Innovation in POM teaching and learning: a new generation of business simulators*. Proceedings of 10th International EurOMA Conference, Como, Italy, 939-948.
- Marquès Graells, P. (2000). Nuevos instrumentos para la evaluación de materiales multimedia. *Comunicación y Pedagogía*, 166, 103-117.
- Martínez Sánchez, F., Prendes Espinosa, M.P., Alfageme González, M.B., Amorós Poveda, L., Rodríguez Cifuentes, T. & Solano Fernández, I.M. (2002). Herramienta de evaluación de multimedia didáctico. *Píxel-Bit, Revista de Medios y Educación*, 18, 71-88.
- Marvel, J.H. & Standridge, C.R. (2009). A simulation-enhanced lean design process. *Journal of Industrial Engineering and Management*, 2(1), 90-113.
- Mayes, J.T. & Fowler, C.J. (1999). Learning technology and usability: a framework for understanding courseware. *Interacting with computers*, 11, 485-497.
[doi:10.1016/S0953-5438\(98\)00065-4](https://doi.org/10.1016/S0953-5438(98)00065-4)
- McKone, K. & Bozewicz, J. (2003). The ISM simulation: Teaching integrated management concepts. *Journal of Management Education*, 27 (4-August), 497-515.
- Miller, G., Pawloski, J. & Standridge, C. (2010). A case study of lean, sustainable manufacturing. *Journal of Industrial Engineering and Management*, 3(1), 11-32.

Morris, J.S. (1997). A New Approach to teaching production operations management in the business core curriculum. *Production and Inventory Management Journal*, 38 (2-Second Quarter), 42-47.

Mukherjee, A. (2002). Improving student understanding of operations management techniques through a rolling reinforcement strategy. *Journal of Education for Business*, 77 (6), 308-312.

[doi:10.1080/08832320209599680](https://doi.org/10.1080/08832320209599680)

Naslund, D. (2005). Online testing for Logistics and Operations Management. Decision Sciences. *Journal of Innovative Education*, 3(2), 357-365.

[doi:10.1111/j.1540-4609.2005.00077.x](https://doi.org/10.1111/j.1540-4609.2005.00077.x)

NCET (1994). I.T.: Stimulate to educate, at *Rapport de la Task Force Logiciels éducatifs et Multimedia*, July 1996. Appendix 3.

New, S. J. (2003). Multimedia for international operations: a case study. *International Journal of Operations & Production Management*, 23 (1), 125-137.

[doi:10.1108/01443570310453299](https://doi.org/10.1108/01443570310453299)

Nielsen, J. (2000). *Designing Web Usability: The practice of Simplicity*. Indianapolis: Ed. New Riders Publishing.

O'Leary-Kelly, S.W. & Vokurka, R.J. (1998). The Empirical Assessment of Construct Validity. *Journal of Operations Management*, 16 (4), 387-405.

[doi:10.1016/S0272-6963\(98\)00020-5](https://doi.org/10.1016/S0272-6963(98)00020-5)

Ozelkan, E. & Galambosi, A. (2009). Lampshade Game for lean manufacturing. *Production Planning & Control*, 20 (5), 385-402.

[doi:10.1080/09537280902875419](https://doi.org/10.1080/09537280902875419)

Parlangeli, O., Marchigiani, E. & Bagnara, S. (1999). Multimedia systems in distance education: effects of usability on learning. *Interacting with computers*, 12 (1), 37-49.

[doi:10.1016/S0953-5438\(98\)00054-X](https://doi.org/10.1016/S0953-5438(98)00054-X)

Pfeffer, J. & Fong, C. (2002). The End of Business Schools? Less Success Than Meets the Eye. *Academy of Management Learning and Education*, 1 (1), 78-95.

Polito, T., Kros, J., & Watson, K. (2004). Improving Operations Management Concept Recollection Via the Zarco Experiential Learning Activity. *Journal of Education for Business*, 79 (5), 283-287.

[doi:10.3200/JOEB.79.5.283-286](https://doi.org/10.3200/JOEB.79.5.283-286)

Puvanasvaran, P., Megat,, H., Hong, T.S. & Razali, M.M. (2009). The roles of communication process for an effective lean manufacturing implementation. *Journal of Industrial Engineering and Management*, 2(1), 128-152.

Raiszadeh, F. & Etkin, L.P. (1989). POM in academia: some causes for concern. *Production and Inventory Management Journal*, second quarter, 37-40.

Rauch-Geelhaar, C., Jenke, K. & Thurnes, C.M. (2003). Gaming in industrial management - quality and competence in advanced training. *Production Planning & Control*, 14 (2), 155-165.

[doi:10.1080/0953728031000107653](https://doi.org/10.1080/0953728031000107653)

Richardson, L. (2003). A challenge to change business education. *Mid-American Journal of Business*, 18 (1), 5-6.

Rogers, L. & Newton, L. (2001). Integrated Learning Systems - an 'open' approach". *International Journal of Science Education*, 23 (4), 405-422.

[doi:10.1080/09500690120039](https://doi.org/10.1080/09500690120039)

Rothberg, S., Lamb, F. & Wallace, A. (2001). Computer assisted learning in engineering degree programmes: A survey at the end of the 20th century. *International Journal of Engineering Education*, 17(6), 502-511.

Rubin, J. & Chisnell, D. (2008). *Handbook of usability testing*. Indianapolis: Ed. Wiley Publishing.

Ruiz Jiménez, A., Ceballos Hernández, C., García Gragera, J.A. & Chávez Miranda, M.E. (2010). Una experiencia de evaluación continua en un entorno masificado. In J.L. Jiménez Caballero & A. Rodríguez Díaz (ed.), *Nuevas enseñanzas de grado en la Escuela Universitaria de Estudios Empresariales de la Universidad de Sevilla* (pp. 279-294). Seville, Spain: Ed. Grupo Editorial Universitario (GEU).

Satzler, L. & Sheu C. (2002). Facilitating learning in large operations management classes using integrated Lego (R) projects. *Production and Inventory Management Journal*, 43 (3/4), 340-345.

Schneiderman, B., & Plaisant, C. (2005). *Designing the user interface. Strategies for effective human-computer interaction* (4th Edition - International Edition). USA: Pearson Addison-Wesley.

Schonberger, R.J. (2007). Japanese production management: An evolution-with mixed success. *Journal of Operations Management*, 25, 403-419.
[doi:10.1016/j.jom.2006.04.003](https://doi.org/10.1016/j.jom.2006.04.003)

SEDISI (2000). *Metodología de evaluación de productos formativos multimedia*. Spain: Ed. Asociación Española de Empresas de Tecnologías de la Información, FORCEM y Fondo Social Europeo.

Shabajee, P. (1999). Making values and beliefs explicit as a tool for the effective development of educational multimedia software – a prototype. *British Journal of Educational Technology*, 30 (2), 101-113.
[doi:10.1111/1467-8535.00099](https://doi.org/10.1111/1467-8535.00099)

Shannon, G.F. (1994). *Multimedia computer based teaching - a case study?*. Proc. of IEEE Int'l Conf. on Multi-Media Engg. Education, pp398-402.

Shuell, T. (1996). Teaching and learning in a classroom context. In Berliner, D.C. & Calfee, R.C., *Handbook of Educational Psychology* (pp. 726-764). New York, USA: Ed.MacMillan Libreyary Reference.

Sims, R. (1997). Interactivity: a forgotten art. *Computers in Human Behavior*, 13 (2), 157-180.
[doi:10.1016/S0747-5632\(97\)00004-6](https://doi.org/10.1016/S0747-5632(97)00004-6)

Slack, N., Lewis, M. & Bates, H. (2004). The two worlds of operations management research and practice: Can they meet, should they meet?. *International Journal of Operations and Production Management*, 24 (3/4), 372–387.
[doi:10.1108/01443570410524640](https://doi.org/10.1108/01443570410524640)

Smith, P.L. & Ragan, T.J. (1992). *A review of the literature investigating the learning benefit of education presented in a multimedia, individualized format*. Technical Report. Oklahoma Univ. of Technology.

Squires, D. & McDougall, A. (1996). Software evaluation: a situated approach. *Journal of Computer Assisted Learning*, 12 (3), 146-161.

[doi:10.1111/j.1365-2729.1996.tb00047.x](https://doi.org/10.1111/j.1365-2729.1996.tb00047.x)

Squires, D. & McDougall, A. (1997). *Cómo elegir y utilizar software educativo*. Madrid, Spain: Ed. Morata.

Sweeney, D., Campbell, J. & Mundy, R. (2010). Teaching supply chain and logistics management through commercial software. *The International Journal of Logistics Management*, 21 (2), 293-308.

[doi:10.1108/09574091011071960](https://doi.org/10.1108/09574091011071960)

Tan, K.H., Tse, Y.K. & Chung, P.L. (2010). A Plug and Play Pathway Approach for Operations Management Games Development. *Computers & Education*, 55 (1-August), 109-117.

Tannen, D. (1995). The Power of Talk: Who Gets Heard and Why. *Harvard Business Review*, 73(5), 138-48.

Tullis T. & Albert, W. (2008). *Measuring the User Experience: Collecting, Analyzing, and Presenting Usability Metrics*. Elsevier.

Van den Akker, J., Gustafson, K., Branch, R.M., Nieveen, N. & Plomp, T. editores (1999). *Design Approaches and Tools in Education and Training*. Luwer Academics Publishers.

Van Dijk, L. & Jochems, W.M.G. (2002). Changing a traditional lecturing approach into an interactive approach. *International Journal of Engg. Education*, 18 (3), 275-284.

Walker, H.L., Gough, S., Bakker, E.F., Knight, L.A. & McBain, D. (2009). Greening operations management: An online sustainable procurement course for practitioners. *Journal of Management Education*, 33 (3), 348–371.

[doi:10.1177/1052562908323190](https://doi.org/10.1177/1052562908323190)

Wang, P.Y., Vaughn, B.K. & Liu, M. (2011). The impact of animation interactivity on novices' learning of introductory statistics. *Computers and Education* 56 (1), 300-311.

[doi:10.1016/j.compedu.2010.07.011](https://doi.org/10.1016/j.compedu.2010.07.011)

Whitely, B.E., Jr (1997). Gender Differences in Computer-related Attitudes and Behavior: A Meta-analysis. *Computers in Human Behavior*, 13, 1-22.

[doi:10.1016/S0747-5632\(96\)00026-X](https://doi.org/10.1016/S0747-5632(96)00026-X)

Yazici, H.J. (2004). Student Perceptions of Collaborative Learning in Operations Management Classes. *Journal of Education for Business*, 80 (2), 110-119.

[doi:10.3200/JOEB.80.2.110-118](https://doi.org/10.3200/JOEB.80.2.110-118)

Yazici, H.J. (2006). Simulation modeling of a facility layout in operations management classes. *Simulation and Gaming*, 37 (1), 73-87.

[doi:10.1177/1046878105282159](https://doi.org/10.1177/1046878105282159)

Yourstone, S.A., Kraye, H.S. & Albaum, G. (2008). Classroom questioning with immediate electronic response: Do clickers improve learning? *Decision Sciences Journal of Innovative Education*, 6 (1), 75-88.

[doi:10.1111/j.1540-4609.2007.00166.x](https://doi.org/10.1111/j.1540-4609.2007.00166.x)

Journal of Industrial Engineering and Management, 2011 (www.jiem.org)



Article's contents are provided on a Attribution-Non Commercial 3.0 Creative commons license. Readers are allowed to copy, distribute and communicate article's contents, provided the author's and Journal of Industrial Engineering and Management's names are included. It must not be used for commercial purposes. To see the complete license contents, please visit <http://creativecommons.org/licenses/by-nc/3.0/>.