Teaching warehousing: Why not using a simulation tool?

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Abstract
This paper presents and analyses the empirical findings of the implementation of asimulation toolfor teaching one of the most critical tasks in the logistics systems; picking. Picking is the process of collecting goods from a warehousing system (distribution center or warehouse) in order to satisfy customer orders. It is the most labor-intensive and costly activity for almost every warehousing system affecting significantly the lead (responsiveness) time. Picking is taught in Warehouse Management and Inventory Management related lectures both at Higher Education University Logistics / Supply Chain Mangement Departments, as well as, Secondary Technical and Vocational Schools. The simulation tool has been applied in the design of a lesson taught to 188 students coming from two Higher Education University departments and two Secondary Technical and Vocational Schools in Greece.The results prove that the educational intervention of the simulation tool in the above classes had a positive effect on students' conceptual understanding of the significance, benefits and critical success factors of picking. Positive feedbacks from the students encourage us for investigating the use of the simulation tool for solving problems and optimizate tasks in a warehouse.

Keywords: simulation software, education, logistics, supply chain management, vocational training.

JEL classifications: A10, A20, A21, A22, A23, M10, M11

Introduction

The use of Information Technology (ICT) in education has been repeatedly associated with the improvement of learning and the promotion of teaching. Many hundreds, if not thousands, of small and large scale researches, on the national and international level, have been realized in the past thirty years in order to clarify the relation between the utilization of Communication and Information Technologies, the teaching process and the outcome of learning (Drenogianni and Kourtis, 2018).
Simulations are one of the most widely utilized types of software, particularly for teaching Natural Sciences, where they are specifically designed so as to simulate certain natural phenomena, systems or processes. Simulation is a form of the representation of knowledge, an association of representations, fantasy and reality. Such software allows the user to change the conditions under which the "virtual" experiment is carried out and to thus understand the manner by which such a change affects the evolution/development of the

natural phenomenon. They incorporate a mathematical model and for this reason they are frequently referred to as simulation models (Bagott and Nichol, 1998; Papadouris and Constantinou, 2001; also cf. Fourlaris, Psillos and Chatzikraniotis, 2004). A simulation model is therefore a set of hypotheses / actions / rules for the operation of a system, the explanation of a phenomenon or the solution of a problem, all expressed in the form of mathematical or logical relations between the system's subjects, expressed in some software or programming language (Psycharis, 2006).

The use of simulation as an educational tool can significantly influence the structure of the learning environment and the conditions of the teaching-learning process. The development of such kind of educational applications begun in the USA in the 60s in Stanford and Irvine Universities with the design of simulation software for natural phenomena and gradually expanded to Europe by means of the introduction of computers in secondary and tertiary education.

In its present form, as information and Communication Technology, educational technology offers opportunities and potential for improving teaching and learning, without geographic or temporal constrains. Computers in economics education offer the following important advantages (Lumsden and Scott, 1988):

- Creation of simulation models, namely models that can show us the possible results of a variable or decision;
- processing, data storage and management of a large quantity of numerical or other data;
- digital manuals, databases and multiple choice questions, transpositions of graphs on the screen.

Despite the fact that there appears to be no agreement on the classification criteria and the accentuation of the key features of software, it would be worthwhile to propose a general distinction between the different types of simulations.

With respect to the subject of the simulation, one could distinguish simulation software between:

- The software which simulates a phenomenon or state.
- The software which simulates the operation of an apparatus or machine.

With respect to the variety of phenomena that such software simulates, these can be distinguished into two broad categories:

- Closed systems: producing simulations of specific and a priori defined phenomena, and
- Open systems: where the user can designate and himself construct the phenomenon under study, by selecting the desired features from a library of available basic entities.

This paper focused on the application of simulation software on an important process in Logistics Management, the Picking process. This process is probably the most important work relating to the storage and execution of the order and refers to the collection of various products from the sites they are stores, in order to group them to orders and dispatch them to the customers. It may regard the collection and dispatch of entire pallets from one warehouse or factory to some other warehouse, factory or distribution centre, or the collection of products from the storage facility of a retail shop to be placed on the shelves. This work is extremely important for a business since the successful execution of an order depends on it and it also absorbs roughly 60% of the labour costs in a warehouse (Dimitrakopoulou, 1999).

A typical collection process commences upon the taking of the order and its entry into the MIS (Management Information System). This system issues the picking list containing the following information: location of the product in the storage space, stock number (storage code number), description, recovery unit (pallet, box, etc.) and required quantity. The picking list is forwarded to the competent warehouse personnel (picker) who will use an appropriate manual or semi-automatic in-warehouse transportation system from the warehouse's depot to collect all the required codes by placing them on the chosen intra-transportation system.

The process is completed by returning back to the same point, the checking of proper picking (quality and quantity control), the standardization / packaging of the order and its dispatch to the customer. It must be understood that this process expends time and cost while not adding value to an enterprise. Thus, both figures, time and cost, must be decreased as much as possible.

Despite the existence of an extensive literature regarding the application and implementation of simulation software to business problems [only indicatively one could cite the work by Jahangirian et al. (2010), Johnson (2011), Ma et al. (2011), Wanhphanich et al. (2010), Chan and Zhang (2011)], most research done is in support of either the decision-making process or the improvement of procedures. A smaller number of research efforts refer to the learning and the support of the comprehension of such business procedures. One could point at the work by Ma and Liy (2008) and Vanany and Syamil (2016) who introduce role games to reinforce the learning ability.

This paper presents the findings of the application of a simulation model in the design of a course for students in two tertiary educational institutes as well as two secondary technical and vocational education training classes in Greece.

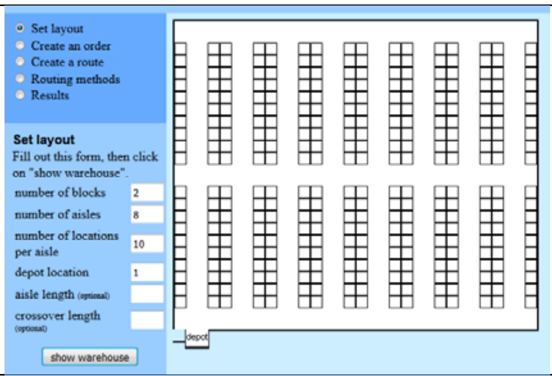
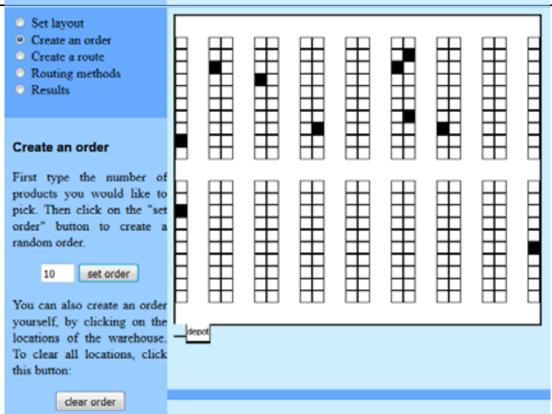
A closed-type questionnaire was used before and after the intervention – application of the software, a questionnaire designed to measure the degree of comprehension as well as the corresponding level of confidence in the knowledge acquired. The findings of the survey accentuated the utility of simulation tools when learning concepts of Supply Chain Management.

The paper is organized as follows: the next section described the recommended simulation software. The third section relates to the presentation of the key parameters of the research methodology, the findings of which are presented and analysed in the section that follows. Finally, some useful conclusions and proposals for future research are made.

Picking process simulation software

The simulation software utilized in this research was Interactive Warehouse by Professor Kees Jan Roodbergen. It is available for free download from his personal website at http://www.roodbergen.com/warehouse/ and, as its homepage suggests, it regards the routing of order pickers in a warehouse. An extensive description of the theorectical framework as well as of its use is offered by Lahmar (2007) and Heragu (2008). The application simulates a common warehouse where the user can set the main layout parameters. More specifically, the user can define the number of blocks, corridors, storage spaces for each block and corridor, as well as set the administration area (starting and finishing point for the picking) (Table 1).

Table 1: Interactive Warehouse Simulation Software
(source: http://www.roodbergen.com/warehouse/)

<table>
<tr>
<td>For example, the screen opposite is the warehouse which ensued from the following information:
• Number of blocks: 2.
• Number of corridors: 8.
• Number of storage points / columns: 10, and
• Number of administration areas: 1.</td>
<td>
</td>
</tr>
<tr>
<td>The user can then define the number of products (stock keeping units) included in an order.
The software uses a generator tocreate random storage areas for the products included in the order and the picking list. Ten products have been defined in the example opposite.</td>
<td>
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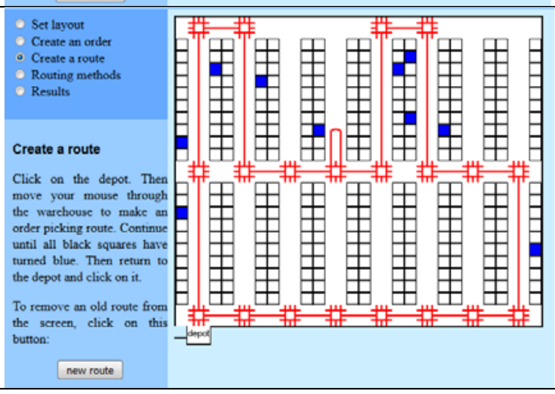
<tr>
<td>The user can set his/her own picking route for the products included in the list (in reality, the user has three attempts to set up the route) beginning from the administration point, crossing the corridors and collecting all codes, before returning to the administration point.</td>
<td>
</td>
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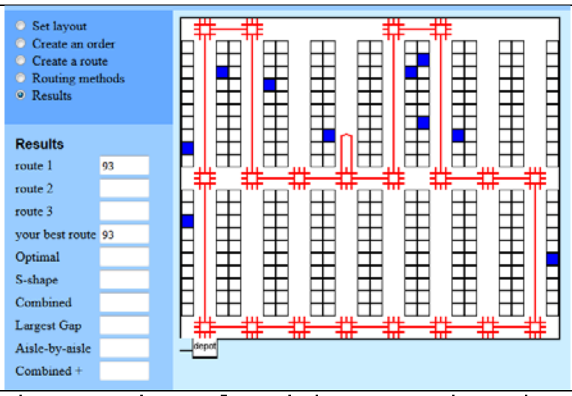
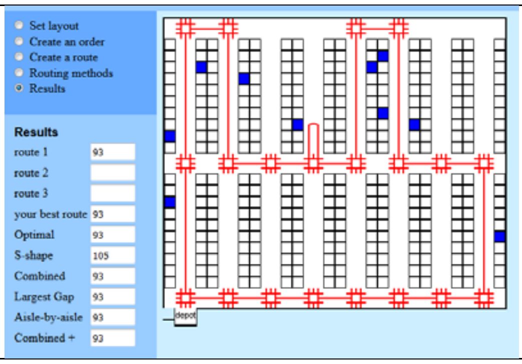
As soon as the user completes his try, he/she can see the results in the fom of the meters that the picker run to collect the products. In our example, the picker had to run 93 meters which is a very good effort, should it be compared to the results from the application of known routing algorithms (as can be seen in the screen that follows).





The routing algorithms are based on the well known problem of the travelling salesman, where a travelling salesman wishes to visit every city in a set of cities exactly once, while returning to the initial city. The results are analysed in detail at: http://www.roodbergen.com/warehous/background.php

The recommended software not only introduces the user-trainee to the concept of picking and the key parameters for its performance, but also manages to accentuate other issues-requirements, such as issues relating to proper layout that rests on specific criteria (choosing where the codes will be stored), the need for the correct codification of spaces and products, the use of routing algorithms, the utilization of specialized software applications, the selection of storage and in-warehouse transportation, design and planning of the available resources, etc. For these reasons, it is deemed an ideal solution for both showcasing the process as well as optimizing it. For the purposes of this study, this software was used in the context of real classrooms and a systematic methodology, described in the following section, was adopted.

Research methodology

The goal of this paper is to present and analyse the findings from the implementation of Interactive Warehouse simulation software for the teaching of the picking process in a warehouse of distribution centre. The sample of the survey comprises of trainees who has chosen logistics and supply chain management as their field of training. More specifically, it regarded:

1. Students in the junior (2nd) and senior (3rd) classes of the Day and Evening Professional and Vocational Senior High Schools (Lyceum) (EPAL) (new three year Evening Senior Vocational High School curriculum since academic year 2018-2019 and the old Evening Professional Senior High School four year curriculum for those already registered and studying in an EPAL). Courses relating to logistics and supply chain management include: Introduction to Supply Chain – Logistics (2nd class of Day EPAL); Organization and Management of Warehouses, Organization and Management of Transportations, Applications of Supply Chain –

Logistics (3^{rd} class of Day EPAL).

2. First year students at the departments of Supply Chain Systems Management in the Technological Educational Institutes (TEI) of Central Macedonia and Central Greece.

Common features between the two groups of the sample was that trainees chose this particular academic discipline, their age and not have been taught picking as part of an order execution system for an enterprise. The tool utilized for the research and collection of data was a questionnaire which included 19 closed type questions. The first four sketched the profile of the trainee student. More specifically, they regarded the sex, age, prior working experience (general and not limited to logistics operations) as well as their educational institute, where they were offered two choices: TEI or EPAL. The remaining 15 questions investigated the degree of comprehension by trainees of the key concepts and parameters of the picking process, and were grouped into three categories:

1. *Conceptual approach questions* ("I know what tasks picking includes", "Picking is performed only by humans", "Each order line is also a code", "A picking may include more than one orders" and "The process of picking is supported by suitable equipment").
2. *Significance questions* ("Picking is an important task", "Picking is a daily activity", "Picking is an activity occurring in every enterprise", "The success of the execution of an order depends on the success of picking", and "Picking is costly for an enterprise").
3. *Improvement factors* ("Picking times are shorter when I know the place of every product in the warehouse", "Picking times are shorter when an order includes less products", "Picking times are longer when I request a large quantity of just one product", "Picking times depend on the place of a product in the warehouse" and "The optimal route must be designated before the employee begins").

Four answers were given and the student could only choose one: "Agree", "Neither agree or disagree", "Disagree" and "I don't know". It must be mentioned at this point that when examining the picking process, the textbook addresses each one of these issues: "How is it defined?", "Why do we study it?", and "How can it be improved?".

The research methodology followed is described in the figure below (Figure 1):

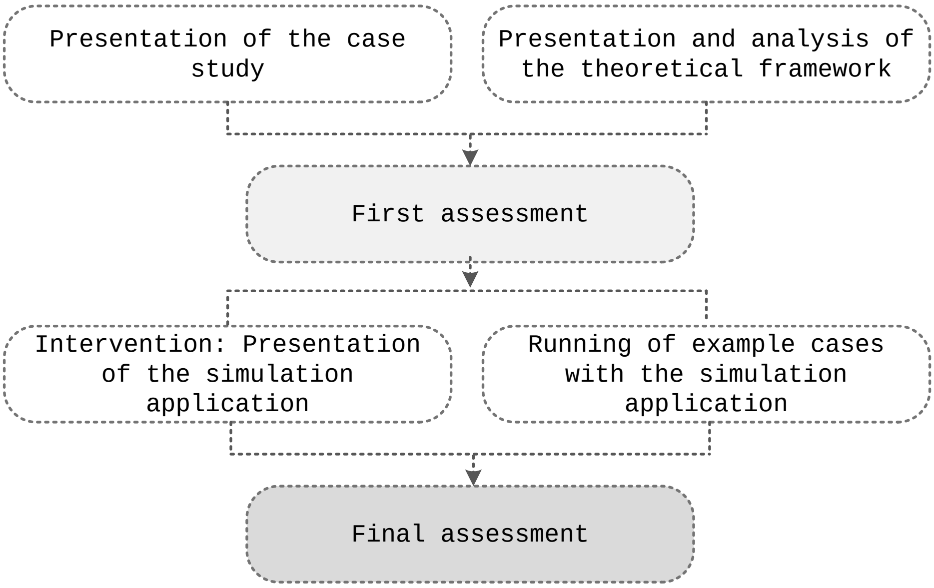


Figure 1: Methodology for the utilization of the simulation software

A small sample (case study) was initially presented, followed by a brief introduction of the theoretical framework with a general theoretical exploration of the field focusing on the key concepts and parameters of the picking process. The questionnaire was then handed out in order to be completed while the intervention followed. Its first stage included the exhibition of the simulation software and was followed by the execution of examples in the simulation software. Finally, students completed the questionnaire relating to the understanding of the key concepts and parameters of the picking process afresh.

4. Research findings

Data was collected in academic/school year 2017-2018. 188 students participated in the survey, 96 men (51,1%) and 92 women (48,9%). They were students in two Day EPAL in the city of Thessaloniki (78 students / 41,5%) and two Technological Educational Institute (TEI) (110 students / 58,5%). The majority of the sample was between 15 to 24 years old (88,2%) and almost one in two (47,9%) had some general work experience. Demographic data is presented in Table 2.

Table2: Sample's demographics

Factor	N (%)
Sex	
Men	96 (51,1%)
Women	92 (48,9%)
Age group	
15-24	176 (88,3%)

	25-34		12 (6,4%)
	35-44		6 (3,2%)
	45-54		4 (2,1%)
>25		22 (11,7%)	
Educational Institute			
Tertiary / TEI		110 (58,5%)	
Secondary / EPAL		78 (41,5%)	
Work Experience			
Yes		90 (47,9%)	
No		98 (52,1%)	
Total		**188 (100%)**	

Analysis of findings

Findings were analysed using SPSS software suite. Students' comprehension of the subject-matter was quantified as the difference between correct and wrong answers to the 15 questions of the questionnaire that was handed out (Comprehension Index), while the number of questions not attempted was considered as a measure of the students' Self-confidence when responding to questions on the examined picking process (Self-confidence index). A parametric ANOVA method was performed in order to investigate whether the educational intervention had a significant effect on students' comprehension. On the other side, given that the distribution of the self-confidence index is not regular but symetrically shaped (Figure 2), the non-parametric Wicoxon test was applied. Spearman's rho was used to calculate the correlation between the two measurements for the two indexes. One two-sided significance level was established at 0.05 for all statistical tests.

Findings

Before the intervention, the mean difference of correct minus wrong answers was 3,5 (SD = 3,8) and the average number of incorrect answers was 2,6 (SD = 2,6). After the intervention, the comprehension index stood at 4,9 (SD = 5,4) while the average number of incorrect answers was 0,9 (SD = 1,3) (Table 3).

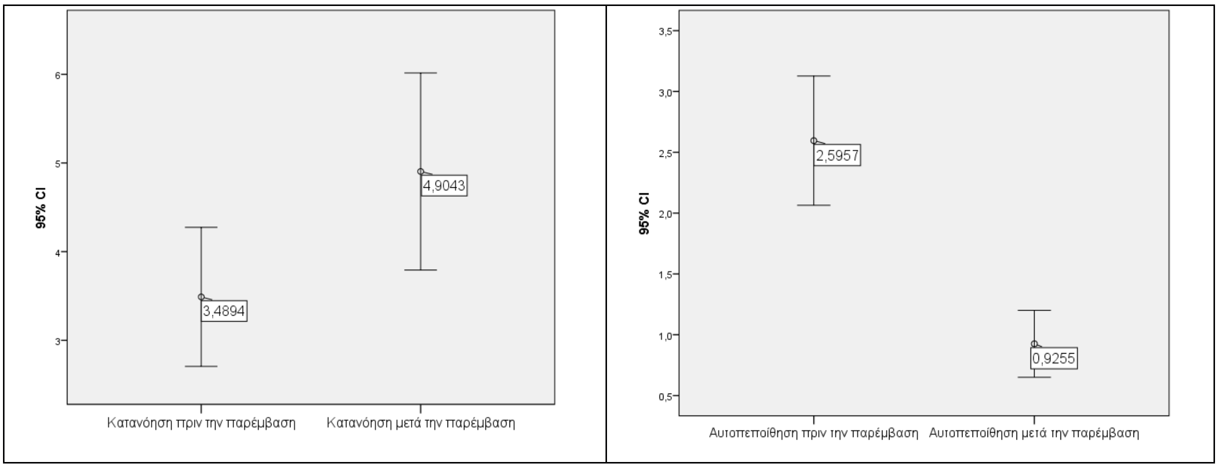
Table 3: comprehension and self-confidence before and after the intervention (Mean, Standard Deviation)

	Before	After	Spearman's ρ
Comprehension index(1)	3,5 (3,8)	4,9 (5,4)	,493
Correct answers	7,9 (2,3)	9,5 (3,2)	
Wrong answers	4,5 (2,3)	4,6 (2,3)	
Self-confidence index(2)	2,6 (2,6)	0,9 (1,3)	,377

(1): Difference of correct minus wrong answers

(2): Number of questions not answered

The following error bar diagrams illustrate the significant increase in comprehension (left diagram) by students after the intervention, by means of the increase of the difference between correct answers minus wrong ones that they gave and the also significant increase in their self-confidence, by virtue of the significant decrease of the number of answers not attempted (right figure).



Figures 2 and 3: Results before and after the intervention

Regarding the question categories as such were cited in the previous section, (namely: (1) Conceptual approach questions, (2) Significance questions and (3) Improvement factor questions) the findings for the two indexes, comprehension and Self-confidence are presented in the table below (Table 4) and show that the greatest improvement for the two indexes occurred, as expected, in the first two categories of questions. Of particular importance is the improvement to comprehension by students of the significance of the process of picking for a storage system, a logistics system and the efficient execution of orders, in general, which can offer one of the most competitive advantages to any enterprise.

Table 4: comprehension and self-confidence before and after the intervention (Mean, Standard deviation) per question category

	Before	After
Conceptual approach questions		
Comprehension index(1)	0,4 (2,2)	2,2 (2,4)
Self-confidence index(2)	1,8 (1,9)	0,2 (1,1)
Significance questions		
Comprehension index(1)	0,3 (1,5)	2,3 (1,6)
Self-confidence index(2)	2,1 (1,9)	0,1 (1,1)
Improvement factor questions		

Comprehension index[(1)]	0,8 (1,6)	1,4 (1,3)
Self-confidence index[(2)]	1,4 (1,9)	0,8 (1,1)
(1): Difference of correct minus wrong answers (2): Number of questions not answered		

The Repeated measures ANOVA was carried out to investigate whether sex, age, working experience and the academic institution (TEI or EPAL) had an impact on students' comprehension. The linear model comprised of the main effects of sex, age, working experience and type of institution as the principal resutls, as well as all possible bidirectional effects between these and the time factor. It was ascertained that there was a significant effect of time on the comprehension index (F (1,78) = 810,411, p <.001) (Table 5).

Table 5: Effects of demographics on the comprehension index

Source	Type III Sum of Squares	Df	Mean Square	F	p
Time	810,411	1	810,411	26,611	,000
Time * Sex	37,096	1	37,096	2,893	,093
Time * Age	19,516	3	6,505	,577	,678
Time * Experience	25,577	1	24,577	1,917	,170
Time * Institution	7,929	1	7,929	,618	,434
Error(time)	1000,138	78	12,822		

With respect to students' confidence in answering the questions posed (self-confidence index), a Wilcoxon test showed that the number of answers "I don't know" after the intervention was statistically lower than before the intervention (Z = 133,000, p <.001).
The results above signify that the learning intervention had an actual positive impact on students' understanding of the picking process.

Conclusions

This paper presented a study of the teaching of core supply chain management concepts using a simulation software and analysed the findings of its implementation by two Technological Educational Institute (TEI) Departments and two Vocational Senior High Schools (EPA.L.). More specifically: (a) a course outline was designed that used simulation as the principal teaching method for teaching the key parameters of picking; (b) a questionnaire was designed to measure comprehension and confidence in it; (c) a research, based on the collection of data prior and after the intervention was carried out, and finally, (d) the findings of this case study were further investigated.
Simulation can be evaluated by the combination of: (a) its potential to offer to the student an interconnection of sub-spaces (hypotheses, experiment, forecast) and (b) by the learning outcomes (the acquisition of knowledge and the acquisition of critical and creative thinking skills). Research does not conclude in clear results, however, it was observed that there were better results when the simulation contained tools providing students with "background information", namely instructions on how to arrange their actions and

“recommendations/suggestions” on the experimental process (Educational Institute, 2006).

Other studies (such as that of Tzimogiannis and Mikropoulou, 2000) have shown that the contribution of simulations in the creation of representations for students on the cinematic concepts is significant, since a move is observed away from inadequate, intuitive approaches to understandings closer to scientific theory and the relevant laws. More specifically, with respect to Supply Chain Management, our findings show that the educational process is more effective when simulation technology is utilized and we are, thus, in agreement with the research of Feng and Ma (2008), while it also contributes to the increase of the comprehension and confidence of students. It would be interesting to explore the effectiveness of the application of simulation tools in a similar sample (namely students of various educational levels who have chosen Logistics and Supply Chain Management during the first years of their studies’ curriculum) in an effort to redesign or improve the picking process and, in general, the storage system of an enterprise.

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