Michel Garcia *et al*, International Journal of Computer Science and Mobile Applications,
Vol.3 Issue. 11, November- 2015, pg. 51-59 **ISSN: 2321-8363**

Usability Study of an Interactive Digital Tool for Teaching Process Scheduling in Operating Systems

Katia Cen[1], Cinhtia Gonzalez[2], Michel Garcia[3], Sergio Gonzalez[4]

[1]*Katia Cen Universidad Autónoma de Yucatán, kathia_cenpuc@hotmail.com*
[2]*Cinhtia Gonzalez Universidad Autónoma de Yucatán, gsegura@uady.mx*
[3]*Michel Garcia Universidad Autónoma de Yucatán, michel.garcia@uady.mx*
[4]*Sergio Gonzalez Universidad Autónoma de Yucatán, sgsegura@uady.mx*

Abstract

Evaluation is very important for improving the quality of any software, including study materials used for teaching any specific topic. One of the parameters by which a study material's quality can be measured is its degree of usability. This paper presents the usability analysis of an educational software that illustrates three algorithms which control the states and life cycle of processes in operating systems. It also describes the basic usability principles which serve to determine the usefulness of the user interface, learning curve, and the efficiency of the materials to achieve the defined learning objectives. Results indicate that the proposed tool is easy to use, and users found it very useful to support their learning process.

Keywords: Usability, learning object, operating system, process scheduling.

1. Introduction

Traditional teaching that until a few years was efficient for students, lately results less attractive for children and young people, perhaps due to the particular characteristics of new generations and the environment in which they live. Students nowadays are familiar with the information and communication technologies (ICT), so these can be used to provide new tools to improve the teaching-learning process.

The development of digital material that helps teaching has become an opportunity area and a wide variety of educational applications have been creating. However, to ensure the quality of these materials, it is highly recommended to analysis them prior to its incorporations as teaching materials in a classroom, attended either personally or virtually.

Usability is a characteristic with high influence in the quality of a software, and is defined in the standard ISO 9241-11 as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [ISO 1998]. In this definition stand out the following elements: users, goals, and a context.

Therefore, one of the parameters by which a material's quality is measured is its ease of use or usability [Zambrano 2007], since it predicts the probability of the material to be used by end users. Utility and benefits provided by that material are very important too, but are obtained only if the material is used in the actual usage scenarios.

This paper describes the usability analysis of a teaching material focused on the issue of process scheduling performed by operating systems. This issue is present in the Operating Systems course of the Bachelor of Computer Science, as well as engineering and other related degrees.

2. Theoretical framework

A Learning Object (LO) is a set of didactic and interactive resources in digital format with a specified objective, and with the capacity to be reused in different contexts, according to the relevance and willingness, in diverse teaching-learning environments [Hernández, Velásquez, 2013], [Prendes, Martínez, Gutiérrez, 2008].

Fonseca [Fonseca, 2008] states that a LO is a set of digital resources that can be used in diverse contexts, with an educational purpose and composed of at least three internal components: content, learning activities and contextualization elements. Besides, a LO must have an external information structure (metadata) that facilitates its storage, identification and recovery.

A LO can be used in online learning [Otamendi, 2002], which is one of its great virtues. Núñez and Castillo [Núñez, 2006] describe it as a new type of computer-based instructional element that emerges from the object-oriented modeling paradigm used in computer sciences and that assists users to perform tasks. From the perspective of Maris and Pesado [Maris, 2012], a LO is defined as "the minimum independent structure that contains an objective, a content, a learning activity, a metadata and a feedback mechanism, besides it can be developed with information and communication technologies (ICT) to facilitate its reuse, interoperability, accessibility and longevity"

Therefore, learning objects are interactive resources that have become increasingly more accessible from the Internet, which allows their adoption for learning a specific topic. Learning objects can be reused as much as necessary and constitute a valuable support tool for learning. Being an educational resource with content, learning activities and feedback mechanisms, it allows to potentiate blended and distance learning.

However, when the content of the learning object is a developed software application, it is necessary to analyze its usability before releasing it. Following there are some definitions around usability.

Usability not only encourages participation but rather makes it possible without being a complex and intimidating process to the participant [Guevara, 2008]. The definition of usability in the standard ISO 9241-11 involves three attributes: effectiveness (about being able to complete tasks in a precise way), efficiency (analyses the amount of resources required, and if they are not wasted) and satisfaction (the user's attitude and feeling toward the software). According to Rodriguez [Rodríguez, 2010], referring to the standard ISO/IEC 9126, a more accurate definition is "usability refers to the extent to which a product can be comprehended, apprehended, used and be attractive for users, in specific conditions of use".

Given the above, to perform the usability analysis of the content of a LO, there are several methods, each one leading to evaluate different aspects.

On the other hand, education is conceived as a set of interactions between students and teachers, where both use tools and systems to interactively support learning, encouraging collaboration between them during the development of activities [Margain, Muñoz, Álvarez, 2009].

In regard to the available learning tools, nowadays there is a wide variety of resources such as educational portals and software, books and others, which serve as support for the learning process of several subjects. In particular, regarding the operating systems course, this resources are not enough to illustrate some issues that are roughly sketched using traditional teaching methods, so it is desirable to expand the types of formative experiences for students.

Some papers [Díaz, Molinari, Zabaljáuregui, 2007] suggest that when teaching Operating Systems, virtualization should be included, but do not delve on how to do it, however, a paper [Reyes, 2006] states that due the voluminous content of this subject, the use of a virtual classroom would be an appropriate way to teach it, since by the short time available is impossible to cover a wide bibliography, educational videos, presentations, teaching materials, simulations and others that allow interaction between students and the teacher. Indeed, this course covers a wide range of topics, making it difficult to be taught at a slow pace, but it would be desirable to make it more flexible, taking into account the diversity of rhythms in the learning process of each student.

Another problem when teaching this theoretical course is the lack of interactivity and motivation, hence the need for teachers to seek new tactics for students to better understand the content. An option to improve these aspects could be the inclusion of educational videos, learning objects, interactive materials, etc. In this regard,

an investigation [Hernández, Velásquez, 2012] states that the main difficulty for developing these materials is the limited time that professors have available for its elaboration, because beside the development of the materials it is necessary to evaluate them based on the scope in which they are going to be used to promote its relevance and willingness.

For these materials to really fulfill their mandate to promote learning, it is necessary that their design meets the usability criteria and to be developed according to the user needs, i.e. taking into account the particularities of students who will use the materials [Colmenares, Villegas, 2010].

In the usability analysis of a learning object content, there are several evaluation methods, each one leads to evaluate different aspects [Tramullas, 2002]. This paper is based on that there are two main methods to perform the evaluation: the analytical method and the empirical one [Maris, 2012]. The analytical method is evaluated in the user interface design process, however this paper uses the empirical method to improve the user interfaces and the product quality assurance, focused on user tests, mainly questionnaires.

This paper describes an interactive digital tool to support the teaching-learning process of a specific topic of the operating system course: Process Scheduling. This material was elaborated with the help of students from the Bachelor of Computer Science that have already completed the course and several iterations were performed supervised by the professors of that course.

3. The digital tool

In the operating systems course, one of the difficult topics is the understanding of the process management performed by the operating system. When studying this topic in a theoretical way, has been observed that there is a risk of falling into a memory-based technique without really understanding the work being done internally by the operating system, whereupon the student hardly would be able to apply the acquired knowledge when required. So, to help the course an interactive animation was developed which simulates the execution of several processes, each one in a different processor.

Concurrent processes execution is the base of multiprogramming in an operating system. To achieve it, the operating system must be able to schedule the execution of processes to maximize the utilization of available resources. Therefore, when a process requires an input/output operation, the processor must not waste time waiting for that operation to finish, instead another process, from the ones stored in memory, should be assigned to the processor. This produces a set of actions and states in which processes can be, depicted in Figure 1.

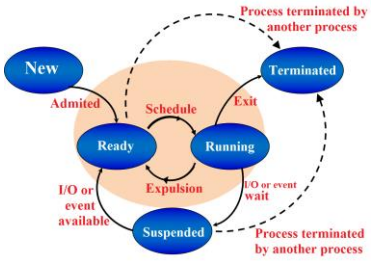


Figure 1. State diagram of process scheduling

In Contiguous memory allocation, all the logical space of a process (Code, Data, Stack) has to be allocated inside a single contiguous area in main memory, i.e. in consecutive physical addresses; and when a process ends its memory must be released. The three commonly policies employed by operating systems to manage this are known as first-fit, best-fit and worst-fit.

The first-fit policy consists in assigning the first available space with enough size to contain it. The best-fit policy scans all the memory and finds the smallest free space block large enough to store the process. The worst-fit policy consists in finding and assigning the largest available hole.

The software Adobe Flash CS5.5 was used to develop the tool, the interaction was achieved with the use of animations created from ActionScript 3.0. The tool shows the queue of processes and allows to observe the execution sequence product of the algorithm, as well as the total amount of time that will take the execution of all the processes.

In the developed tool, all the algorithms receive as input data: length and size of the processes, order of arrival of the same, size of the memory available to the operative system and the space occupied by the operative system. Once introduced these data, the user chooses the desired algorithm to simulate and the process scheduling by the operative system is graphically represented.
The tool has four screens, the first one displays the theoretical content (Fig. 2), the second one is to select the number of processes to execute (Fig. 3), to specify its respective sizes and lengths, the amount of memory available (between 100 and 512) and the size of the operating system. The third screen shows the specified algorithm simulating the execution of the processes (Fig. 4); during the execution, the user can add new instances of each process to the queue and the tool simulates their executions according to the selected algorithm. The fourth screen shows a test with immediate feedback that allows the user to evaluate his learning progress (Fig. 5).

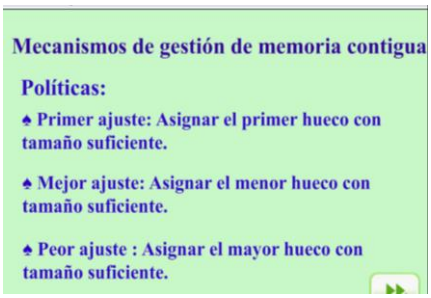


Figure 2. Screen of the theoretical content

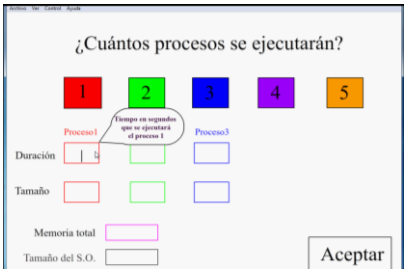


Figure 3. Screen to specify sizes and lengths of each process

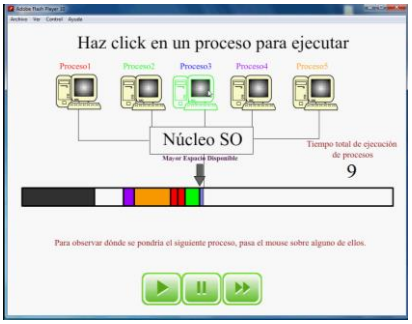


Figure 4. Algorithm simulating the simultaneous execution of five processes

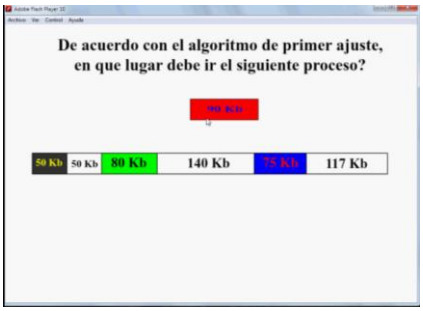
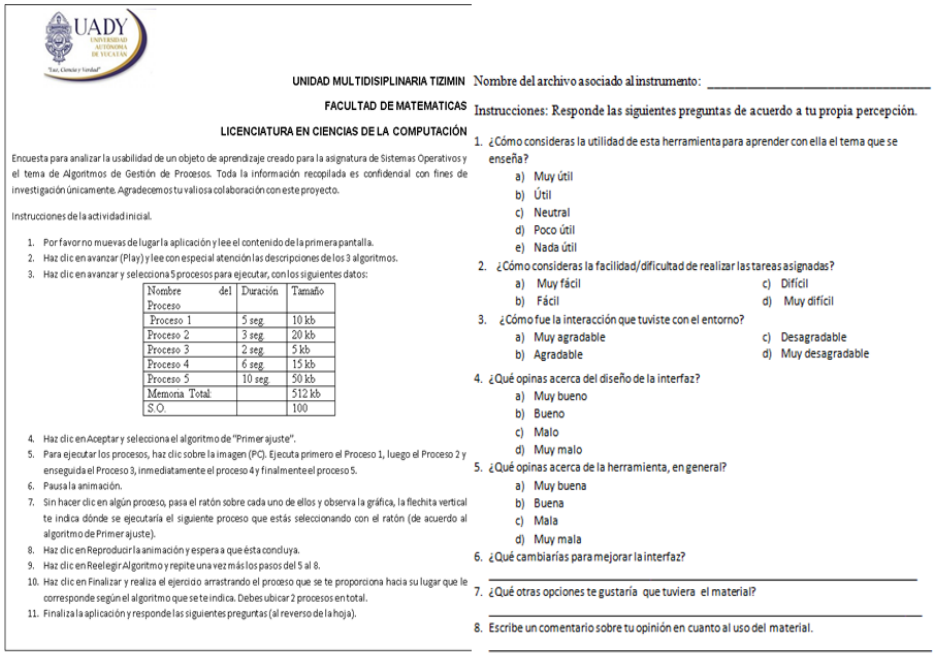


Figure 5. An auto evaluation exercise

4. Usability analysis

To evaluate the usability of the learning object, an instrument (Fig. 6) was designed and built. The attributes to measure according to ISO 9241-11 and based in some previous work [Mora, Fontanals, 2005] [Maris, Pesado, 2012] consists of a set of questions with respect to variables such as: organization of the information, clarity and user-intuitiveness, usefulness, design of the interface, if the program has errors, among others.



UADY

UNIDAD MULTIDISIPLINARIA TIZIMIN
FACULTAD DE MATEMATICAS
LICENCIATURA EN CIENCIAS DE LA COMPUTACIÓN

Encuesta para analizar la usabilidad de un objeto de aprendizaje creado para la asignatura de Sistemas Operativos y el tema de Algoritmos de Gestión de Procesos. Toda la información recopilada es confidencial con fines de investigación únicamente. Agradecemos tu valiosa colaboración con este proyecto.

Instrucciones de la actividad inicial.

1. Por favor no muevas de lugar la aplicación y lee el contenido de la primera pantalla.
2. Haz clic en avanzar (Play) y lee con especial atención las descripciones de los 3 algoritmos.
3. Haz clic en avanzar y selecciona 5 procesos para ejecutar, con los siguientes datos:

Nombre del Proceso	Duración	Tamaño
Proceso 1	5 seg.	10 kb
Proceso 2	3 seg.	20 kb
Proceso 3	2 seg.	5 kb
Proceso 4	6 seg.	15 kb
Proceso 5	10 seg.	50 kb
Memoria Total		512 kb
S.O.		100

4. Haz clic en Aceptar y selecciona el algoritmo de "Primer ajuste".
5. Para ejecutar los procesos, haz clic sobre la imagen (PC). Ejecuta primero el Proceso 1, luego el Proceso 2 y enseguida el Proceso 3, inmediatamente el proceso 4 y finalmente el proceso 5.
6. Pausa la animación.
7. Sin hacer clic en algún proceso, pasa el ratón sobre cada uno de ellos y observa la gráfica, la flechita vertical te indica dónde se ejecutaría el siguiente proceso que estás seleccionando con el ratón (de acuerdo al algoritmo de Primer ajuste).
8. Haz clic en Reproducir la animación y espera a que ésta concluya.
9. Haz clic en Reelegir Algoritmo y repite una vez más los pasos del 5 al 8.
10. Haz clic en Finalizar y realiza el ejercicio arrastrando el proceso que se te proporciona hacia su lugar que le corresponde según el algoritmo que se te indica. Debes ubicar 2 procesos en total.
11. Finaliza la aplicación y responde las siguientes preguntas (al reverso de la hoja).

Nombre del archivo asociado al instrumento: _____

Instrucciones: Responde las siguientes preguntas de acuerdo a tu propia percepción.

1. ¿Cómo consideras la utilidad de esta herramienta para aprender con ella el tema que se enseña?
   a) Muy útil
   b) Útil
   c) Neutral
   d) Poco útil
   e) Nada útil
2. ¿Cómo consideras la facilidad/dificultad de realizar las tareas asignadas?
   a) Muy fácil
   b) Fácil
   c) Difícil
   d) Muy difícil
3. ¿Cómo fue la interacción que tuviste con el entorno?
   a) Muy agradable
   b) Agradable
   c) Desagradable
   d) Muy desagradable
4. ¿Qué opinas acerca del diseño de la interfaz?
   a) Muy bueno
   b) Bueno
   c) Malo
   d) Muy malo
5. ¿Qué opinas acerca de la herramienta, en general?
   a) Muy buena
   b) Buena
   c) Mala
   d) Muy mala
6. ¿Qué cambiarías para mejorar la interfaz?
   _____
7. ¿Qué otras opciones te gustaría que tuviera el material?
   _____
8. Escribe un comentario sobre tu opinión en cuanto al uso del material.
   _____

Figure 6. Usability questionnaire of the learning object content

The questionnaire was applied to a sample of 24 students, randomly selected among the students of the Bachelor of Computer Science. This sample is represents approximately 30% of the current student population of that degree offered in the Multidisciplinary Unit Tizimin, of the Autonomous University of Yucatan, Mexico.

During the experiment, the participant students used the developed educational software in some computers located in a laboratory, in which the software was already installed and running. At the beginning, to each student was provided a guide document containing a data set that he should employ when using the system. Table 1 shows the processes and durations included in the provided guide.

Table 1. Data provided to use the application.

Process ID	Length (seconds)	Size (MB)
Process 1	5	10
Process 2	3	20
Process 3	2	5
Process 4	6	15
Total Memory:		512
O.S.		100

Each user's action was registered in a video in which the performed movements were recorded, what subsequently allowed to analyze the usage times, wrong answers and movement sequences of each user.
Subsequently to the use of the software, each student answered anonymously a questionnaire, which was internally linked with the video recording of the use of the software by the same user.

5. Results

Once analyzed the videos and questionnaires answered by participants, it was noted that the application was used between 4 and 18 minutes, with an average and standard deviation of 8.9825 and 8.24 minutes respectively. It is worth mentioning that all users went through the three stages of the application: theory, simulation and exercises.
Results are summarized in Table 2, in which the first column identify the user, the second one depicts the total time spent in the application by each user. The third column shows the number of user's wrong answers occurred in the auto evaluation exercises of the software.

Table 2. Data obtained during the user tests.

User	Time spent	No. of wrong answers
1	11:35	1
2	10:44	3
3	4:38	1
4	6:26	2
5	7:20	1
6	12:57	1
7	17:51	3
8	7:16	1
9	11:22	1
10	13:35	1
11	7:01	1
12	17:08	1
13	7:50	1
14	10:22	2
15	6:45	1
16	4:02	1
17	3:47	1
18	3:49	1

19	4:48	2
20	9:34	1
21	5:32	1
22	8:17	1
Un 23	12:38	1
24	17:49	1

It was noted that all the students considered a defect that in the application cannot be selected to execution a single process, since it can be chosen only between two and five, however, the reason of this is that a single process would execute directly, and the logic of the algorithm would not come into play. Fig. 7 shows the screen that corresponds to this situation.

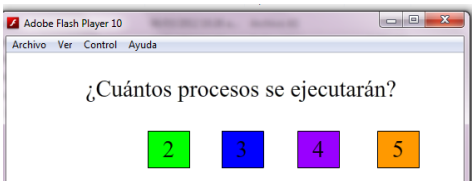


Figure 7. Options to select the number of processes that will be executed in the operating system

As for the usefulness of the tool to learn with it its taught topic, 61% ranked it as "very useful" and 39% as "useful", having discarded the options "neutral", "unhelpful" and "useless". That is, more than 50% of users agree in that this tool is useful for learning the subject that it teaches.
As for the ease/difficulty to perform the assigned tasks, 50% considered it "very easy" and the remaining 50% "easy".
As for the experience of interaction with the environment, 100% of users answered that it was "very nice", discarding the following 4 options ranging from greater to less pleasure, like the above questions.
As for the interface design, 13% of users said that the tool is very good, 74% that is good, and 13% that is bad. The design of any tool is very important so that a user wants to handle it, but even more for him to desire to learn a topic with that tool. This percentage, the lowest of the evaluation, suggest to improve the interface of the application, although it is in the range of positive user acceptance.

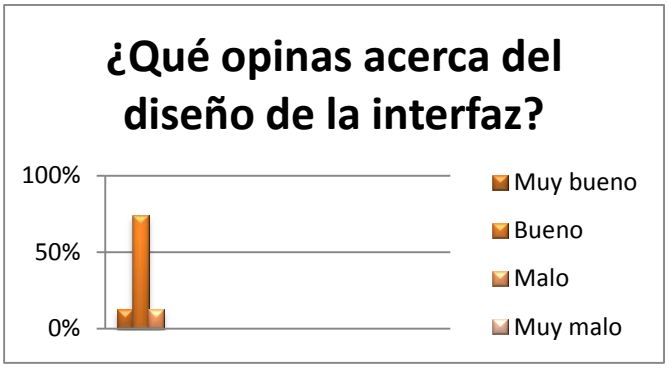


Figure 8. Opinions about the design of the interface

As for the general opinion about the tool, 100% of users granted the best rating on the scale, answering that it is "very good". In the concluding remarks, it was stated that the tool is in general very good, since it teaches a specific topic and has a feedback section. "To learn of the fit methods you do not need to know much about the subject of operating systems, with this tool and a little bit of concentration it is learned".

The remaining positive reviews were oriented to the user friendliness of the system and that it looks a good material. The negative comments were related with the inclusion of instructions or help messages, and one more comment indicating that the application run with random clicks, without indicating any specific operation. It is worth mentioning that the software was designed to be executed by students interested in using the tool for their learning, without validating actions that intentionally seek to cause a fail in the application.
Some suggestions to improve the interface were: to include written help instructions to guide the user, to include a reset button to start again the execution of the application, to improve the way in which the processes and arrow animations are presented.
Likewise, among the additional options suggested to be included in the application, was mentioned the ability to sort and execute the processes, the option to start the animations of all processes with a single click, to extend the length of animations showing the execution graph of all processes, to show more clearly performed during the execution of processes, and to include more theory of the topic.

6. Conclusions

The usability analysis of the content of a LO has as purpose that said object complies with certain characteristics, such as to possess: ease of use, of learning and necessary features. Then it will satisfy the user expectative as well as its relevance and willingness, for which quality is a key aspect. To achieve this, in this work it was necessary to collect information concerning the analysis of usability, based in the attributes given in the standard ISO 9241-11 [Mora, 2005]. Subsequently an evaluation instrument was designed and applied, using previous works, for which students of the Bachelor of Computer Science that have already taken the course of Operating System participated, selected randomly.
The usability analysis indicates that the tool is easy to use, besides that users consider it useful to support their learning process. In addition, some possibilities for improvement were detected, such as the inclusion of a help menu to make it easier for users the use of the system, as well as the integration of more exercises to enhance for users the feedback and evaluation of their learning progress.
Once concluded the usability analysis and done the suggested improvements, the proposed LO is a quality tool since it has a good level of usefulness for the achievement of educational goals, promoting the work of users and therefore promoting learning. So this tool is ready to be distributed in any repository that allows easy access to the users

References

[1]. ISO 9241-11:1998 *Ergonomic requirements for office work with visual display terminals (VDTs)* -- Part 11: Guidance on usability.
[2]. Zambrano, F.: La Usabilidad Entre La Tecnología Y Pedagogía, Factores Fundamentales En *La Educación A Distancia. Revista Digital Universitaria*, Vol. 8, No 5, (2007).
[3]. Hernández, Y.; Silva, A.; Velásquez, C.: Instrumento de Evaluación para Determinar la Calidad de los Objetos de Aprendizaje Combinados Abiertos de tipo Práctica. *Séptima Conferencia Latinoamericana de Objetos y Tecnologías de Aprendizaje LACLO*, Vol. 3, No 1, pp. 2,3 (2012).
[4]. Prendes, M.; Martínez, F.; Gutiérrez, I.: Producción De Material Didáctico: Los Objetos De Aprendizaje RIED. *Revista Iberoamericana de Educación a Distancia*, Vol. 11, pp. 4,5 (2008)
[5]. Fonseca, D.: Iniciativa colombiana de objetos de aprendizaje: situación actual y potencial para el Futuro. *Apertura*, Vol. 8, pp.5,6 (2008)
[6]. Otamendi, A.; Belfer, K.; Nesbit, J.; Leacock, T.: Instrumento para la evaluación de objetos de aprendizaje *(LORI_ESP)*. pp. 2,3 (2002)
[7]. Núñez, Y.; Castillo, P.: Propuesta para el diseño de objetos de aprendizaje. *Revista Facultad de Ingeniería*, Vol. 14, No.1, pp.2,3 (2006)
[8]. Maris, S.; Pesado, P.: Evaluación de la usabilidad de un Objeto de Aprendizaje por estudiantes. *Revista Iberoamericana de Tecnología en Educación y Educación en Tecnología TE&ET*, No. 8, pp.1-3 (2012)
[9]. Guevara, B.: Construcción de un Objeto de Aprendizaje basado en el tema de Investigación Comunidades Virtuales con Usabilidad y Sociabilidad. *V Simposio Pluridisciplinar sobre Diseño y Evaluación de Contenidos Educativos Reutilizables*. Salamanca, Madrid. Octubre, pp.2-4 (2008).
[10].10. Mora, C.: Fontanals, C.; Evaluación De La Usabilidad En Sistemas De Información Web Municipales Metodología De Análisis Y Desarrollo. *ISKO congreso* 7, pp.3 (2005)

[11]. Rodríguez, D.: Diseño De Interfaces Y Condiciones De Usabilidad Definición de pruebas heurísticas para evaluar la usabilidad en sitios web sobre gestión cultural. *II Congreso Iberoamericano de Investigación Artística y Proyectual y 4º Jornadas Nacionales de Investigación en Disciplinas Artísticas y Proyectuales*, pp.2,3 (2010).
[12]. Tramullas, J.: Propuestas de análisis usabilidad para sedes web. Contenidos y Aspectos Legales en la Sociedad de la Información. Universidad Politécnica de Valencia, pp.1-9 (2002)
[13]. Margain, M.; Muñoz J.; Álvarez F.; Metodología de Aprendizaje Colaborativo Fundamentada en patrones para la producción y uso de Objetos de aprendizaje. *Investigación Y Ciencia*, No.44, pp.24,25 (2009)
[14]. Díaz, Javier.; Molinari, L.; Zabaljáuregui, M.: Desarrollo de un framework para la enseñanza de los Sistemas Operativos usando Lguest. *V Congreso de Tecnología en Educación y Educación en Tecnología*, pp.1-3 (2007)
[15]. Reyes, K.: Aula Virtual Basada En La Teoría Constructivista Empleada Como Apoyo Para La Enseñanza De Los Sistemas Operativos A Nivel Universitario. *Revista de Educación a Distancia*, No.21, pp.3, 4 (2006).
[16]. Colmenares, L.; Villegas, H.: Metodología para el desarrollo de interfaces de materiales educativos basados en computador. *25 Años de Integración Escolar en España*, pp.1-3 (2010).

Acknowledgements
We thank the Autonomous University of Yucatán and the Faculty of Mathematics from all facilities in the accomplishment of this work.

A Brief Author Biography

1st Katia Cen-Puc – Bachelor in Computer Science for the Faculty of Mathematics at the Multidisciplinary Unit Tizimín. Has been involved in software development, robotics and electronics.

2nd Cinthia Maribel González Segura – Master in Computer Sciences for the Institute Technology of Monterrey in México, is professor of the Autonomous University of Yucatán. Responsible of the Intelligents Systems lab. His researcher lines: Optimization, Artificial Intelligence, Mobile Robots

3nd Michel García García - Master in Computer Sciences for the Institute Technology of Monterrey in México, is professor of the Autonomous University of Yucatán, Actually collaborate in the Intelligent Systems Lab. His researcher lines: Machine Learning, Artificial Intelligence, Mobile Robots.

4nd Sergio Alejandro González Segura - Master in Computer Sciences for the Centre for Research and Technological Development. Is professor of the Autonomous University of Yucatán and responsible of the electronic laboratory. His researches lines: Intelligent systems, stereo vision, robotics.

