Article

Journal Computer Technology

December 2021, Vol.5 No.15 1-12

Effectiveness of the use of a learning object in students of the programming area in higher education

Eficacia del uso de un objeto de aprendizaje en estudiantes del área de programación en el nivel de educación superior

CASTILLO-PÉREZ, Iliana†*´, ALONSO-LAVERNIA, María de los Ángeles´, MUÑOZ-SÁNCHEZ, Yira´´ and MARTÍNEZ-LAZCANO, Verónica´

´Universidad Autónoma del Estado de Hidalgo, Instituto de Ciencias Básicas e Ingeniería, Pachuca, Hidalgo, México.
´´Universidad Autónoma del Estado de Hidalgo, Escuela Superior de Ciudad Sahagún, Hidalgo, México.

ID 1st Author: *Iliana, Castillo-Pérez* / **ORC ID:** 0000-0002-8130-9231, **CVU CONACYT ID:** 339989

ID 1st Co-author: *María de los Ángeles, Alonso-Lavernia* / **ORC ID:** 0000-0002-9839-8250, **CVU CONACYT ID:** 217926

ID 2nd Co-author: *Yira, Muñoz-Sánchez* / **ORC ID:** 0000-0002-4876-2747, **CVU CONACYT ID:** 280735

ID 3rd Co-author: *Verónica, Martínez-Lazcano* / **ORC ID:** 0000-0003-2172-4000, **CVU CONACYT ID:** 256998

DOI: 10.35429/JCT.2021.15.5.1.12

Received: July 10, 2021; Accepted December 30, 2021

Abstract

This paper shows the application of a Learning Object (LO), to teach an Object Oriented Programming theme, considering the involvement of the levels of the thinking skills according to Bloom´s taxonomy and the strategies for the development of activities that support autonomous learning. The kind of research used to measure the effectiveness of the applied multimedia material is exploratory-investigative. The selected sample was 110 students who attended the subject, 23 of them constituted the experimental group and the other 87 the control groups. In order to appraise the students learning, a cognitive assessment instrument was designed, in addition to a questionnaire to evaluate the quality of the educational material from the user´s perspective. The results when comparing the scores obtained by the experimental group with the established control groups show a favorable increase in the students' approval rate for the topic, perceiving a favorable autonomous learning.

Learning object, Programming languages, Higher education

Resumen

El presente trabajo muestra la aplicación de un Objeto de Aprendizaje (OA), para la enseñanza de una temática de Programación Orientada a Objetos, considerando el involucramiento de los niveles de habilidades del pensamiento de acuerdo con la taxonomía de Bloom y de las estrategias para el desarrollo de actividades que apoyan el aprendizaje autónomo. El tipo de investigación utilizada para medir la eficacia del material multimedia aplicado fue exploratorio-investigativo. La muestra seleccionada fue de 110 estudiantes que cursaron la asignatura, de los cuales 23 constituyen el grupo experimental y 87 pertenecientes a los grupos de control. Para valorar el aprendizaje de los estudiantes, se diseñó un instrumento de evaluación cognoscitiva, además de un cuestionario para evaluar la calidad del material educativo desde la perspectiva del usuario. Los resultados al comparar las calificaciones obtenidas por el grupo experimental con los grupos de control establecidos muestran un incremento favorable en el índice de aprobación de estudiantes para el tema abordado, percibiendo un aprendizaje autónomo favorable.

Objeto de aprendizaje, Lenguajes de programación, Educación superior

Citation: CASTILLO-PÉREZ, Iliana, ALONSO-LAVERNIA, María de los Ángeles, MUÑOZ-SÁNCHEZ, Yira and MARTÍNEZ-LAZCANO, Verónica. Effectiveness of the use of a learning object in students of the programming area in higher education. Journal Computer Technology. 2021. 5-15:1-12.

* Correspondence to the author (Email: ilianac@uaeh.edu.mx).
† Researcher contributing as first author.

Introduction

The trend in the use of Information and Communication Technologies (ICT) within education has increased so much that they are currently used on a day-to-day basis as part of the teaching-learning process.

A wide variety of methods, methodologies, strategies, approaches or techniques have been implemented with the intention of supporting student learning and improving their academic performance, in recent years those that strengthen student autonomy have highlighted, such as the inverted class, Orozco-Infante (2020), mentions that not only is the transfer of time and space in the learning process beneficial, but of the timing and proper use of digital resources; another strategy that has attracted attention has been gamification, which seeks through the use of game mechanics, to guarantee the competency and active learning of the student, discovering that the innovative use of ICT benefits their learning and motivates them (Lazarte & Gómez, 2021). For their part Valenzuela, Ramírez, Arellano, and Mondaca (2021) highlight the importance of feedback in formative evaluation processes in virtual teaching-learning environments (EVEA), in which technology has been shown to improve efficiency and effectiveness in student performance.

Learners from all areas of knowledge benefit from the use of digital teaching materials because they allow them to present more effectively the knowledge they require for their development as professionals, which is due to the management, already natural, of multimedia that make the interaction with these resources more attractive and motivating. Another benefit of the use of didactic resources is that students can carry their own pace of learning, allowing that by interacting independently with digital didactic materials, students identify their own learning strategies to appropriate the knowledge immersed in these technological environments, which strengthens them in their training and prepares them to perform in the future in the professional field.

Digital teaching materials have characteristics that enrich the training process as well as motivate learning and facilitate didactic and formative action.

The latter two, because they act as a guide with a defined didactic strategy and provoke the appropriation of knowledge respectively.

Under this conception, in education, ICT has been used for the benefit of students, allowing them to be at all times close to information, living in the age of knowledge in a way in which they can access at any time and from anywhere to educational content that allows them to promote their autonomous learning, and even socialize knowledge in a much more agile way.

In this sense, autonomous learning allows the student to be the protagonist of their own development, giving them the responsibility of planning, organizing and carrying out the pertinent actions and at their own pace to obtain the objective learning, which in turn will allow them to strengthen the competence of autonomy, which is of vital importance for their inclusion in today's society (Lobato, 2006; Torrano, Fuentes, & Soria, 2017).

Many are the studies that disseminate the relevance of technology as a means for training, demonstrating the effectiveness of its use, and in this sense the Learning Objects (LO), are characterized by their reusability, which implies a certain degree of granularity, focused on a particular objective of learning, with availability so that the student learns at any time and place at his own pace, through interactive multimedia activities, allowing him, in the end, to know his learning through elements of self-assessment included, facilitating autonomous learning (Almendra & Elvas, 2020; Cabrera, Sánchez & Rojas, 2016; Redmond et al., 2018; Williams, O'Connor, Windle & Wharrad, 2015); emulators stand out for their ability to manipulate variables in a virtual environment, represent real or hypothesized phenomena, provide a dynamic and interactive learning experience for students on a particular topic (Falloon, 2019; Jamil e Isiaq, 2019).

Multimedia applications, enriched with videos, texts, audios, graphics, animations, among others, promote the development of digitales skills related to the use of ICT (knowing how to access, search and select information according to the student's own learning objective), motivate the student according to their dynamics and challenges proposed for the acquisition of knowledge (García & Tejedor, 2017; Huertas & Pantoja, 2016; Nketiah-Amponsah, Kumi Asamoah, Allassani & Kwami Aziale, 2017; Sánchez & Espada, 2018; Yáñez & Nevarez, 2018); echomendators and intelligent systems are used to guide learning activities and the selection of resources in the learning path of each student, in deposition of their pace, abilities and motivations, which influences the autonomy of their learning (Rodríguez Chávez, 2021; Romero, Saucedo, Caliusco & Gutiérrez, 2019), all the technological tools mentioned have been applied at different educational levels and various areas of knowledge with favorable results, manifesting the improvement of school performance and student motivation.

With all the above, it is demonstrated that the use of didactic resources, accompanied by methods, strategies, methodologies or approaches, impacts on all areas of knowledge because they lead to a learning process that depends on the learner's own effort (autonomous learning) and their motivation. Hence, technological tools in the form of digital teaching materials represent a relevant support in the training trajectory of every student, making prevailing the need for mastery of digital skills by teachers for their development (García Vélez, Ortiz Cárdenas, & Chávez Loor, 2021).

In this context, and referring to educational programs focused on computing and specifically, in subjects such as Object-Oriented Programming (OOP), students become more competent the more independent and hard-working they are, and this is because they look for a way to solve for themselves the problems they face in the development of their tasks, on the contrary, its kinesthetic profile makes theoretical topics more complex to learn.

Despite the kinesthetic characteristics of this area, learners require the acquisition of theoretical knowledge, which is fundamental for the mastery of knowledge, with the intention that they understand and appropriate it, which is essential to later apply it (Muradul & Latiful, 2016; Ochoa, 2018; Öqvist & Nouri, 2018). The same is indicated by Figueredo and García-Peñalvo (2018) "Programming is a process of transformation of a mental plan of ordinary terms into terms compatible with the computer" (p.2), which is not easy for students, since it requires the development of abstract thinking skills to be able to create computer programs that solve real problems (Sánchez-García, Urías-Ruiz, & Gutiérrez-Herrera, 2015; Insuasti, 2016).

The topic of constructors for any object-oriented programming subject is basic, as it represents the genesis of objects, since they are created from the constructors and are initialized with valid values that subsequently change their state during the course of the application, so it will be of great importance that students learn various concepts and rules that they must then implement correctly.

Consequently, for these theoretical topics, the use of didactic resources becomes even more motivating, since they provide a different alternative to books or textual sources that could be rejected by students who are more attached to technology, this with the purpose that they can, firstly, appropriate all relevant information for their learning and secondly, strengthen autonomous learning skills.

Some study evidence, focused on learning programming, has had the objective of investigating the impact of ICT on the learning of concepts and the development of programming skills and has come to the conclusion that digital educational materials must include certain aspects for this task to be fulfilled, Jamil and Isiaq (2019) highlight the importance of educational material linking learning content with future work and the profession, and that it should include behavioral, emotional and cognitive exercises in a balanced manner; Lappalainen, Lakanen and Högmander (2016) mention the need to include exercises and tests to improve learning efficiency, while Muradul and Latiful (2016) point out that including a problem bank supports learning.

The above criteria promoted the development of a Learning Object (LO) on the types of constructors in the C++ programming language, which reinforces the self-learning of said topic as part of the theoretical concepts of the students of the subject of OOP.

This type of resource was selected, since in recent years its use has reached great relevance because it is a digital didactic unit designed to achieve a learning objective and to be reused in different learning environments and in different contexts, in addition to having metadata that favors its location, and allows to address its contextualization (Astudillo, 2011; Dabbagh et al., 2016; Frantiska, 2016).

The LO are instructional components focused on detailing a concept, procedure or specific knowledge with an essential characteristic that is the ability to be self-contained, that is, where external references are not required to achieve the proposed learning objective, being all explained within it and preferably, but not mandatory, includes exercises and/or evaluations to feed back to the student.

As has been observed, in the international context, there has been much evidence of the success achieved through LO, and the educational methodological change caused by the current pandemic has contributed to the increase in the production of digital educational resources that support the continuation of studies by the students. In Mexico 7.1 million higher-level students are enrolled in the 2021 school year, and 65.3% have a laptop or desktop computer, while 34.7% continue their studies through smartphones or tablets (INEGI, 2021), therefore, another important reason for working with LO has been their characteristic of being adaptable (responsive) to the electronic device in which they are used, in addition to not requiring that they be necessarily accessed through a repository, which facilitates their access by students.

This paper presents the application of LO on the topic of Builders in C++ for incorporation into the subject of OOP in order to promote autonomous learning of students of the Bachelor's Degree in Computational Sciences or related careers. It is important to note that, responding to the quality guidelines, its development was based on the Methodology for the Development of Learning Objects (MEDOA) (Alonso, Castillo, Martínez, & Muñoz, 2013a) and its effectiveness as educational material was validated, as well as its quality from the user's perspective through the results obtained by the students who used it.

In order to facilitate the understanding of the study carried out and the characteristics of this LO, the work has been structured in the following sections: *Development of the LO* where the primary elements of the educational material in relation to learning are described and highlighted; *Methodology,* section that presents the objective and way of carrying out the study; in section 3, the *Results* obtained both in the implementation of the LO and its assessment by the users; in section 4 a *Discussion* of said results and possible improvements is included and finally, the *Conclusions*.

Learning Object Development

Considering that a methodology is a set of guided, systematized and structured steps to carry out research in an appropriate way, the development of an LO requires a methodological process in an indispensable way for its creation, in the same way that any technological system needs it.

A methodology must guarantee compliance with the essential requirements in the creation of the didactic material, as well as the development process itself, in addition to enabling the control and monitoring of this process. Under these reasons, and even though there is a diversity of methodologies for the development of LO, the use of MEDOA was chosen because it is a methodology that guarantees the fulfillment of these purposes and above all, because it supports the entire creation process.

MEDOA, consists of seven phases: planning, analysis, design, implementation, validation, implementation and maintenance for the process of creating an LO, considering not only its development, but also the implementation to make it available to users and maintenance for its modification or expansion.

Within the phases of this methodology, the following aspects of the LO were established: the digital material is aimed at students of upper middle or higher level and in the user´s profile the knowledge, skills and attitudes are considered so that he can learn with the LO, such as: basic knowledge about programming, basic use of the computer, proactive and collaborative attitude. In addition, the Builders in C++ LO includes five examples, each of which presents the implementation of a constructor type. In the case of the activities, three are presented with different level in the skills of thinking in correspondence with Bloom's taxonomy, the first verifies the learning of theoretical concepts through the creation of a conceptual map on the constructors that involves actions of analysis and synthesis of thought (knowledge), the second activity considers the application level by referring to the coding of an object class that implements some of the concepts learned within a preset structure, the third achieves a minimum level of synthesis by requesting the coding of at least two different types of constructors within a new class of objects (constructor overload), as well as an application in which the objects that invoke them are urged; the last two activities are intended to develop in the student the know-how, in addition to suggesting that they be carried out under a collaborative learning strategy, promoting the socialization of learning.

On the other hand, in the evaluation section, three are contemplated that make use of different types of reagents such as false/true questions, multiple choice, complete, relate columns, multiple selection, among others. Notably, the questions also consider levels of thinking skills ranging from knowledge to analysis in relation to Bloom's taxonomy.

On the other hand, the defined activities have an identifier, the learning objective (according to Bloom's taxonomy), the instructions, the type of evidence to be delivered, the time required for the activity, the type of evaluation (Heteroevaluation, Co-evaluation or Self-Evaluation), as well as the qualification or score that can be obtained.

It is important to mention that MEDOA contemplates a series of guidelines that define a base structure with the intention of standardizing the development of LO and ensuring that they have characteristics that distinguish them from other types of educational software (Alonso Lavernia, Castillo Pérez, Pozas Cárdenas, Martínez Lazcano, & Muñoz Sánchez, 2013b). The resource developed under this methodology is composed of various elements, which are:

- Introductory.
- Content.
- Reinforcement-Evaluation.
- Complementary.
- Identification and Location.

The intrinsic knowledge of the topic addressed in the LO is broken down through the elements of the didactic resource, being able to use sections and subsections for its presentation through interactive materials with which the student will learn the theoretical concepts, reinforcing their application with examples.

The elements of reinforcement and evaluation are introduced as a fundamental part within a digital didactic material since with these the probability of assimilating the knowledge that is learned with the didactic resource is increased. For the Constructors in C++ LO, they are applied through the different activities and evaluations that allow to strengthen the knowledge and skills that are described in the content elements. This material includes, as indicated by the MEDOA methodology, three activities.

ISSN 2531-2197

December 2021, Vol.5 No.15 1-12

All evaluations provide feedback for each of the items they present. On the other hand, the complementary elements support all the above, by providing help to the user for the understanding of the content. These elements are materialized with the sections: *glossary* (the meaning of certain terms used in the LO is presented), *bibliographic references* (as a way to expand the knowledge presented) and *credits* (the authors of the LO are recognized).

The combination of all these elements allows users to have various learning strategies based on the use of multimedia, evaluation and exercise techniques. In addition, some of them support the user to develop autonomy and independence capabilities in their learning.

Methodology

To validate the effectiveness of the didactic resource developed in the learning of the students, a methodological design was followed that consisted of the following steps:

1. Definition of the objective of the research

2. Definition of the type of research

3. Definition of variables

4. Selection of the sample and application of the didactic resource

5. Obtaining results and discussion

The steps of the methodological strategy of the research carried out are described below.

Definition of the research objective

The purpose of this study is to know the effectiveness of the use of learning objects as educational materials that promote the autonomous learning of students in the area of programming, by addressing topics with extensive theoretical bases.

Definition of the type of research

According to the defined objective, the research to be carried out can be framed in two research approaches:

1. *Exploratory*, as it is a known scientific problem, since it has been worked by various authors to demonstrate the effectiveness of the use of digital didactic materials, reaching a certain level of clarity, however, work continues to establish causal relationships between technological resources and learning.

2. *Development work and technology evaluation*, because it is a study dedicated to completing, developing and perfecting new materials, products or procedures. In this case, the work is a research study based on the same methodological patterns as any other research, the purpose being to know the validity and reliability of the technique or technology or to quantify the benefits it produces and the impact that its introduction has had in practice.

Definition of variables

To evaluate the effectiveness of the Learning Object from the point of view of the pedagogical contents, depending on the conception of learning and the application of knowledge by students, the following considerations are established for the analysis:

a) It is considered a history of the results obtained in the partial evaluation, by the students who have regularly taken the subject of OOP and who had not used interactive educational materials as a means of reinforcing learning and promoting autonomy in the student. For this analysis, only those items within the partial theoretical-practical evaluation of the normal course, which correspond to the topic of constructors in C++, are considered.

b) An *ad-hoc* test was designed to measure the learning achieved after having interacted with the LO and having developed the activities and evaluations proposed in it. The test was composed of six items, of which four were considered to estimate the theoretical concepts and two, particularly, for the assessment of the implementation of these concepts (items 4 and 5), since it is requested that through the evaluation of a code, the relationship that has the instantiation of a series of objects with the type of constructor that is presented in the code of the class of objects and for which, the student must go through several levels of thought in Bloom's taxonomy (Knowledge of the theoretical concept, up to evaluation, to deduce or assess its implementation), considering that only the one who has reached the highest levels will be able to respond correctly to these items, thus demonstrating the achievement of learning.

Table 1 presents the relationship of each of the items of the *ad-hoc* test with the level of knowledge within Bloom's taxonomy and the verb to which it refers in relation to the abstract thinking that is demanded of the student to respond adequately.

Ítem	Level of knowledge in Bloom's Taxonomy – Verb
1	Remember – Define
2	Understand – Predict
3	Analyze – Differentiate
4	Evaluate – Relate
5	Evaluate – Evaluate
6	Evaluate – Evaluate

Table 1 Level of knowledge requested in the items of the *ad-hoc* test
Source: (self made)

Selection of the sample and application of the didactic resource

The study was carried out at the Autonomous University of Hidalgo State, using the Builders in C++ LO in an experimental group of 23 third-semester students who took the subject of Object-Oriented Programming from a total sample of 110 enrolled in the six periods evaluated, all of them from the educational program of Bachelor´s Computer Science.

As already mentioned, the analysis of the results was carried out among the history of the evaluations presented by the control groups, whose students have previously taken the subject and have not used the Learning Object, compared to the experimental group that applied the *ad-hoc* evaluation, after having used the LO. To assess the quality of the LO, an instrument was applied to the same 23 students who worked with it, because according to some authors it is important to evaluate a didactic resource from the perspective of the user (Alonso et al., 2019; Gordillo, Barra & Quemada, 2018; Massa, De Giusti & Pesado, 2012; Velázquez et al., 2014).

According to Morales, García, Moreira, Rego and Berlanga (2006), a comprehensive evaluation of the quality of a digital educational material must consider many aspects and be evaluated from various approaches. For this study, the criteria of Morales et al. (2006) regarding the following aspects were taken into account: *psychopedagogical* to evaluate the adequacy of the contents to the users, the depth and relevance; *didactic-curricular* to determine the level of relationship between the LO and the curricular objective according to the context in which it was applied; *technical-aesthetic* oriented to assess its degree of legibility, adequate colors, size of letters, design, all with the intention of motivating the user; and finally, *functional* to assess if it is an effective and usable LO and does not hinder the navigation and learning of students..

According to the authors, psychopedagogical and didactic-curricular criteria are of greater importance within an educational context since a didactic resource could be very functional, but not be adequate to the characteristics of the users or not meet the learning objective.

In addition, some aspects to be evaluated for each criterion were established, which are shown in Table 2. The Likert Scale was used in the range: strongly disagree, disagree, agree and strongly agree for its assessment.

Criterion	Aspects
Psychopedagogical	The learning objective is clear. The learning object helped him to better understand the subject. The examples are clear for each of the cases. The activities are understandable. The examples have to do with the computer science profession.
Didactic-curricular	The content of the object is adequate for the achievement of the learning objective. The learning object provides feedback. The examples were according to the theme. The activities allow you to develop other skills in addition to programming.
Technical-aesthetic	The font used is the right one. The font size is adequate. The color used in the learning object is appropriate.
Functionality/ Navigation	The navigation is understandable. Navigation buttons are visible. No broken garters were found.

Table 2 Aspects to assess the quality of the LO from the perspective of the students
Source: taken and modified by Morales et al. (2006)

Results

The results achieved are presented in two parts, one dedicated to the application of the Learning Object and the other, related to the application of the evaluation instrument of the resource mentioned.

Application of the Learning Object

The scores obtained by the students of the experimental group in each of the items that make up the *ad-hoc* test are presented in Table 3.

No. Pupil	Ítem 1 (1 pto)	Ítem 2 (1 pto)	Ítem 3 (1 pto)	Ítem 4 (2 ptos)	Ítem 5 (5 ptos)	Ítem 6 (2 ptos)
1	1	0	1	2	3	2
2	1	0	1	0	1	2
3	1	0	1	2	4	2
4	0	0	1	2	5	2
5	1	1	1	2	3	1
6	1	0	1	0	2	2
7	1	0	1	2	4	2
8	1	1	1	2	4	2
9	1	1	1	2	4	2
10	1	1	1	0	5	2
11	1	0	0	0	2	1
12	1	0	0	0	2	1
13	1	0	1	2	4	2
14	1	0	1	0	4	1
15	1	0	1	0	2	2
16	1	0	1	2	4	1
17	1	0	0	2	5	2
18	1	0	0	0	4	1
19	1	0	1	2	3	2
20	1	0	1	2	4	2
21	1	0	0	0	4	2
22	1	0	1	2	3	2
23	1	0	1	2	4	2

Table 3 Results of the experimental group in each item of the knowledge test
Source: (self made)

In general, it can be observed that except in item 2, in the rest of the items most of the students obtained the highest score, which indicates that the use of the didactic resource to complete the learning of the students in this subject was satisfactory.

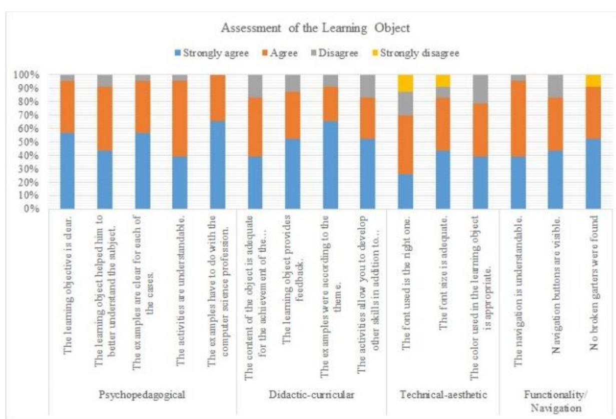
On the other hand, the results obtained by the students of the experimental and control groups in the partial theoretical-practical evaluation of the subject of OOP, for the school periods analyzed, are presented in Table 4.

Group type	Period	Approved	Failed	Total students
Control groups	Cycle1-A	53.33%	46.67%	15
	Cycle1-B	28.00%	72.00%	25
	Cycle2-A	46.15%	53.85%	13
	Cycle2-B	65.00%	35.00%	20
	Cycle3-A	35.71%	64.29%	14
Experimental group	Cycle3-B	73.91%	26.09%	23

Table 4 Index of results obtained by students from different groups
Source: (self made)

Implementation of the LO Assessment Tool

The results achieved in the application of the evaluation instrument are presented in Graph 1, with 47% of students valuing the set of aspects with *Totally agree*, 41% *Agree*, 10% evaluated it *In Disagreement* and 2% as *Totally disagree*. It should be noted that the main aspects that were negatively valued by the students are the technical-aesthetic and functionality-navigation criteria.



Graphic 1 Results of evaluation of the LO by the user
Source: (self made)

ISSN 2531-2197

Among the aspects best valued by users are *the examples have to do with the profession of computational sciences* of the psychopedagogical criterion and *the examples were in accordance with the theme* of the didactic-curricular criterion; in general, the criterion best valued by the users was the psychopedagogical one, where *the objective aspects of learning* and *clear examples* also obtained favorable scores; the aspects of *the LO provide feedback* and *the activities allow the development of other skills in addition to programming* favored the general score of the didactic-curricular criterion, however, the technical-aesthetic criterion presented the most unfavorable scores, so the aspects related to *the type and font size* and *the color used in the LO* should be improved in the maintenance step, as well as *the links for navigation*, the Functionality/Navigation criterion, which also had some unfavorable points, should be verified.

Discussion

When analyzing the results of the knowledge test of the experimental group (Table 3), it was observed that in items 1, 3 and 6 scores were obtained that adequately satisfy the achievement of learning; in item 4 and item 5 (considering for the latter that 4 and 5 points reflect a good level of achievement) it was achieved that 60.87% of the students responded correctly. Regarding item 2, only four students were able to answer with certainty, which could mean that the item was not formulated correctly or the way in which the topic was addressed in the LO was not enough or it was necessary to reinforce it through the activities and/or evaluations.

When examining the set of results, it is clear that the use of the Learning Object achieved an increase in the percentage of students approved (73.91%), since in the control groups, the best approval rate had been 65%.

As for the evaluation of the quality of the LO by the students, it can be interpreted that it is quite satisfactory (88% favorable) and the disagreements are mainly focused on the aspects of aesthetics and functionality, whose improvement is achieved by attending to some programmatic issues of this resource.

Conclusions

The results of this study corroborate that the use of digital didactic resources harmonizes perfectly with the methods of learning theoretical contents in computer science, in particular, programming languages, demonstrating that they are efficient to improve the performance of students and promote their autonomous learning.

It should be noted that to achieve favorable results it is essential to carry out a process of elaboration of the resource that from the first moment attends to its quality. In the particular case of the study presented, the use of the MEDOA methodology for the creation of the LO has been key to achieving the effectiveness of this resource, since in each step of its development the articulation of the different elements that compose it is considered responding to the learning needs of the topic that is addressed, as well as the relevance of activities and assessments that reinforce knowledge, all based on the established learning objective and the levels of thinking skills to be promoted.

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