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Open educational resources: An analysis of the learning objectives referenced by Bloom's digital taxonomy

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ABSTRACT
This article presents an analysis of educational metadata related to the learning objectives employed in Educational Objects and in teachers' activities at PhET Colorado. We have as main question, how the teachers have appropriated the educational objects available in PhET for the construction of activities. To this end, the research is based on the cognitive principles of Bloom's digital taxonomy and its adaptations to classify learning objectives. As a result, we found that teachers apply learning objectives in a more diversified way in the construction of their activities, and explore the six levels of taxonomy in a more harmonious way.

Keywords: Educational objects, Cognitive domain, Learning objects, Repository.

1 INTRODUCTION

In the current world panorama driven by knowledge, education systems have faced a great challenge in the production of educational material for the digital environment. In view of this, the use of *Open Educational Resources* (OER) emerges as a pedagogical potential for collective use. OER "are educational support materials that can be accessed, used, modified and shared freely" [UNESCO 2015 p.1]. Over the past two decades, an increasing amount of OER has become available for educators to use, reuse, re-publish, and share knowledge supporting collaborative learning [Clements, Pawlowski & Manouselis 2015].

Currently there is a large number of repositories on the internet whose purpose is to store, classify and make available educational objects [Diana 2015]. As examples we have MIT[1] Opencoursewar , which provides videos, books, texts and classes organized by area of knowledge, MERLOT[2], provides collections of didactic-pedagogical materials and content creation tools, and we also have PhET COLORADO[3], which offers more than 150 interactive simulations and 2000 teacher-

[1] MIT Opencourseware - https://ocw.mit.edu/index.htm [Access: 31-Jan-2020].
[2] MERLOT - https://www.merlot.org/merlot/index.htm [Accessed: 31-Jan-2020].
[3] PhET COLORADO - https://phet.colorado.edu/ [Acessado: 20-Jan-2020].

submitted activities covering topics in physics, chemistry, biology, earth sciences and mathematics. We bring PhET as a highlight due to the large flow of access to educational objects, with more than 750 million simulations accessed.

The use of these resources promotes a culture of open education and constant updating, thus establishing an important relationship with the current context of digital education [Mattar, 2013]. With this, the use of OER contributes to the development and improvement of educational materials and curricula, assisting in the development of quality teaching and learning. Thus, the transformative potential of OER also includes collaboration and sharing, enhancing the role of OER creativity and innovation in the creation of new educational models [UNESCO 2015].

Many of the resources educatesis bring in the structure of their *Educational Objects* (OE) the use of lesson plans, exercises and activities related to the contents. These materials contain, in the vast majority, information about the object and its possible use, as well as pedagogical information and *Learning Objectives*. In the process of teaching and learning, deciding and defining the objectives to be achieved involves articulating the educational process so that it enables the establishment of new cognitive structures in the learner. Therefore, the objectives are at the center of the planning process, defining them means outlining the learning process as well, making it easier, more enjoyable and meaningful [Gil, 2006].

So This article analyzes the different educational objects registered in the PhET Colorado database, in order to identify the *Learning Objectives* that are arranged in the educational objects and in the activities produced by the teachers. Having as main question: how have teachers appropriated the educational objects available in PhET for the construction of activities? Observing mainly the *Learning Objectives* that they use in the description of their activities.

The article is organized as follows. Section 2 presents the cognitive domain of Bloom's digital taxonomy, in Section 3 we have the methodological process with the use of taxonomy, to draw a model of analysis of the characteristics described in the educational metadata of each object of the cited base, Section 4 are presented the results and discussions in the OER analysis and, finally, in Section 5 we have the conclusions of the work.

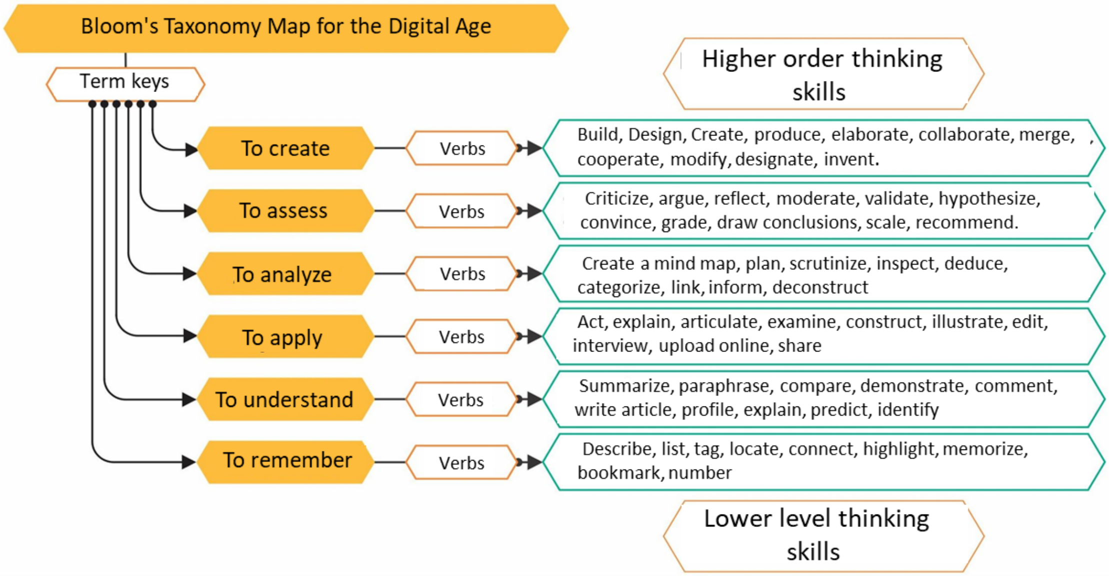
2 COGNITIVE DOMAIN OF BLOOM'S TAXONOMY

Bloom's Taxonomy [Lomena, 2006; Guskey, 2001; Bloom et al., 1956; Bloom, 1972; School of Education, 2005; Clark, 2006] was structured from a set of instructional theories with the objective of offering differentiated strategies to facilitate and evaluate the performance of students at different levels of knowledge acquisition, as well as to assist educators during the educational process in a structured and conscious way. Originally, Bloom's taxonomy was structured from three domains: (i)Cognitive, (ii)Affective and (iii)Psychomotor.

In 2001 TaxonoBloom's mia was reviewed by Krathwohl and Anderson (2001) who gave greater emphasis to the effectiveness of the educational process, expanding the scope of this planning beyond the activity itself. This revision of the taxonomy proposed a reorganization, especially in the higher items of the taxonomy. For the cognitive level, the author establishes a set of six categories to guide educational planning: *Remember, Understand, Apply, Analyze, Evaluate and Create*. The most basic level is the *"Remember,"* by requiring students to resume concepts already learned, while the most complex level is the "*Create*", which requires the combination of different sources of knowledge [Dorodchi, Dehbozorgi & Frevert, 2017]. Thus, taxonomy is a way of classifying learning levels to format measurable instructional outcomes.

In 2009 Bloom's revised taxonomy was adapted by Churches (2009) to approach educational resources in digital learning environments, as shown in Figure 1. The objectives, processes and actions arising from Information and Communication Technologies (ICTs), began to require the implementation of new layers (secondary verbs) to those addressed in the taxonomy. This adequacy, justified by the increase in learning in a technological context, presents a complementation to the main verbs, detailing a second layer of secondary verbs that help in the application of this methodological approach. From this set of planning system steps are evidenced the thinking skills that start from the lower level to the higher order skills.

Figure 1. Bloom's taxonomy for the digital age



In this sense, the Bloom taxonomy for the digital age presents a cognitive organization, by proposing a set of categories with the use of a variety of verbs that seek to guide educational planning for the digital context. These verbs promote a series of cognitive actions within the main categories, being built based on the memories and understandings of knowledge to lead students to use and apply skills, involving analysis and evaluation of processes, consequences and results so that they elaborate, create, and innovate [Churches, 2009].

3 METHODOLOGICAL PROCESS

The research conducted an analysis of *the learning objectives* used in the description of the educational objects arranged in PhET Colorado. We sought to analyze *in the learning objectives of* each material the presence of different levels of cognitive development, for this, we used Bloom's taxonomy for the digital age elaborated by Churches (2009) and referenced in the research of Dorodchi, Dehbozorgi & Frevert, (2017) and Wiley (2002) in order to classify them.

PhET offers more than 150 interactive simulations called Educational Objects (OE). These objects cover various topics in the fields of physics, chemistry, biology, mathematics and earth sciences, with over 2000 related activities translated into over 90 languages. PhET provides the EO and activities at levels of learning knowledge, which are: Primary School, Elementary School, High School and University. The PhET educational resource is based on providing OE and together making available a series of related activities that are posted by teachers from various parts of the world. Regarding the number of activities that each EO has, this number varies greatly, and Some contain a small number of activities, while others provide more than 50 related activities.

As part of this research we chose the category associated with High School that covers the five areas of knowledge. In the High School category we have over 120 original OE of PhET and their respective activities. Of this total LE, a sample of 20 EOs were randomly taken and from these were removeds 05 activities of each, totaling 100 activities of the teachers. For the analysis of *Learning Objectives* of the PhET EO, two methodological steps are proposed: (i) collection and classification of *Learning Objectives* of the original PhET EOs, these goals being elaborated by the feature's own design team; (ii) collection and classification of *Learning Objectives* of the activities that were posted by the teachers who use the EO via the PhET platform. Both analyses were referenced by Bloom's digital taxonomy to form a subsidy material for the discussions.

Regarding the first step, we observed that PhET adopts a customized design to make the information in its educational objects available to the public on the web. Each OE/simulation has six metadata fieldss containing the following information: ABOUT (pedagogical information of the object), FOR TEACHERS (information for teachers), TRANSLATIONS (available languages), RELATED SIMULATIONS (related simulations), SOFTWARE REQUIREMENTS (technical requirements for operation) and CREDITS (Design Team, third-party libraries and indication of authors).

From the set of information present in the metadata we chose to analyze the field *Sample Learning Goals*) linked to ABOUT, this field indicates the *Learning objectives that the resource is willing to perform during use. These learning objectives* It has a main function of assisting teachers in the activities. Of the 20 selected EOs and their respective *Learning Objectives*, we obtained a total of 94 items, which were analyzed and classified with their indications of cognitive levels. Thus, we obtained a percentage of cognitive use in the objectives for each level of the taxonomy, which we can verify in the results of the research.

For the second stage of the analysis, we used the same 20 EO to extract the 05 activities proposed by teachers, in which we mapped the *Learning Objectives* of each, for analysis and classification we used the same process as before. Of these 100 activities we obtained a total of 326 *Learning Objectives*.

The process of classifying *Learning Objectives*, uses the cognitive levels of Bloom's digital taxonomy elaborated by Churches (2009). Thus, for each learning objective found, we assigned a cognitive level of the taxonomy, relating the intentionality proposed in the objective with the actions of each verb of the taxonomy. As an example, Table 1 shows the extraction of *Learning Objectives* of 1 OE PhET original (simulation - addition of vectors), in which they point out that permeates the levels *remember, understand, apply and analyze*. Thus, we can observe in the first objective, "Describe a vector in its own words" the intentionality in describing, this action relates to the level of *remember* according to the classification of verbs elaborated by Churches (2009).

Table 1. Field analysis *Learning Objectives* of OE vector addition

Objetivos de Aprendizagem (OE Phet originais)	Verb. Taxonomia
Descreve um vetor com suas próprias palavras	Recordar
Explicar um método para adicionar vetores	Entender
Comparar e contrastar estilos de componentes	Entender
Decompor um vetor em componentes	Analisar
Descreva o que acontece com um vetor quando multiplicado por um escalar	Recordar
Organize vetores graficamente para representar adição ou subtração de vetores	Aplicar

4 RESULTS AND DISCUSSIONS IN THE OER ANALYSIS

Many education researchers use Bloom's taxonomy to construct and apply their activities and tests in their classes. As Crowe, Dirks, & Wenderoth (2008) points out, the alignment of activities and tests with learning outcomes is critical to effective course design. The research did not aim to point out whether teachers are using or placing the learning objectives in their activities *correctly, but to* *understand what levels of* learning objectives teachers are appropriating or exploring when using the EO as a basis for the construction of their activities. Thus, the real importance of having observed the use of *learning objectives* in research corroborates with Pozo & Gómez Crespo (2009) that these objectives are necessary means for students to achieve certain capacities and ways of thinking.

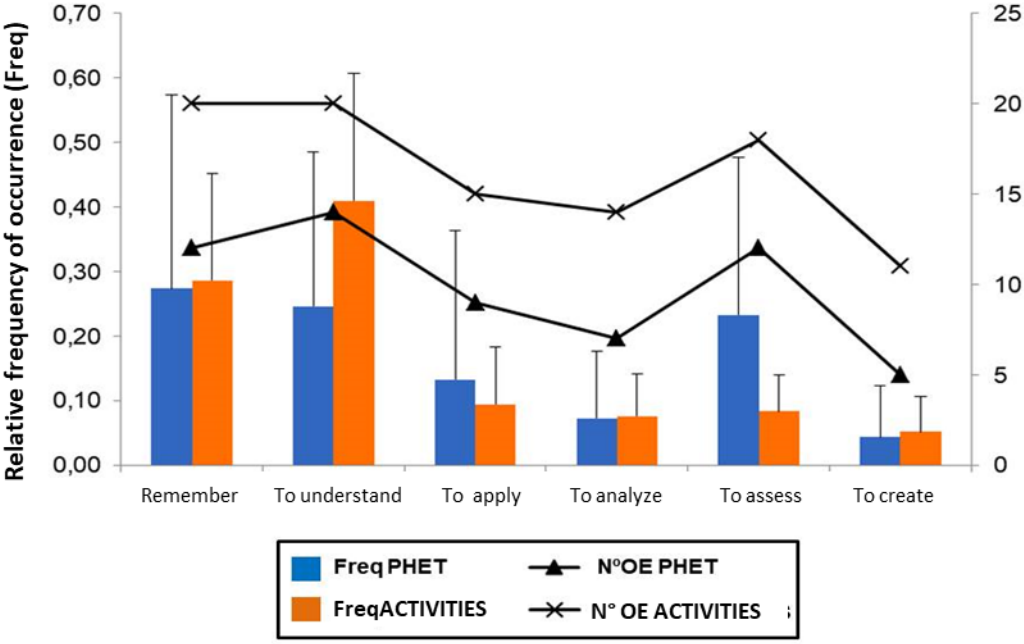
To discuss the use of *Learning Objectives* of the original PhET EOs and the activities of the teachers, we can use the percentage values of Table 2, in which we can visualize the *Learning Objectives* grouped according to their pedagogical characteristic referenced by the cognitive level of Bloom's taxonomy. We realize that the levels *remember, understand and evaluate* totaled the most expressive percentages of *Learning Objectives* of the original OE PhET. We show that the levels *apply, analyze and create* they're not being explored much in the resource goals. Already in the activities of the teachers we had a more expressive value in the levels *remember and understand*, the most preponderant being those of the level *understand*.

Table 2. Analysis of learning objectives.

	Objetivos de aprendizagem nos OE PhET originais		Objetivos de aprendizagem nas Atividades Professores	
Níveis cognitivos de aprendizagem Analisados	**Percentuais**	**Itens**	**Percentuais**	**itens**
Recordar	24,5%	23	27,9%	91
Entender	24,5%	23	42%	137
Aplicar	13,8%	13	9,8%	32
Analisar	7,5%	7	7,4%	24
Avaliar	24,5 %	23	7,7%	25
Criar	5,3 %	5	5,2%	17
Total de objetivos de aprendizagem dos 20 Objetos Educacionais		94		326

In order to analyze the relationship between the *Learning Objectives* of the original OE PhET and the activities of the teachers we present in Figure 2 the mean and standard deviation of the frequency of relative occurrence of the objectives in each cognitive level of the taxonomy. Thus, we can observe that the learning objectives of the teachers' activities, in most of the cognitive levels of the taxonomy, present a greater representativeness of use. However, these usage values are quite close, with the exception of the level *understand and evaluate.* From this we could infer that teachers use the *Learning Objectives* proposed by the original PhET EO.

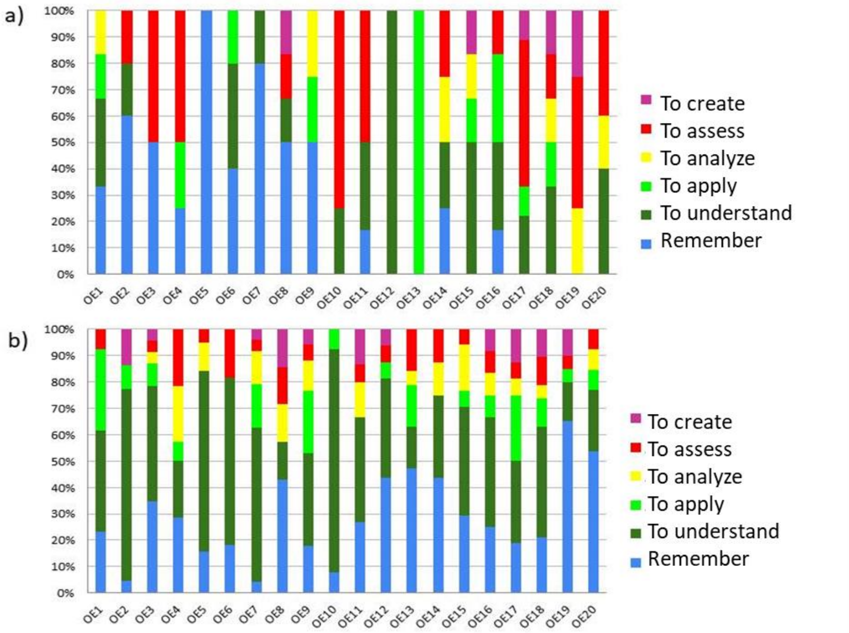
Figure 2. Distribution of Learning Objectives in the original PhET EOs and Teacher Activities. The values represent the means and standard deviation of the relative frequency of occurrence (Freq) at each level of the taxonomy.



However, when we observe the *Learning objectives in the original OE PhET we noticed that they present a high standard deviation, which tells us that within each EO there is a difference in the distribution of the objectives of each level. Thus, there are some EOs that have a very high number of learning objectives*, while others have few or almost none at the said level of Bloom's taxonomy. This is evident when we look at the number of EO at each level of the taxonomy according to the secondary axis of Figure 2, for example, at the level *remember*, we see that although the relative occurrence values of the original PhET EOs and the activities are close, the number of EOs that includes the *Learning Objectives* at the level *remember* in the original PhET is 12 OE and the activities of the teachers is present in the 20 OE. Therefore, it is noticed that the amount of *Learning Objectives* are better distributed throughout the activities elaborated by the teachers, thus increasing the diversity of levels of taxonomy in the exploration of each OE.

Therefore, at each level of the taxonomy the number of EO explored by the teachers through the activities was higher than those proposed by the original OE PhET. This factor that the analysis demonstrated suggests that the teachers explored in their activities a greater diversity of *Learning Objectives*. From this we can infer that a better distribution of *Learning Objectives* and levels of taxonomy may increase the complexity of exploration of EOs and the cognitive exploration of learning at more levels by both students and teachers.

Figure 3. (a) Analysis of the learning objectives of the original 20 PhET Eos and (b) Teachers' activities in the EOs



With the comparaction of graphs (a) and (b) of Figure 3 we can observe the diversity of Bloom's cognitive levels explored in each LE. In the original OE PhET, Figure 3 (a), it is noticed that some activities explore few or only one level of taxonomy in the performance of the *Learning Objectives*. And on the other hand, in Figure 3 (b), referring to the activities of the teachers, we observed that the *Learning Objectives* contemplate a minimum number of three levels, and some LE, such as EO 17, 18 and 19, contemplate all cognitive levels of taxonomy. Thus, the teachers distributed in a more diversified way the levels of learning throughout the activities of the OE, in addition to exploring other cognitive levels, which were not foreseen in the *Learning Objectives* originally proposed by PhET.

During the analysis process, we can observe that some activities proposed by the teachers involved other cognitive levels, going beyond the use of the basic levels of the *remember and understand* for the more complex levels like evaluating and creating. According to Thompson et al (2008) in their research were observed significant discrepancies between the classifications suggested by different teachers for the same question of educational activities, evidencing that an understanding about the application of taxonomy can undergo classification changes within the same activity. This means, that the classification can be updated or revisited, or even that the activity can cover other levels that were not previously foreseen, with this, the data generated by the analysis can bring other possibilities of use to the *Learning Objectives* of the OE PhET that were not originally foreseen by the appeal.

We can also report that teachers had a concern to always use learning objectives at the level *remember and understand* in the activities in each OE. This concern highlights the importance of students understanding the content to explore other levels of OE use, even doing exercises in more complex activities such as evaluating and creating. For Pozo & Gómez Crespo (2009) the use of conceptual bases is very important for the exploration of more complex actions in the learning process, because to analyze and evaluate a content it is necessary to have understood its most basic concepts.

The research data, in relation to the *Learning Objectives*, demonstrated that teachers use diverse possibilities of exploration of the use of OE, envisioning activities of higher cognitive levels, many of which were not originally foreseen at the time of conception by PhET. According to Ávila et al. (2016), the contribution of teachers can also help in the definition of a set of guidelines and standards supporting the new generation of knowledge and consequently in the improvement of OER.

All in all we have found in the studies challenges in the design of OERs, which identify that the lack of collaboration and involvement of teachers, students and designers impacts on the improvement of OER, and that considering the involvement of these parts, results in more significant OERs and that make more sense to users [Santana & Silveira 2017]. Clarity in the elaboration, structuring and construction of an OER can lead to a better guarantee of resource use and enhance teaching and learning. On the other hand, the active participation of teachers in the co-creation of an OER contributes to the improvement and development of the OER itself and in the construction of new ones [Ávila, et al. 2016].

5 CONCLUSION

In this study, we apply the levels of the cognitive domain of Bloom's Digital Taxonomy as a theoretical framework to classify/distinguish the *Learning Objectives* of the activities of the professors that are listed with the original PhET EOs. The study allowed the visualization of how teachers are appropriating the EO for the elaboration of activities. The analysis concludes that teachers apply more diverse the *Learning Objectives* in the construction of their activities, and explore more harmoniously the six levels of Bloom's taxonomy. In addition to prioritizing the use of *remember and understand* how *Learning Objectives* basis for learning.

Therefore, PhET could support teachers in creating new activities with the use of *Learning Objectives* as a requirement for sharing in the repository contributing to the database. In addition, PHET could exploit these objectives posted by teachers to update the available EOs themselves, thus enriching the possibilities of the resources. This information could indicate cognitive levels that each student would work on when performing the activities of the OE. Thus, the availability of cognitive levels in each activity could help students in the exploration of EO allowing the progression from simpler to more complex levels of resource content, maximizing learning possibilities.

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