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Curriculum Analysis According To Bloom's Revised Taxonomy In Science And Mathematics

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1.Introduction

To achieve scientific literacy, curriculum design is fundamental and, in addition to the content, it must take into account the cognitive development characteristics of the learners (Sacristán, 2007; Razzouk, 2008), as well as how to approach them with practical proposals and guidelines (Acevedo, 2004; De Ibarrola, 2012). Given the abstract component of mathematics and science, to achieve the correct literacy of individuals it is necessary to minimise anxiety (Hopko et al., 2003) and rejection of this type of discipline (Pérez-Martín, 2018). For this reason, the design of the curriculum is fundamental not only in terms of content, but also in the way it is approached, with practical proposals and guidelines to guide students in their learning and evaluation (Acevedo, 2004), considering the cognitive development of the students (Sacristán, 2007; Razzouk, 2008). In terms of scientific knowledge, there are two similar concepts: literacy (acquisition of knowledge) and competence (use, applicability, and transfer of content) (Cañal et al., 2012). Active learning methodologies such as Context-Based Learning (CBL) (Avargil et al., 2012; Sanmartí and Márquez, 2017), guided constructivist methodologies such as the 5E methodology (García-Grau et al., 2021) and others have been shown to be useful for students' scientific literacy. Thus, Pedrinaci (2013) states that the scientifically literate individual is the one who can be scientifically competent.

Literacy (knowledge acquisition) in STEM areas (science, technology, engineering and mathematics) is fundamental to achieve scientific competence (Cañal et al..., 2012) which is the ability to apply those skills and knowledge to real problems and situations that arise (Tanık and Saraçoğlu, 2011; Cañas and Nieda, 2013,) with the use of critical thinking and communication skills (Ozcan and Akcan, 2010), thus Pedrinaci (2013) states that the scientifically literate individual is the one who can be scientifically competent. In the educational context, taxonomies of learning objectives such as Bloom's (Bloom, 1956) have been used to organise the planning of teaching and learning experiences as well as the expected outcomes (assessment) of learning (Bakırcı and Erdemir, 2010). In Bloom's revised taxonomy (RBT) the categories are classified according to cognitive processes (LOTS [low-level thinking skills] and HOTS [high-level thinking skills]) and the type of knowledge: factual (point facts), conceptual (understanding of facts), procedural (practical skills) and metacognitive (about one's own knowledge of the subject) with a verb (or more than one) identifying it.

Some countries such as Cyprus (Koç 2020), Singapore and Australia (Ang, 2019), Turkey (Seraceddin et al., 2019; Elmas et al., 2020), Indonesia (Poluakan et al., 2019) or Finland (Elmas et al., 2020) have already used Bloom's revised taxonomy to analyse their curricula as it is a simple tool because it forms a two-dimensional matrix. The aim of the study is to code the assessment criteria of two curricula according to Bloom's revised taxonomy in a two-dimensional table (according to cognitive demand and type of knowledge) to know the typology of the assessment criteria of each of them and whether there has been a change and to provide a basis for comparing the curricula of different countries.

2. Method

2.1 Selected Curriculum Documents

The curricula of LOGSE and LOMCE have been selected since LOGSE was the law that introduced compulsory schooling until the age of sixteen, while LOMCE was the last educational law in force, but its curriculum is still in force. For the LOGSE, the documents analysed were Royal decree

2.2 Codification of assessment criteria according to the rbt

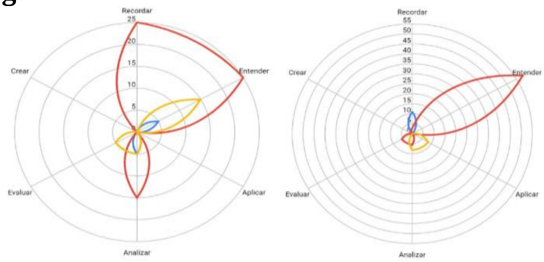
The assessment criteria of each curriculum (expressed as statements with a verb of reference) corresponding to the subject of Biology and Geology have been analysed/coded, which allows, according to the RBT: to count and classify in a two-dimensional table that facilitates the work of analysis, interpretation, and possible comparison

with other curriculum documents. To avoid interpretation errors, three people (three university professors, two of them also teachers of compulsory stages and the other a doctor in Psychology) have been involved in the coding of each of the criteria, following the following steps:
1. Identification of the assessment criteria and the verb that identifies them in the corresponding curriculum.
2. Coding in the corresponding categories, both in the knowledge and cognitive dimension (at the individual level).
a. First, the main verb of the assessment criterion was classified into one of the six categories of the cognitive dimension.
b. Then the knowledge dimension (factual, conceptual, procedural, and metacognitive) was decided.
c. And so on with all evaluation criteria.
3. Sharing and consensus of the codifications according to the categories of the RBT. 4. Counting and calculation of the frequencies and percentages according to the category to which they belong in a two-dimensional table.

3. Results

For ease of reading the results are shown in graphical form, and the tables with the frequencies and percentages of the assessment criteria of Curriculum analysis of LOGSE (1991, revised in 2001)
Figure 1 shows that most of the criteria in science curricula (in Primary) correspond to the conceptual category and a smaller proportion to the procedural. Both factual and metacognitive knowledge are not representative (less than 10%) or do not appear at all. The low representation of factual knowledge under the category "remembering" may compromise the learning and/or assimilation of knowledge and skills of higher cognitive demand. Regarding secondary education, it can be observed that most of the criteria correspond to a type of conceptual knowledge, but in this case, it is concentrated in the cognitive category of "understanding", and a small proportion to factual knowledge. It is worth noting that the few criteria corresponding to the procedural category are grouped in the categories of application and analysis.

Figure 1



Note: The radial graphs shown in the figure correspond to the primary and secondary curricula respectively. Colour coding is established for the knowledge categories: factual (blue), conceptual (red), procedural (yellow), metacognitive (green).

Figure 2 shows that most of the criteria in Math curricula (in Primary) correspond to the conceptual (35%) and procedural (25%) categories, the latter being predominant for the application category. Both factual and metacognitive knowledge are not representative (less than 10%).
The low representation of factual knowledge under the category "remembering" may compromise the learning and/or assimilation of knowledge and skills of higher cognitive demand, since knowledge cannot be interrelated when the facts that form it are not mastered. Regarding secondary education, there is a common pattern with primary education (observable briefly in figure 1), since most of the criteria correspond to conceptual knowledge, which in this case is also concentrated in the cognitive category of "understanding" and "applying". It should be noted that the criteria corresponding to the procedural category are mainly grouped in the application category. From these diagrams the tendency in the mathematics curriculum is not the memorization of factual content (remembering) but its understanding and putting into practice (application), but it is striking that no greater effort is devoted in curricular terms to going beyond the simple understanding and mechanization of exercises (application).

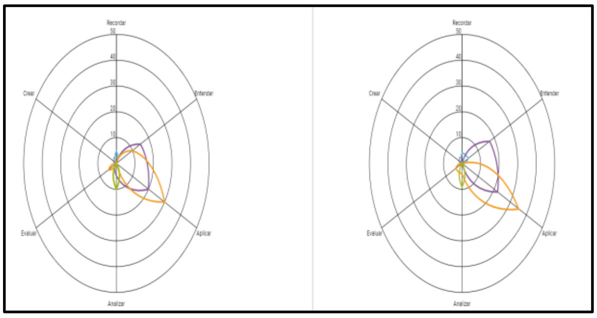


Figure 2. Radial distribution of the frequency (in percentage) of assessment criteria according to

RBT in the primary and secondary curricula of the 1991 LOGSE (revised in 2001). Note: The radial plots shown in the figure correspond to the primary and secondary curricula respectively. Colour coding is established for the categories of knowledge: factual (blue), conceptual (purple), procedural (orange), metacognitive (green).

3.2 Curricular analysis of the LOMCE (2013)

Figure 3 shows how there is a great variety in the distribution of assessment criteria in science curricula, both in the hierarchy of cognitive levels and of knowledge, especially at secondary level. In primary education, most of the criteria are distributed between two types of knowledge, conceptual knowledge (in the category of comprehension) and procedural knowledge, equally distributed between the categories of analysis (analysing) and evaluation (assessing). Both factual and conceptual knowledge account for 50% of the criteria analysed. This distribution favours the laying of the foundations to be able to reach the cognitive processes of higher demand. It can also be seen how the procedural criteria are distributed among the categories "understand", "apply" and "analyse", i.e., they allow us to put into action the knowledge acquired beforehand in practical situations. Following the primary-secondary axis, the great variety that existed in terms of categories of knowledge and cognitive demand in the curriculum is reduced in the transition from primary to secondary school, with the disappearance of factual and metacognitive knowledge. This decrease in factual knowledge may negatively affect the acquisition of higher-level skills, abilities and knowledge.

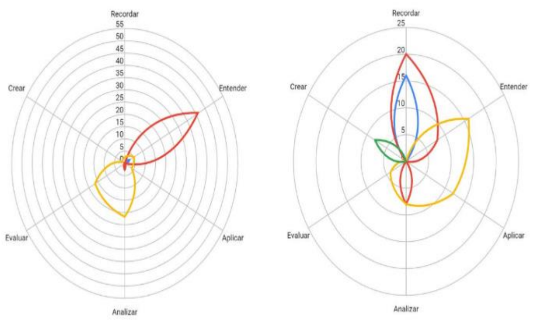


Figure 3. variety in the distribution of assessment criteria in science curricula

Note: The radial graphs shown in the figure correspond to the primary and secondary curricula respectively. Colour coding is established for the knowledge categories: factual (blue), conceptual (red), procedural (yellow), metacognitive (green).

Figure 4 shows that there is a greater variety and diversity in Math curricula (including 10% of the criteria classified as metacognitive) than at secondary level, but at primary level those basic conceptual skills are very restricted, as can be seen in the figure, practically in the centre of the diagram without standing out.

If we compare both diagrams, we can see that at the secondary stage the need to understand conceptual knowledge increases drastically, both in the categories "understand", "apply" and "analyse", and that although this increase is necessary, they have not previously worked following a similar scheme in primary school, which may mean that when they reach secondary school they do not have the skills developed for the degree of abstraction required by mathematics at these stages. This decrease in factual knowledge may negatively affect the acquisition of skills, aptitudes, and knowledge at higher levels, since a concept cannot be understood if the factual knowledge in question is not known. As can be seen in the figure almost 10% of the students aim for conceptual understanding in the category "analyse", but this does not have any practical knowledge to reinforce it.

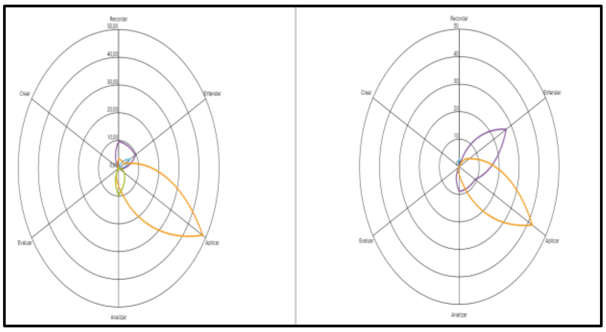


Figure 4. Radial distribution of the frequency (in percentage) of assessment criteria according to RBT in the primary and secondary curriculum of the LOMCE (2013).

Note: The radial graphs shown in the figure correspond to the primary and secondary curricula respectively. Colour coding is established for the knowledge categories: factual (blue), conceptual (purple), procedural (orange), metacognitive (green).

3.3 Comparative Analysis Between Curricular Laws

In both the LOGSE and the LOMCE there is a decrease in the number of criteria for the cognitive processes "Remembering" and "Understanding", with an increase in those of a procedural nature in the LOMCE with respect to the LOGSE.

Regarding the categories of knowledge, Figure 1 (Science) shows that, in LOGSE, in both primary and secondary education, there is a mastery of theoretical content (conceptual and factual), which accounts for at least 75% of the assessment criteria, whereas this is reduced to 50% in the latest curricular regulations, leaving this space mainly for procedural aspects.

Looking at the categories of knowledge, Figure 2 (Math) shows that, in LOGSE, in both primary and secondary education, there is a mastery of theoretical conceptual content (both in the categories of comprehension and application), which accounts for at least 75% of the assessment criteria, whereas this is reduced to 50% in the latest curricular regulations, leaving this space mainly for procedural aspects.

4. Discussion and Conclusions

In the curricular documents analysed, conceptual and procedural knowledge objectives predominate, these being necessary to achieve higher cognitive processes. The categorisation that RBT allows can help in the design of learning strategies guided by the cognitive processes (from basic to advanced). The first ones (remembering and understanding) need to be established (Brown, Roediger and Mc-Daniel, 2014) in order to be able to develop higher cognitive skills (Thamraksa, 2005) in order to achieve a correct scientific literacy and competence. Willingham (2009), based on studies by Ausubel (1978), confirms the need for factual and conceptual learning, although these must be proposed from the beginning as a necessary basis for acquiring subsequent learning, therefore, integrating it as conceptual knowledge (interrelating concepts and knowledge, giving them meaning) and not only in a factual way (simple facts or information).

The trend in the Biology and Geology curriculum is to incorporate procedural and analytical processes, as well as application, but this should not be done at the expense of conceptual ones as it implies a decrease in basic knowledge on which to build new learning. It is therefore necessary to increase the proportion of students' higher knowledge and to make it the focal point of teachers working at all levels, always bearing in mind the need for the knowledge and objectives of the early stages of taxonomy to be entrenched.

Assessments (in their different forms) promote learning in turn of the knowledge they are intended to assess (Agarwal, 2019) and in turn students regulate their learning and knowledge acquisition skills depending on the type of assessment they participate in (Agarwal, D'Antonio, Roediger, McDermott, & McDaniel, 2014; Jensen et al., 2014). Numerous studies have been conducted on practice through testing and assessment and how these affects and support higher process learning (Agarwal et al., 2012; McDaniel et al., 2013; McDermott et al., 2014; Roediger et al., 2011).

In countries such as Australia, Singapore and other Asian countries, the focus is on factual and conceptual theoretical knowledge (Ang et al., 2019; Lee et al., 2015), while the trend in Spain is to reduce this type of knowledge. We know that learning outcomes and curriculum standards are planned with influences from their cultural, political, and historical background (Lee et al., 2017). This paper intends to understand and appreciate the differences using the revised Bloom's taxonomy and not to discuss or judge whether countries have a 'better' or 'worse' curriculum according to their learning outcomes. In practice, curricula, tasks, assessments, and lessons often need to be made to improve, enhance, and provide effective lifelong learning for students and determine the efficiency of the process as a result of teaching (Amer, 2006). It is necessary to promote the elaboration and design of a curriculum having those objectives of low cognitive demand and to plan educational actions from the most basic aspects to be able to reach higher levels on the scale.

Limitations And Perspectives

Currently, the draft curricular texts of the latest education law in force (LOMLOE, acronym for Organic

Law for the Modification of the Organic Law on Education) are being submitted to exposure and revision by the Autonomous Communities to introduce the changes/suggestions they consider pertinent.) Once the final legislative text has been approved, it will allow for further analysis to show trends and whether there are variations in terms of assessment criteria and learning objectives. This type of analysis of curricular texts provides the basis for evaluating whether other documents such as textbooks follow the guidelines and are in line with the curricular texts, as well as the possibility of evaluating the practices carried out in the classroom (activities, programmes, etc.) following this methodology.

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