Comparative analysis of real gases topic in Physics and Chemistry university books: a proposal based on revised Bloom's taxonomy

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Abstract

In this work, a tool for comparative analysis of the contents of 16 (sixteen) university textbooks is proposed based on Bloom's revised taxonomy. The Blooming Scientific Topic Analysis Tool (or BSTAT) assigns to each of the six categories of the dimension of the cognitive process originally proposed by Bloom, an equal score (so that its sum is 100) in order to quantify how close to the proposed learning objectives are the authors of the works analyzed. For that, investigations about approach used by Physics and Chemistry books in discussions concerning 'Real gases' has demonstrated variations in the treatment provided by both fields of knowledge when discussing the same topic: High Order Thinking Skills (HOTS) are better explored than Lower Order Thinking Skills (LOTS) in the Chemistry books, while these two thinking skills (LOTS and HOTS) are almost equally explored in Physics books in relation to same subject. It is worth mentioning that the research does not intend to generalize the results, however, the results are promising for such comparative analyzes, being able to benefit Chemistry and Physics teachers, textbook writers and other researchers to develop the implementation of adequate thinking skills (mainly higher-order) in the teaching and learning of these Sciences.

Keywords: Blooming Scientific Topic Analysis Tool, Real gases, Revised Bloom's Taxonomy.

Resumen

En este trabajo, se propone una herramienta para el análisis comparativo de los contenidos de 16 (dieciséis) libros de texto universitarios basados en la taxonomía revisada de Bloom. La herramienta Blooming Scientific Topic Analysis Tool (o BSTAT) asigna a cada una de las seis categorías de la dimensión del proceso cognitivo originalmente propuesto por Bloom, un puntaje igual (para que su suma sea 100) para cuantificar qué tan cerca del aprendizaje propuesto Los objetivos son los autores de los trabajos analizados. Para eso, las investigaciones sobre el enfoque utilizado por los libros de Física y Química en las discusiones sobre 'Gases reales' han demostrado variaciones en el tratamiento proporcionado por ambos campos de conocimiento cuando se discute el mismo tema: las habilidades de pensamiento de alto orden (HOTS) se exploran mejor que el orden inferior Habilidades de pensamiento (LOTS) en los libros de Química, mientras que estas dos habilidades de pensamiento (LOTS y HOTS) se exploran casi por igual en los libros de Física en relación con el mismo tema. Vale la pena mencionar que la investigación no tiene la intención de generalizar los resultados, sin embargo, los resultados son prometedores para tales análisis comparativos, pudiendo beneficiar a los maestros de Química y Física, escritores de libros de texto y otros investigadores para desarrollar la implementación de habilidades de pensamiento adecuadas (principalmente orden superior) en la enseñanza y el aprendizaje de estas ciencias.

Palabras clave: Blooming Scientific Topic Analysis Tool, Gases reales, Taxonomía revisada de Bloom.

I. INTRODUCTION

The physical and chemical descriptions of matter are intimately related. For a wide range of phenomena, the division of forces into "physical" and "chemical" is arbitrary. It is convenient to distinguish between strong attractive (chemical) forces leading to the formation of chemical species, and weak attractive (physical) forces, called van der Waals forces [1]. For physicists and chemists, the development of thermodynamics in the 19th century and early 20th century recognized the nature of heat and temperature, discovered the conservation of energy, and there was a perception of stochastic and probabilistic aspect of natural processes. It turned out that the doctrine of energy and entropy rules the world [2, 3, 4].

Within the scope of Thermodynamics, it is well known that the study of gases properties gives power to its intrinsic phenomenology [5], being essential in all basic courses in Physics and Chemistry, both in high school and higher education. However, reports of conceptual difficulties faced by students of thermodynamics has been registered for a long time [6, 7, 8, 9, 10]. They range from tangible difficulties to the concepts of heat and work [11, 12, 13], through the laws of thermodynamics [14, 15, 16], especially the second - from which the cogitative (not to say confused) concept of entropy emerges [17, 18, 19]. The behavior of real gases follows this trend: with the focus of textbooks almost exclusively on the properties related to ideal gases, little is discussed about the possible extensions of the ideal gas model: even Van der Waals equation, which was the first attempt to include terms of interaction and size of molecules in the description of gases, in some cases, needs further deepening. One possible factor that tends to corroborate with this scenery is the distinct approach used by physicists and chemists to describe the same phenomena in their respective textbooks, which can cause obstacles in the teaching and learning process.

In view of the wide use of textbooks - considered a common characteristic of classrooms worldwide, in addition to playing the role of valiant vehicles for the promotion of curricula [20], this study dialogues with Discipline-Based Education (DBER), based on the analysis of how students acquire knowledge from textbooks, with the purpose of (being able to) be a useful instrument for the optimization of teaching and learning of specific topics of these disciplines [21], helping professors in possible curricular transitions. For that, a comparison of the dimension of the content that should be taught by the Chemistry and Physics books widely used today in the context of university world education has been done, analyzing the dimensions of the cognitive process supposedly present in them through differences in the approach to concepts related to the properties of real gases, in an attempt to highlight the consequences of possible disparity of approaches in the face of assimilation of such concepts.

A proposal is being developed, called Blooming Scientific Topic Analysis Tool or simply BSTAT, aiming both to evaluate topics belonging to the Natural Sciences curricula and to understand the ability (in textbooks) to promote this body of knowledge, based on the Revised Bloom's Taxonomy (RBT). In other words, BSTAT is a mechanism that assists in the analysis of the scientific content of a certain topic present in a textbook aiming to identify how much of the lower order cognitive skills (LOCS) or higher order cognitive skills (HOCS) are explored by certain textbook topics in students. The literature reveals research on the use of Bloom's Taxonomy generally in analysis of questions in books [22, 23, 24, 25], confirming the innovative character of this article because, according to the knowledge of the authors, no research has yet been carried out that applies RBT as a way to evaluate the contents, that is, to verify whether textbooks, even if implicitly, provide thinking skills of different orders, which thus result in critical thinking in students. The choice of the topic is justified due to the fact of its importance for Scientific Education, especially for researches in Chemistry Education [26, 27] and Physics Education [28], among other studies. It is interesting to emphasize the lack of empirical studies that reveal how a certain content covered in textbooks can influence the ability to promote critical thinking. So, we believe that the model based on Bloom's Revised Taxonomy becomes promising in the assistance it will provide to Chemistry and Physics teachers, better aligning their assessments with teaching activities, in addition to help students in order to improve their study and meta cognition skills [29].

Briefly, this work addresses the following research questions: 1. What are the differences in the approach to the topic 'Real Gases' given by Physics and Chemistry textbooks? 2. What are the prevalent cognitive domains in the topic in question? 3. Which thinking skills make up the dimension of the cognitive process are most pronounced by the analyzed books? Therefore, the paper is organized as follows. In Sec. II, we provide a detailed approach of the Revised Bloom Taxonomy (RBT), the section III is dedicated to explain how Chemistry and Physics books teach the behavior of real gases; in section IV there will be discussions about methodology employed; in the section V, the results will be analyzed. Final remarks follow in Sec. VI.

II. THE REVISED BLOOM'S TAXONOMY

Bloom's Taxonomy, originally proposed by the American psychologist Benjamin Bloom, defends the importance of offering lower-level cognitive information during an instruction to later move towards higher levels of cognition [30]. After more than forty years, there have been advances in relation to the taxonomy initially proposed: it has been condensed, expanded and reinterpreted in various ways over time [31]; in the 2000s, the work carried out by Anderson and collaborators brought contributions to taxonomy by incorporating aspects related to the theme or subject that must be learned (dimension of content), as well as the process that must be used by students to learn (dimension of process). In this way, the content dimension is composed of a continuum of knowledge that must transition between the factual, conceptual, procedural and the metacognitive. Regarding the dimension of the cognitive process, it is composed of six skills defined in verbal terms that assist in the classification of a particular object that is being evaluated at one of the levels of taxonomy. According to Anderson and Krathwohl [32], the object, in turn, intends to describe the knowledge that students must acquire or build. Figure 1 below shows the verbs that make up the amalgam of the cognitive process in the light of the Revised Bloom's Taxonomy (RBT).

Therefore, Bloom's Taxonomy can be understood as a tool that measure whether the learning objectives have been achieved, resulting in a positive interference in cognitive development. It is an apparatus with an evaluative character of learning capable of determining, through levels, what educators want students to learn about a certain topic or subject, being one of the most widely used tools around the world. world, and that allow professionals to reflect on the learning of their students.

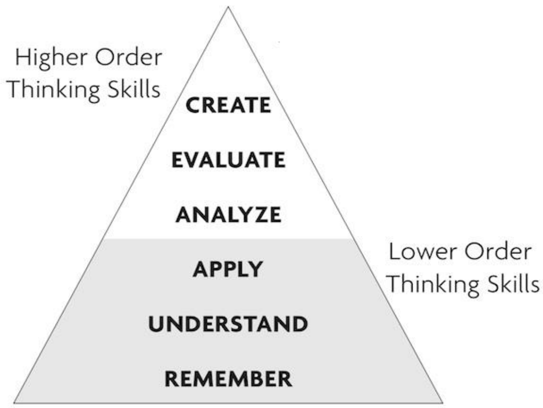

Figure 1. High order and low order thinking skills.

The combination of two dimensions has potential for the educational environment, as it adds a two-dimensional character, as advocated by Razmjoo and Kazempourfard [22]. That said, it can be understood that such two-dimensionality allows teachers to clearly define the objectives of their teaching process and establish ways to evaluate student learning in relation to the complex nuances existing between knowledge and cognitive processes, even though most of teachers depends heavily only on the six levels of the cognitive domain to structure the way they deliver content in the classroom. Figure 1 also reveals the framing of verbs that can trigger higher-order thinking skills (HOTS) and lower-order thinking skills (LOTS). Momsen *et al*. [33] consider that cognitive skills are organized hierarchically in Bloom's Taxonomy: during an instruction, the teacher must provide his students with learning situations that allow lower-order cognitive advances to reach higher-order skills.

Thus, adopting a reverse approach to the use of RBT in order to verify if cognitive domains are present in the content about 'Real Gases' described in the textbooks, specifically, in a sample composed of university books on Physics and Chemistry, we describe below, the methodological aspects that guided this study.

III. METHODOLOGY

A. General Context

This is a qualitative study of the Content Analysis type. Therefore, the materials (textbooks) were analyzed in order to identify specific characteristics [34] in a systematic review of the text materials including the structure, the focus, and special learning assists, being a tool generally used by the scientific community as a way to test (or prove) the adequacy of the contents in face of the existing curricular reforms [35, 36, 37, 38, 39, 40, 41]. To proceed with content analysis, we followed a classic coding-categorization scheme that was based on the classic grounded methodology [42]. In turn, the encoding of the content of a text consists of reproducing information using a list of items that are called content units [43]. To this end, a coding scheme was developed to classify and evaluate the 'Real Gases' content through the Revised Bloom Taxonomy. This topic is present in the university curriculum of Chemistry and Physics, being regularly discussed in the textbooks of Physics and Chemistry at higher level.

With regard to higher education, the analysis of textbooks tends to be more subtle as it encompasses an irregular boundary about what can be considered basic in university education [44, 45]. In the so-called natural sciences, several analyzes of different themes have been carried out [46, 47, 48], although, according to the knowledge of the authors, none has been made in an attempt to compare the treatment given by physics and chemistry teachers to the same topics covered in different disciplines / courses, as the case of real gases behaviour.

The analyzed Physics and Chemistry books are part of the curriculum of science and engineering students around the world, and are listed in tables I and II. We will start from the assumption that both approaches are provided at a basic level for introductory nature of the subjects, offered in the initial years of undergraduate courses and, therefore, the fact that students will have contact with these topics in a deeper way in future: the discipline of Thermodynamics, offered to Physicists and Engineers, and the discipline of Physical - Chemistry, offered to students of Chemistry, Pharmacy and similar courses.

B. Sample Selection

The sample consisted of 16 textbooks, with 8 belonging to each of the two areas. Tables I and II shows the books which were expended at the next page.

Table I. University Chemistry books which has been analyzed.

Book	Author(s)
Chemistry – 11th ed.	R. Goldsby and R. Chang [49]
General Chemistry: Media Enhanced Edition – 8th ed.	D. D. Ebbing and S. D. Gammon [50]
Chemistry & Chemical Reactivity – 10th ed.	J. Kotz, P. Treichel, J. Townsend and D. Treichel [51]
General Chemistry , 7th ed.	K. W. Whitten [52]
Principles of general chemistry – 3rd ed.	M. Silberberg [53]
Chemistry The central science – 11th ed.	T. Brown, H. LeMay and B. Bursten [54]
Chemical Principles – 8th ed.	S. Zumdahl and D. Decoste [55]
Chemical Principles: The Quest for Insight - 6th ed.	P. Atkins, and L. Jones [56]

Table II. University Physics books which has been analyzed.

Book	Author(s)
Fundamentals of Physics – 8th ed.	D. Halliday, R. Resnick and J. Walker [57]
Physics for Scientists and Engineers with Modern Physics	R. A. Serway and J. W. Jewett, Jr. [58]
Sears and Zemansky's University Physics with Modern Physics	H. Young and R. Freedman [59]
Physics for Scientists and Engineers 6th edition	P. Tipler and G. Mosca [60]
Physics for Scientists & Engineers with Modern Physics	D. Giancoli [61]
University Physics Volume 2	S. Ling, J. Sanny and W. Moebs [62]
Curso de Física Básica Volume 2	H. M. Nussenzveig [63]
Physics for Scientists & Engineers - a strategic approach	R. D. Knight [64]

C. Instrument and procedures

In order to achieve the proposed objectives and answer the research questions that guide this study, an analysis tool for topics belonging to Natural Sciences was developed - the Blooming Scientific Topic Analysis Tool (BSTAT). A priori, it was only tested for the topic 'Real Gases' and aims to draw conclusions about the process used by the book to teach students (dimension of the process). Unlike many studies that use Revised Bloom's Taxonomy (RBT) to assess the level of cognitive domain, the proposed tool aims to analyze these levels based on the approach used by the book to provide learning to students. For each one of six categories in the cognitive domain (remember, understand, apply, analyze, evaluate and create) the same score was given so that the sum of the scores of the six categories together would result in 100 points: a scale (from 0 to 100) of learning objectives on the theme of real gases was created according to table V in Appendix A, where the criteria for measuring the score of each textbook are specified using a comparative analysis process to analyze the data [65]. The zero index is indicative of complete absence of categories in that respective cognitive domain, while 100 means completeness in relation to the objectives of knowledge.

It is true that we do not expect the authors to have relied on RBT to write the books, however, this does not invalidate the idea that they can be evaluated as to their level of stimulus to higher-order thinking skills (HOTS) and lower-order thinking skills (LOTS) in students.

The proposed tool is relatively simple and consists of three constituent phases that need to be executed in sequence, as shown in Figure 2. It was developed with a focus on surveying the dimension of the process and, therefore, is limited to the analysis of the six cognitive levels which have already been mentioned. When looking at the Figure, phase 1 is found, which consists of selecting the topic that must belong to a specific Natural Science. After selecting the topic or subject, you should scan the topic to find elements that provide evidence of the use of a given cognitive level. This step is meticulous, so it must be carried out very carefully. Finally, the researcher in possession of the data collected, can draw an overview of the type of skills provided by the exposure of the topic in the book, as well as infer, qualitatively, if he is able to favor critical thinking. In step 2, remembering that the lower three levels form the LOTS triplet and the upper three levels comprise the HOTS triplet, the results can be measured in terms of frequency of incidences or pre-established criteria according to what the authors consider a complete approach to the theme, as was the case in this work, and is shown in the table V in Appendix A in the appendix. From this quantitative approach, some important conclusions can be (will be in the next section) listed in view of the need for uniformity in the approach to content by physics and chemistry teachers in higher education.

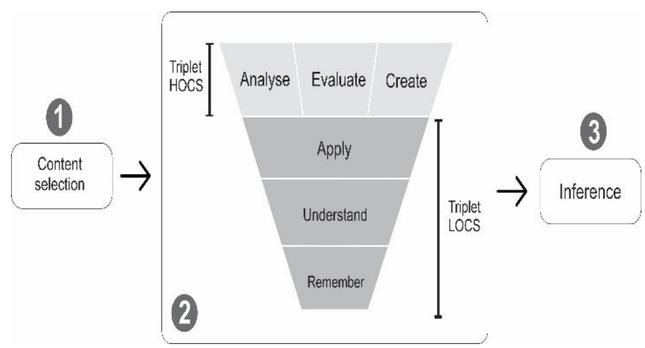

Figure 2. Detailing of Blooming Scientific Topic Analysis Tool.

IV. REAL GASES

A. University Physics Books

General Physics books tend to address the properties of gases first when approaching fluids (macroscopic perspective), and later (and in more depth) linked to thermodynamics, where, from the concept of absolute temperature scale and the properties of ideal gases are exploited to exhaustion. The books also present, at their final part, the analysis of the kinetic theory of gases. In this context, generally the behavior of real gas is addressed in an introductory manner through its first prototype: the Van der Waals equation of state and its phase diagram.

With the exception of first two analyzed books in tables I and II, which did not present any mention of real gases or Van der Waals (VW) equation in their content, the approach of real gas topic by General Physics' books is quite similar: the VW equation is stated as a correction of the ideal gas equation, followed by a brief explanation of their coefficients a and b, with a later phenomenology of the behavior predicted by the equation with support of its PV phase diagram (Fig. 3):

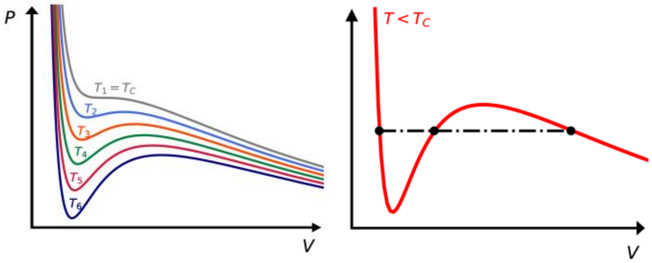

Figure 3. Left: Van der Waals isotherms on the PV diagram where is shown critical temperature T_C. Right: theoretical behavior predicted by the VW equation for isotherm where $T<T_C$ (red curve) and the indication of gas-liquid phase transition region (hatched region).

In most cases there may also be an extension of analysis to the behavior of the phase diagram of some substances (Fig. 4), where concepts such as vapor pressure, triple point, critical point and phase equilibrium are explained.

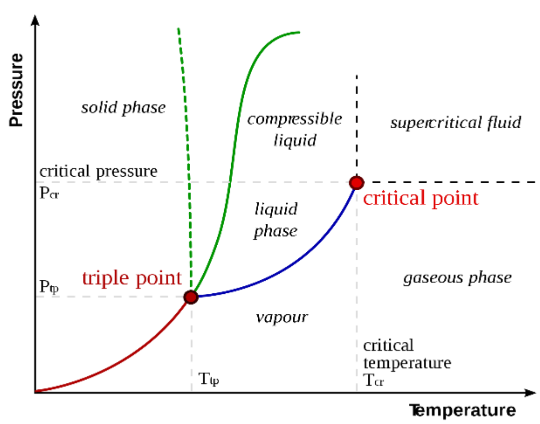

Figure 4. Phase diagram for water.

B. University Chemistry Books

The General Chemistry books analyzed (tables I and II), in turn, approach the gas content in a more synthesized way - usually in a chapter where the concepts of Pressure, ideal gas law, stoichiometric problems, gas mixtures are addressed, within a introduction to the kinetic theory of gases as well as the behavior of real gases.

Most part of them start from the graph PV/RT as a function of P, in order to visualize the deviations (different depending on the substance) from the ideal behavior for high pressures or low temperatures (Fig. 5), in addition to exploring the phenomenological parameters of Van der Waals: the finite size of molecules and their interaction (Fig. 6). Phase diagrams are covered in another chapter, usually when liquids and solids are discussed. The only book dealing with the virial equation, and therefore, does not induce the student to think that the VW equation describes (with total precision) the behavior of real gases is Chemical Principles from Atkins & Jones [56].

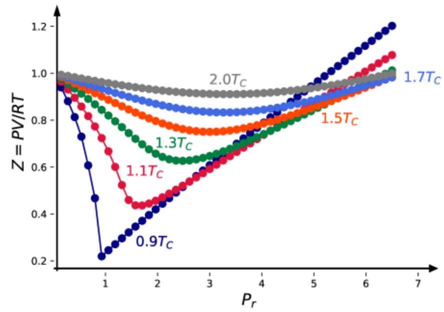

Figure 5. The behavior of real gases in terms of reduced pressure.

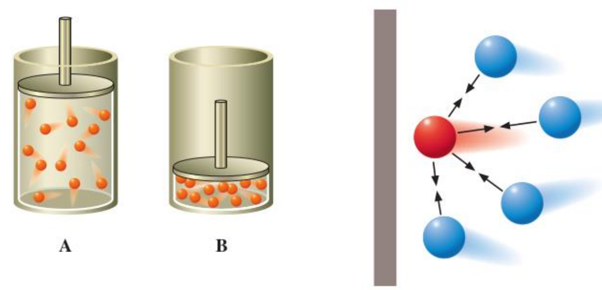

Figure 6. Effect of (left) molecular volume at high pressure and (right) intermolecular attractions on gas pressure [50].

V.RESULTS AND DISCUSSION

A. University Chemistry books

The table I contain the results of scores for the Chemistry books, whose anlysis is favoured when the categories of the cognitive process are grouped into lower order and higher order thinking skills (Fig. 7), which are summarized in fig (Fig. 8).

TABLE III. Chemistry books score from cognitive domain in Bloom taxonomy. R=Remember; U = Understand; Ap=Apply; An=analyze; E = Evaluate; C=Create.

Book	R	U	Ap	An	E	C	Score
Atkins	16.7	8.3	16.7	11.7	16.7	16.7	86.7
Chang	16.7	4.2	16.7	11.7	16.7	16.7	82.5
Brown	16.7	4.2	16.7	11.7	16.7	16.7	82.5
Kotz	16.7	4.2	16.7	11.7	16.7	16.7	82.5
Ebbing	16.7	4.2	16.7	11.7	16.7	16.7	82.5
Whitten	16.7	4.2	16.7	5.8	16.7	16.7	76.7
Sildeberg	16.7	4.2	16.7	11.7	16.7	16.7	82.5
Zumdhal	16.7	4.2	16.7	11.7	16.7	16.7	82.5

1. The Atkins' book is the one that comes closest to the objectives of knowledge from the understanding category, for treating the Van der Waals equation as

another particular variation of the virial equation (this one, quite general), although it does not address the liquid gas transition;

In figure 7, we can see that the Chemistry books have similar performance in the Remember and Apply categories, while presenting discrepancies regarding the Understand category. The reason for the discrepancy in relation to the aforementioned category comes from the criteria listed for scoring (table V in appendix A}), therefore being related to the level of generality of the content covered (in this case, real gases). It is noted that:

2. The other Chemistry books fail in this respect, since the vast majority of them got 1/4 of the total score.

We observe similar behavior for higher order skills: while the Evaluate and Create categories demonstrate a uniform approach in the analyzed books, the Analyze category becomes distinguished, since this category is directly related to the amount of illustrative material (tables, graphs, diagrams) used by books in their approach to the topic. Whitten's book has a slightly lower standard in the Analyze category (less tables and graphs explaining the behavior of real gases) in relation to the others.

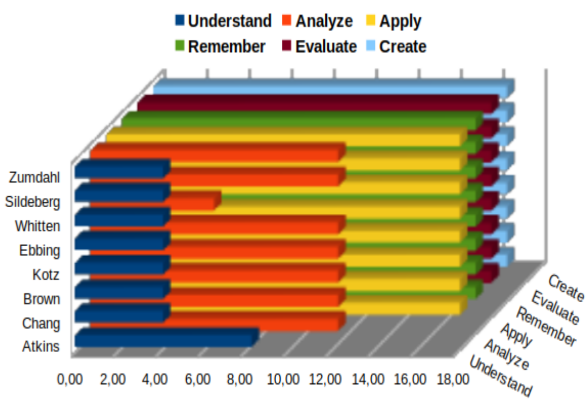

Figure 7. Bar graph indicating performances of distinct cognitive domains in Chemistry books.

The result that brings together the two previous figures in terms of LOTS and HOTS is shown in figure 8:

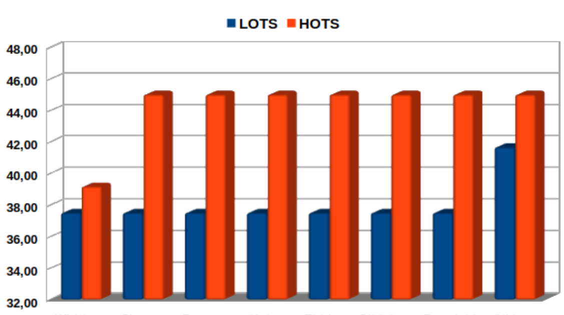

Figure 8. Bar graph indicating performances of Low Order and High Order Thinking Skills in Chemistry books according to BSTAT.

The analysis of this graph allows us to conclude that the Higher Order Thinking Skills (orange bars) are better explored than Lower Order Thinking Skills (blue bars) in the Chemistry books in relation to the theme Real Gases. One way of interpreting the uniform behavior of four of the six categories analyzed is the fact that the theme 'Real Gases' is a specific subject, therefore, approached in a subtle way in introductory courses.

B. University Physics books

The table II contain the results of scores for the Physics books.

TABLE IV. Physics books score from cognitive domain in Bloom taxonomy. R=Remember; U = Understand; Ap=Apply; An=analyze; E = Evaluate; C=Create.

Book	R	U	Ap	An	E	C	Score
Giancoli	16.7	12.5	16.7	11.7	16.7	16.7	90.8
Young	16.7	10.0	16.7	11.7	16.7	16.7	88.3
Tipler	16.7	12.5	16.7	11.7	16.7	16.7	90.8
Sanny	16.7	10.0	16.7	11.7	16.7	16.7	86.7
Moises	16.7	12.5	16.7	11.7	10.0	16.7	84.2
Halliday	Does not display content						
Raymond	Does not display content						
Randall	Does not display content						

It's possible to see that:

1. There are three set of authors books which do not present the contents of real gases in their books, which causes some concern because these are widely adopted around the world;
2. In Physics books the variability is little larger than chemistry case.

Analogously to what we did for the Chemistry books, we group the categories of the cognitive process into lower order and higher order skills; physics textbooks showed variability only in a lower order skill - Understand (although with slightly higher performance than Chemistry textbooks). All other categories performed equally in all five books analyzed, as we can see in Fig. 9:

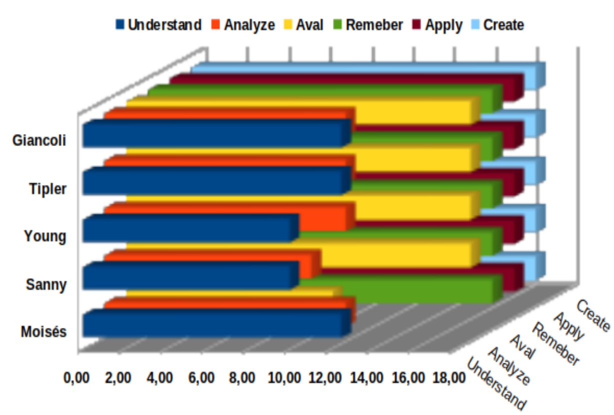

Figure 9. Bar graph indicating performances of distinct cognitive domains in Physics books.

The result that brings together the two previous figures in terms of LOTS and HOTS is shown in figure 10:

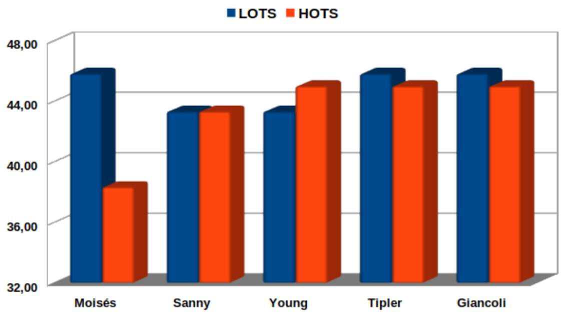

Figure 10. Bar graph indicating performances of Low Order and High Order Thinking Skills in Physics books according to BSTAT.

The analysis of this graph allows us to conclude that, with the exception of the Nussenzveig's book [64], the Higher Order Thinking Skills (orange bars) and Lower Order (blue bars) are almost equally explored in Physics books in relation to the theme Real Gases.

VI. GENERAL RESULTS

In terms of bar graphs, which display, for each book, the sum of the scores obtained by the six categories, results are shown in figures 11 and 12, where it's possible to see that the university Physics books have a slightly better performance than chemistry books in real gas topic, and that there is a larger uniformity in approach of real gas topic in Chemistry books: it's possible to see more variation in treatment of real gas in Physics books according to our BSTAT instrument.

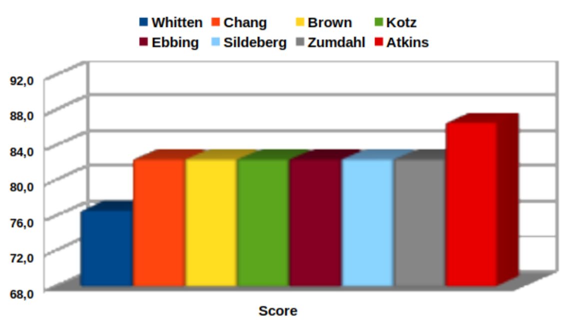

Figure 11. Score from Chemistry books by BSTAT.

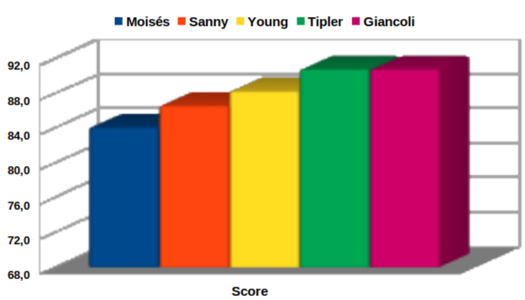

Figure 12. Score from Physics books by BSTAT.

In terms of Thinking Skills of Low and High order, Physics books also have a better accomplishment, as can see in fig 13:

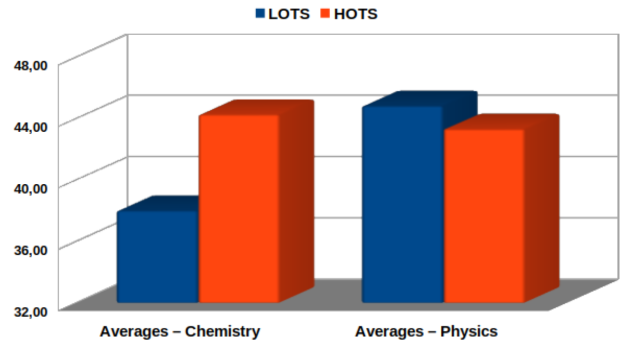

Figure 13. Comparison between Chemistry and Physics books separating skills in low and high order.

Physics textbooks has showed slightly lower levels of higher-order thinking skills. As the studies by Guimba *et al*. [66], the fact of having lower levels of higher-order thinking skills (HOTS) than higher learning objectives should not affect the judgment of textbooks, since authors have their own views on content and teaching methods, assuming a high level of scientific thinking [67].

However, the finding can serve as a guide to improve such aspects in future editions of them, in addition to enhancing the importance of teachers proposing complementary materials for their students, considering that the book cannot be configured as the only source of information. The six levels are present in the books in different proportions, that is, they present the two triplets's LOTS and HOTS. This corroborates the idea defended by Al-Hasanat [68] that it is not necessary to make the percentages equal, but it should also not focus on a single level and, consequently, neglect the other levels.

VII. CONCLUSIONS

An alternative method of content analysis in textbooks - the Blooming Scientific Topic Analysis Tool (BSTAT) - was proposed, which proved to be quite useful to compare the way of the "Real gases" theme is treated in university books on Physics and Chemistry. The fact that the real gases are treated in an introductory way in the analyzed textbooks facilitated the thorough examination of the six categories of the cognitive domain analyzed, however, the study is promising for investigations of more extensive contents in a comparative perspective between the way in which Physics and Chemistry address basic themes in the light of the learning objectives listed in Bloom's Revised Taxonomy.

There was a tendency for Physics books to explore the theme around the Pressure-Volume phase diagram containing Van der Waals isotherms, while Chemistry books, in turn, sought a more phenomenological analysis, showing the deviations in the behavior of the ideal gas for high pressures or low temperatures by law of corresponding states, in addition to the treatment of Van der Waals phenomenological parameters by both areas.

From assigning an equal score to each of the six categories in the domain of the cognitive process (so that the sum of the six categories had a maximum score of 100 points), we could see that the Higher Order Thinking Skills (HOTS) and Lower Order (LOTS) are almost equally explored in Physics books in relation to the Real Gases theme, while the HOTS are better explored than LOTS in the Chemistry books in approach of real gases.

It's possible that the succinct nature of the content brings approaches very close. Perhaps a more extensive analysis of topics such as ideal gases or First law of thermodynamics would serve as a basis for more robust interpretation, proving the promising utility of BSTAT for such comparative analyzes, being able to benefit Chemistry and Physics teachers, textbook writers and other researchers to develop the implementation of adequate thinking skills (mainly higher-order) in the teaching and learning of these Sciences.

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APPENDIX A

Table V. Criteria used in the BSTAT for textbook analysis.

Category	**Interpretation in therms of textbook analysis**	**Evaluation criteria in textbooks**	**Score**
Remember	Definition of concepts	Clear definitions of concepts	16.7
Understand	Explanation, classificaton, sinthetization	1) VW (particular) and Virial(general) equations; 2) Phenomenology of the VW parameters a and b; 3)PV phase diagrams from the VW equation; 4)Emphasis on experimental behavior: region of the liquid-gas phase transition;	16.7
Apply	Using, suggesting, differenciating, and comparing	Comparison between ideal gas behaviour and VW parameters	16.7
Analyze	Demonstrate formula deductions, interpretate graphs, tables	1)Graphical demonstration of deviation from ideal gas behavior; 2)VW a and b table for some gases; 3)PV diagram - VW isotherms; 4)Table with critical or triple properties; 5) Phase diagrams: critical points and triple point;	16.7
Evaluate	Suggest quantitative and conceptual questions	Answered, conceptual and quantitative questions	16.7
Create	Propose new ideas about the subject, products or methods, portfolios, mind maps	Conceptual maps, schemes, summaries	16.7