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An analysis of representation level and cognitive level in curriculum-2013 chemistry textbook

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Abstract. This paper aims to describe 10th-grade chemical textbook, representation level from the materials and tasks in chemical bonding chapter, cognitive level based on Bloom's taxonomy in chemical bonding chapter, and use of representation level in questions and textbook. Some problems arise related to the achievement of the curriculum from the implementation of the use of textbooks. Textbooks can be used as students' reference in finding knowledge. Data collection was conducted by analyzing three 2013 Curriculum chemistry textbooks related to the suitability of textbooks, the representation level, and cognitive tasks of chemical bonding materials. Suitability of textbooks identified by three of Indonesia's Regulation of the Ministry of Education and Culture. The representation level was identified by chemical bonding chapter from the textbook. The problems were identified based on the cognitive level and the representation level. The results show that three chemistry textbooks consisted of the display, content, activity load, curriculum basic framework, level of education, and material scope. The materials and tasks include macroscopic, sub-microscopic, symbolic, and mathematics. The cognitive level based on Bloom's taxonomy is at the level of remembering, understanding, applying, and analyzing. The representation level used is assisted by technology for images, videos, and slides.
Keywords: *cognitive, representation, textbook.*

1. Introduction

Textbooks should be equipped with pictures, video, text, examples of problems, and exercises [1]. In addition, textbooks should follow the current curriculum [2]. Course materials arranged systematically and can improve students' cognitive development [3]. However, some of the textbooks used at school have less concern to the curriculum in terms of content, context, process, and competencies that resulting in the decreasing of students' cognitive development [4]. The preparation of textbooks must consider the aspect of appearance, content, and student activity [5]. The appearance aspects related to the book cover, table of contents, preface, and the author bio. The content aspects related to the description of the material, language, presentation material, and graphics. Student activity aspects include assignments, discussion topics, and completion of tasks [5]. However, there all three aspects have not been implemented optimally because the material presented has not affected student understanding and students are more likely to get the knowledge from teachers. In addition, the textbooks have not met the needs of students, for example the material is incomplete [4]. The textbooks must fulfill the aspects of education in Indonesia. The senior high school curriculum should include basic framework curriculum, education, and the scope of the material. The basic curriculum framework deals with the suitability of core competencies, basic competencies, and school level. The 2013 curriculum can improve student understanding related to chemistry learning [6]. The scope of the

material is related to the suitability of student learning loads in each semester that must be taken to achieve learning objectives [7], [8]. However, textbooks are less integrating every material with the available questions, so it requires textbook designs that are able to describe every material used in the learning process [4].

Students' cognitive abilities can be improved by integrating the representation level in the text contained in the textbooks [2]. Besides, the representation level in the textbooks can facilitate students in solving problems of abstract knowledge [9]. The use of representations in learning sources can minimize misunderstandings in achieving learning objectives [10]. However, the effort in improving the students' cognitive ability through high cognitive learning are integrated through representation assistance [11]. The question of the tests should facilitate the students in knowing the ability of problem-solving, a chance to think and act systematically through the learning process. However, the students' cognitive ability assessed by using question is not showing a maximum result yet, students have difficulty in the question that contains macroscopic, sub-microscopic, and symbolic representation [12]. The dominating and important topic of chemistry material in the usage of the representation is chemical bonding. In chemical bonding, students have to understand chemical bonding material, including how atoms or other particles fused [13]. However, some students still have difficulties in understanding chemical bonding material and the students believe that atoms and electrons are not moving in creating the bonds [14].

2. Research method

This research is qualitative descriptive research, aimed to describe how (1) 10^{th}-grade chemistry textbook, (2) suitability of representation level from the materials and questions in chemical bonding chapter, (3) cognitive level based on Bloom's taxonomy in chemical bonding chapter, and (4) use of representation level in questions and textbook. Participants of this research are 10^{th}–grade-science students in Yogyakarta which deliberately chosen to obtain representation information on materials and questions and chemistry teacher in Yogyakarta. Data collection in this research was identification used chemistry textbooks, recordings, and interviews. The instrument of interviews data collection was in the form of five interview questions to describe participants' answers and there are three chemistry textbooks from three different schools identified used three Ministry of Education and Culture regulation. The chemistry textbooks identified include identification in curriculum-2013 based on three Ministry of Education and Culture regulations such as 8 of 2016, 69 of 2013, and 21 of 2016 include of display, content, activity load, curriculum basic framework, level of education, and material scope. Identification in the curriculum related to the book criteria that can be used by the education unit, the basic framework of high school curriculum, and the content standards of primary and secondary education. Furthermore, the representation level in textbooks identified is related to macroscopic, sub-microscopic, symbolic, and mathematic. The cognitive level identified based on Bloom's taxonomy is related to remember, understand, apply, analyze, evaluate, and create. The interviews were done with twelve participants from 10^{th}-grade-science and one high school chemistry teacher in Yogyakarta. Interviews results were recorded and coded. Students answer in the first part of the interview related to the preparation of daily tests, the second part is related to the type of questions used, the third and fourth parts related to the availability of pictures and symbols in the daily test questions. The Interviews with chemistry teacher related to the cognitive level of students and the representation level. Interviews results were analyzed by reading repeatedly to deepen the results of students and teachers regarding the use of the representation level and cognitive level.

3. Results and Discussion

This section presents the result and discussion regarding research analysis of chemistry textbooks.

3.1. Curriculum

This section identified the current curriculum (Curriculum-2013) in Indonesia based on three Ministry of Education and Culture Regulations, which are book criteria that can be used by education units, the

basic framework of the high school curriculum, and content standards for primary and secondary education.

3.1.1. Book criterion

Three 10^{th}–grade chemistry textbooks on chemical bonding chapter have been identified in various aspects including the cover of the book, introduction, content, closing chapter, and content of student activities. The chemistry textbooks that have been identified show some results, that is, on the cover displaying the book title, book designation, ISBN number, and publisher (TB1, TB2). There is a publisher logo, the font on the cover is not the same as the contents of the book. Chemistry textbook does not include the price of the book, and on the back of the book for the title and designation of the book is not written according to American style (TB1). The other textbooks are showing the book prices, table of contents, no publisher logo, writing the title of the book and the designation of the book on the back of the book does not follow American style (TB2, TB3). In the beginning, the part has included the title page, copyright information, preface, the numbering at the beginning has used roman numerals, to the end of the book is using Arabic numerals and continued into one (TB1, TB2, TB3).

The material aspects are incomplete because they only mention the material. The tasks question already included many questions that should be done by students in the chemical bonding chapter. The linguistic aspect is suitable with the level of education that is designed for 10^{th}-grade students with an easy-to-understand and not ambiguous language (TB1, TB2, TB3). Furthermore, the aspects of material presentation have met the positive norms prevailing the educational environment (TB1, TB2, TB3). However, the presentation is less interesting because the material is not equipped with interesting pictures (TB1). The material presentations and questions really help students in understanding chemistry because the material is presented and the questions trigger the students' curiosity (TB2). For example, like the question What is the process of forming KF and HF compounds? What's the difference?

Next, the display layout such as paper size is suitable for 10^{th}-grade students, the front and back cover colour is showing the letter, chapter title is written briefly and attractively (TB1, TB2, TB3). However, this aspect lacks an illustration in the book section because it only includes compound formulas, such as CO, BF_3, PCl_5, NO, and N_2O (TB1). There are markers in the sub-section, sub-chapter, sub-sub-section that is written with A; 1: a; 1) which is suitable with the systematic writing. There are tables, charts, figures, symbols, and the writing of electrons with dots (TB2). The end of the book, only contains the biodata of the writer and creative team (TB1). However, there is no bibliography, glossary, index, and appendix (TB1). The student activity section contains questions in the form of multiple choices and essays. In the end, there is a glossary and bibliography ordered alphabetically (TB2, TB3). However, there is no index and attachment (TB2). There are no activities that require student to do it individually or in groups (TB1). There are group activities, such as investigating the tendency of elements to achieve stability and electron configurations, identifying the process of chemical bonds in compounds, comparing the properties of several substances based on the type of bond, and designing experiments to distinguish ionic and covalent compounds (TB2). In addition, there are individual activities where students have to do the test competency which consists of objective and subjective questions. The chemistry textbook utilizes technology in learning, as in the discussion of Lewis's structure, students are given instructions to scan the QR code than learn more about how the elements achieve stability (TB2). Learning media can motivate students to learn more about chemistry by using interesting technology and making learning more meaningful [15]. Moreover, textbooks become one of the aspects that will have a positive impact on the planning and implementation of learning because teachers usually assign students to read without further explanation [16]. Group activities include the formation of compounds with ionic bonds, covalent

bonds, comparison of properties, coordination of covalent bonds, and polarity properties (TB3). Next, individual activities include writing Lewis structures on ionic and covalent bonds, and polarity of compounds (TB3).

The three chemistry textbooks in completing individual and group assignments as a whole are carried out by discussion, presentation, making observational reports, completing observation tables, and gathering discussions results to the teacher. However, the level of the truth of scientific information in books needs to be considered, so it does not become a problem for the teachers and students in learning [17]. Chemistry textbooks identification based on Regulation of the Ministry of Education and Culture is as shown in Table 1.

Table 1. Three ministry of education and culture regulation.

No.	Ministry of Education and Culture Regulation	Aspect	TB1	TB2	TB3
1	8 of 2016	a) Display	√	√	√
		b) Content	√	√	√
		c) Activity load (individual and group)	√	√	√
2	69 of 2013	a) Curriculum basic framework	√	√	√
		b) Level of education	√	√	√
3	21 of 2016	a) Material scope	√	√	√

3.1.2. Senior high school curriculum structure

The three chemistry textbooks are based on the Curriculum-2013. The contents of the first chemistry textbook begins with core competencies and basic competencies, including the cognitive domain, namely remembering, understanding, applying, and analyzing for high school education level. The second chemistry textbook does not write down core competencies and basic competencies. However, the book writes learning objectives. Sub-chapters described in the first chemistry textbook include atomic stability, ionic bonds, covalent bonds, and metal bonds. The second chemistry textbook discusses the stable electron configuration sub-chapter, the role of electrons in chemical bonds, the Lewis symbol, ionic bonds, covalent bonds, and the comparison between ionic bonds and covalent bonds. Next, the third chemistry textbook studies sub-chapters on the configuration of noble gas electrons, Lewis structures, octet, and duplet theory, exceptions to octet rules, ionic bonds, covalent bonds, and the properties of ion and covalent compounds.

3.2. Representation level

The explanation of the chemistry textbook only includes symbols, such as CO, BF_3, PCl_5, NO, and N_2O (TB1). Next, the explanation on chemistry textbooks shows a macroscopic representations related with glass figure and Lewis, sub-microscopic in the form of ions through electrons in atomic shells (Figure 1), electrons surrounding atoms, and crystal lattices on metals, and symbolic and mathematic in the form of compound symbols, stable electron configurations, chemical structure formulas, electron configurations, valence electrons, bond lengths, bond energies in molecules or compounds, dipole moments, melting points, and electronegativity values (TB2). Next, the chemistry textbook includes macroscopic, sub-microscopic, symbolic, and mathematic representations (TB3). Macroscopic related to images of buckets, ceramics, and table salt. The microscopic features are the image of the path of the electron configuration of the atomic shells, the figure of the determination of polar and nonpolar solutions, and the figure of valence electrons motions and positive ions in metal bonds. The symbolic form is the electron configuration symbol 2 8 8 18, symbols of atoms and ions such as Na and Na^+; Lewis structures in molecules and compounds (Figure 2); electron configuration $1s^2$ $2s^2$ $2p^6$ $3s^2$, line symbols for the direction of molecules and polar and nonpolar compounds,

formulas symbol for compounds or molecular structures. The mathematic aspect involves the calculation of the electron valence of atoms to describe the Lewis structure and the dipole moment.

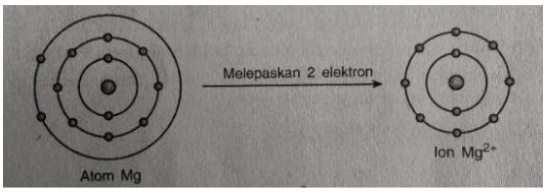

Figure 1. Electrons in atomic shells.

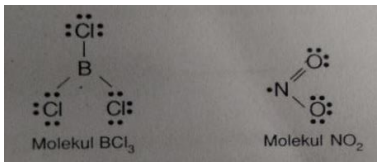

Figure 2. Lewis structure.

Representation level identified in materials is as shown in Table 2 and representation level identified on the tasks is as shown in Table 3.

Table 2. Representation level identification in the material.

No.	Sub Chapter	TB1				TB2				TB3			
		M	SM	S	MAT	M	SM	S	MAT	M	SM	S	MAT
1	Stable electron configuration	-	-	-	-	-	√	√	√	-	√	√	√
2	Octet rules	-	-	-	-	-	√	√	√	-	√	√	√
3	Ionic bond	-	-	-	-	-	√	√	√	√	√	√	√
4	Covalent bond	-	-	√	-	√	√	√	√	-	-	√	√
5	Single covalent bond	-	-	√	-	√	√	√	√	-	-	√	√
6	Double covalent bond	-	-	√	-	-	√	√	√	-	-	√	√
7	Coordinate covalent bond	-	-	-	-	-	√	√	√	-	-	√	√
8	Polar and nonpolar	-	-	√	-	-	√	√	√	-	-	√	√
9	Metallic bond	-	-	-	-	-	√	-	-	-	-	√	-

Table 3. Representation level identification on the tasks.

No.	Sub Chapter	TB1				TB2				TB3			
		M	SM	S	MAT	M	SM	S	MAT	M	SM	S	MAT
1	Stable electron configuration	-	-	√	√	-	-	√	√	-	-	√	√
2	Octet rules	-	-	√	√	-	-	√	√	-	-	√	√
3	Ionic bond	-	-	√	√	-	-	√	√	-	-	√	√
4	Covalent bond	-	-	√	√	-	-	√	√	-	-	√	√
5	Single covalent bond	-	-	√	√	-	-	√	√	-	-	√	√
6	Double covalent bond	-	√	√	√	-	√	√	√	-	-	√	√
7	Coordinate covalent bond	-	√	√	√	-	√	√	√	-	√	√	√
8	Polar and nonpolar	-	-	√	√	-	-	√	√	-	-	√	√
9	Metallic bond	-	-	√	-	-	-	√	-	-	-	√	-

Questions representation in chemistry textbooks includes sub-microscopic, symbolic, and mathematic aspects (TB1) (Figure 1). The whole sub-material integrates two representations namely symbolic and mathematic. However, there are sub-materials which have integrated three representations on the material of double covalent bonding and coordination, namely for the level of sub-microscopic, symbolic, and mathematic representation. Questions representation in chemistry textbooks includes sub-microscopic, symbolic, mathematic (Figure 2), and symbolic-mathematic (TB2). Furthermore, chemistry textbooks include sub-microscopic, symbolic, and mathematic representations (TB3).

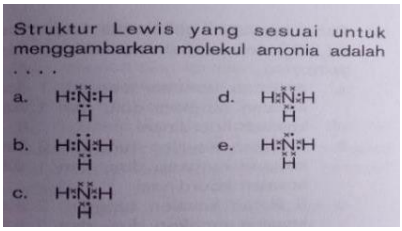

Figure 3. Symbolic representation.

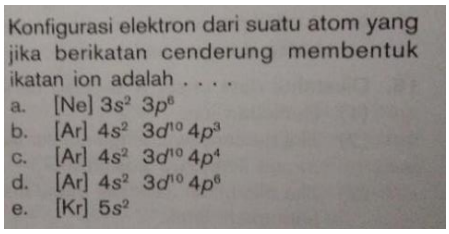

Figure 4. Mathematic representation.

The addition of figures in the materials or questions can refer to the student's representation ability in solving chemical questions. Chemistry learning must be able to direct students to understand sub-microscopic, so students can understand the concept of chemistry correctly [18]. Based on the identification of the three a0th–grade chemistry textbooks, sub-microscopic representations are not implemented yet whether in the material or existing tasks. The representation that is presented is mostly symbolic, followed by mathematic representation. The integration that occurs in the four representations is still not optimal. Students need to understand abstract chemistry through the phenomena representation that happens and the teacher's role as a science facilitator to explain to the students [19]. Besides, that representation is really needed for students to learn education and improve cognitive skills [19]. The importance of representation should be implemented in learning so that the difficulties in the discussion of chemistry content can be overcome as much as possible [20]. For example, in the discussion of octet rules that have to be focused on electron configurations because chemical bonds are formed to achieve the noble gas configuration that meets the octet rules. In addition, the writing of electron configuration with Lewis structure is in the form of dots symbol can represent the symbolic representation level [21]. Each type of bond has a different representation and there are problems in terms of understanding. Furthermore, the discussion of ionic bonds can be in the form of ion formation from compounds that contains ionic bonds and for the discussion of covalent bonds in the form of compound formation [21]. This has been seen in chemistry textbooks (TB2, TB3) which present the formation of ions in sodium chloride (Figure 5) (Figure 6).

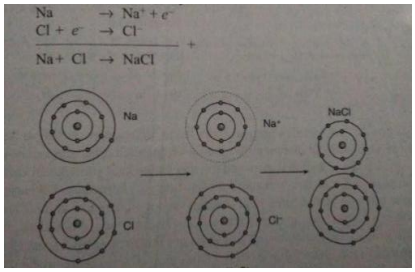

Figure 5. Ionic bond formation.

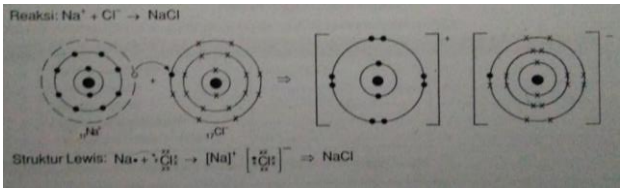

Figure 6. Ionic bond formation.

Covalent bonds in chemistry textbooks (TB2, TB3) show a representation of the use of shared electrons in two atoms to form covalent bonds (Figure 7). The representation should be presented as electrostatic force using electrons between the two nuclei. This is done so that students can avoid the formation of covalent bonds by uniting atoms to follow the octet rules [22], [23].

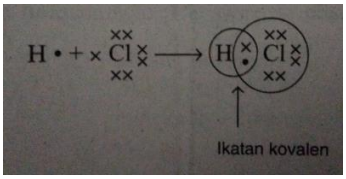

Figure 7. Covalent bond.

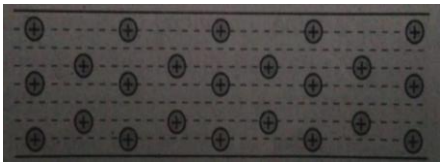

Figure 8. Metallic bond.

Metallic bond in chemistry textbooks (TB2, TB3) is explained using representations (Figure 8). The chemistry textbook explains metal bonds by mixing positive ions and negative electrons. Supposedly, the explanation of metal bonds can start from changes in the physical properties of metals such as electrical conductivity should be explained in chemistry textbooks to avoid difficulties experienced by students when they learn about metal bonds [21].

3.3. *Cognitive level*

Overall, cognitive level based on Bloom's taxonomy concerning to remember, understand, apply, and analyze has been carried out from three chemistry textbooks. Cognitive questions for evaluating and creating are still rare. Examples of questions students should be solved:

- Show the forming of covalent bonds of Br_2, F_2, SO_3, and H_2SO_4!
- Write down the electron configurations and the valence electrons of Li, Ca, S, Br, He, Ne, and Ar!
- Design simple experiments with materials such as ammonia and sodium chloride by using test tubes, spatulas, thermometers, statives, and spiritus burners!

These questions can be easily resolved by students with the help of the representations presented in the questions. However, the questions presenting in the three chemistry textbooks have not maximized the use of representation yet and only limited to symbolic representations, such as compound formulas and chemical structure formulas. Representations are important to increase students' knowledge in minimizing misconceptions about chemical content [10]. The cognitive level based on Bloom's taxonomy which is identification on the tasks is as shown in Table 4.

Table 4. Cognitive level identification on the tasks.

No.	Sub Chapter	TB1				TB2				TB3			
		C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4
1	Stable electron configuration	√	√	√	-	√	√	√	√	√	√	-	-
2	Octet rules	√	√	-	-	√	√	-	-	√	√	-	-
3	Ionic bond	√	√	√	-	√	√	√	-	√	√	√	-
4	Covalent bond	√	√	√	-	√	√	√	-	√	√	√	√
5	Single covalent bond	√	√	√	-	√	√	√	-	√	√	-	-
6	Double covalent bond	√	√	√	√	√	√	√	-	√	√	-	-
7	Coordinate covalent bond	√	√	√	√	√	√	√	√	√	√	√	√
8	Polar and nonpolar	√	√	√	-	√	√	√	√	√	√	√	
9	Metallic bond	√	√	-	-	√	√	√	-	√	√	-	-

Cognitive domain development aims to provide a series of cognitive processes in achieving learning objectives. Verbs in cognitive processes include six categories, namely remembering, understanding, applying, analyzing, evaluating, and creating [24]. Based on the identification of the three 10^{th}–grade chemistry textbooks, the number of questions in the cognitive domain is low, the first three: remembering, understanding, and applying appears more than the next high cognitive domain, namely analyzing, evaluating, and creating. In fact, almost no problems were found at the cognitive level of evaluating and creating.

3.4. Interviews

First, researchers conducted interviews with 10th-grade students who had finished doing daily tests on atomic structure material. Based on the results of the interview, all students explained the results of the daily tests they had completed.

Question: How do you prepare the daily test on the atomic structure chapter?

Aulia : I studied from notes and slides that teachers share

Zahra : Yes. Like learning from this recommended textbook from school

Jati : Sometimes from the internet, using learning videos, and slides that shared by the teachers

Naufal : I was asked to present in front of the class to draw an atom. That can be as a preparation for daily tests

Students are given questions about preparation in facing the chemistry daily test of atomic structure chapter. They revealed that in preparing for the test, learning through slides, notes, and someone opened the internet to view the learning video. The use of technology can help students in learning to solve the problems given [25].

Other questions are related to: Is the form of the question a multiple-choice or essay?

Kenaya : The test is done by using a mobile phone. The questions are multiple-choice. So the results of the test can be known immediately

Kenaya answered that the result of the daily test can be known directly because the teacher utilizing technology in learning. The use of technology has helped create products composed by humans [26].

Next, the question is about: are the questions in the form of pictures and calculations?

Hamzah : Many calculations, such as looking for valence electrons, looking for mass numbers and atomic numbers, are not thorough because there is no picture, only sentences. So, that should be answered correctly, but incorrect

Anggun : There is so difficulties when doing a test without a picture, so we had to imagine what is the questions about, then do it using a mobile phone, there is a picture of a chemist and one atomic model picture, other questions are about calculation

Diffa : Happier when doing the test with the help of picture

Hamzah said that there are calculations in the test. Then, Diffa said that she likes questions with a picture. Meanwhile, Anggun answered that the questions had no picture, there were calculations, and the atomic model was directly drawn. Hamzah said that he was not careful in reading the questions because the problems did not include many pictures, there were pictures but not many. The use of pictures and text can help to solve science problem to achieve learning objectives [9].

Next, questions related to: Are images, illustrations, good display, color on the textbook and the questions really needed?

Rafly : Yes. Add more pictures and illustrations

Yoga : Necessary. The paper used should be brighter

Arjuna : The color and suitability of the material with the questions. For example, if the explanation does not discuss topic X, then do not include make questions about topic X.

Syifa : Add more exercise, I will be more prepared in facing the final exam.

Rafly, Yoga, Arjuna, and Syifa want chemistry textbooks to be a better source of learning with some improvements in appearance, material, and exercise. Science developed through the learning process by perfecting interesting concepts, solutions, and presentations [27].

Second, the researcher conducted an interview with the chemistry teacher about Whether the questions at the low cognitive level are still dominant over the high cognitive level so far? Do you use the representations (macroscopic, sub-microscopic, symbolic, and mathematic) in learning?

Miss Dewi: So far, what can I see is the ability of students is still at the cognitive level of remembering, understanding, applying, and analyzing. At the cognitive level of creating and evaluating it is still rarely found in questions in the textbook used by students. If there

is a percentage at creating and evaluating, it would be better if arranged as minimal as possible. This is to balance out students who have low cognitive abilities. The representations used today are still limited to symbolic and mathematic usage.

These results are in line with the theory stating that cognitive abilities have a role in science and technology effectively to learn about the performance in the needs of high and low abilities in terms of the ability to ask, make decisions, and think critically [28]. The use of representation has not been maximized so that the cognitive level reached to the cognitive level is analyzed. A learning process will be successful and cognitive abilities increase when involving maximum representation [19].

4. Conclusion

The representation of chemistry involving macroscopic, sub-microscopic, symbolic, and mathematic aspects can be integrated through the use of learning resources such as books as a learning media. A textbook is considered complete when it is able to fulfill the aspects of the curriculum. The identification result of the three textbooks used in the school have not shown good results and still have weaknesses. This is supported by the data from students' interview about the textbook they use. Students complain that the textbook needs improvement in terms of the display color and the questions. Data from teacher's interview shows that low cognitive abilities based on Bloom's taxonomy concerning: remembering, understanding, applying, and analyzing are still dominant in the practice of daily tests and exams.

References

[1] Farida I, Helsy I, Fitriani I and Ramdhani M A 2018 *Proc. The 2nd Annual Appl. Sci. Engineer. Conf. (Bandung)* vol 288 (Bristol: IOP Publishing) p 1-7 http://doi.org/10.1088/1757-899X/288/1/012078

[2] Enero U J and Umesh R 2019 *Chem. Educ. Res. Pract.* **20** 146-59 http://doi.org/10.1039/c8rp00191j

[3] Nyachwaya J M and Wood N B 2014 *Chem. Educ. Res. Pract.* **15** 720-28 http://doi.org/10.1039/c4rp00113c

[4] Fitriani H, Djamas D and Fauzi A 2019 *Proc. International Conference on Research and Learning of Physics (Padang)* vol 1185 (Bristol: IOP Publishing) p 1-11 http://doi.org/10.1088/17426596/1185/1/012072

[5] Menteri Pendidikan dan Kebudayaan Republik Indonesia 2016 *Peraturan Menteri Pendidikan dan Kebudayaan No. 8 Tahun 2016 tentang Buku yang Digunakan oleh Satuan Pendidikan*

[6] Muntholib, Pratiwi Y N, Yahmin and Parlan 2019 *Proc. International Conference on Mathematics and Science Education (Malang)* vol 1227 (Bristol: IOP Publishing) p 1-12 http://doi.org/10.1088/1742-6596/1227/1/012007

[7] Menteri Pendidikan dan Kebudayaan Republik Indonesia 2013 *Peraturan Menteri Pendidikan dan Kebudayaan No. 69 Tahun 2013 tentang Kerangka Dasar dan Struktur Kurikulum Sekolah Menengah Atas/Madrasah*

[8] Menteri Pendidikan dan Kebudayaan Republik Indonesia 2016 *Peraturan Menteri Pendidikan dan Kebudayaan No. 21 Tahun 2016 tentang Standar Isi Pendidikan Dasar dan Menengah*

[9] Corradi D M J, Elen J, Schraepen B and Clarebout G 2013 *Int. J. Sci. Educ.* **36** 715-34 http://doi.org/10.1080/09500693.2013.824630

[10] Olimpo J T, Kumi B C, Wroblewski R and Dixon B L 2015 *Chem. Educ. Res. Pract.* **16** 143-53 http://doi.org/10.1039/c4rp00169a

[11] Pantiwati Y and Husamah 2017 *Int. J. Instruct.* **10** 185-202

https://doi.org/10.12973/iji.2017.10411a
[12] Dawati F M, Yamtinah S, Rahardjo S B, Ashadi A and Indriyanti N Y 2019 *International Conference on Mathematics and Science Education (Bandung)* vol 1157 (Bristol: IOP Publishing) p 1-7 http://doi.org/10.1088/1742-6596/1157/4/042017
[13] Coll R K and Treagust D F 2003 *Res. in Sci. Teach.* **40** 464-86 http://doi.org/10.1002/tea.10085
[14] Nicoll G 2001 *Inter. J. Sci. Educ* **23** 707-30 http://doi.org/10.1080/09500690010025012
[15] Cahyana U, Paristiowati M and Fauziyah S 2018 *Proc. The32rd Annual Appl. Sci. Engineer. Conf. (Bandung)* vol 434 (Bristol: IOP Publishing) p 1-8 http://doi.org/10.1088/1757-899X/434/1/012095
[16] Gericke N, Hagberg M and Jorde D 2012 *Res. Sci. Educ.* **43** 755-80 http://doi.org/10.1007/s11165-012-9288-z
[17] Boo H K 1998 *J. Res. Sci. Teach.* **35** 569-81 https://doi.org/10.1002/(SICI)10982736(199805)35:5%3C569::AID-TEA6%3E3.0.CO;2-N
[18] Tima M T and Sutrisno H 2018 *Asia-Pasific Forum on Sci. Learn. Teach.* **19** 1-18
[19] Justi R S and Gilbert J K 2002 *Int. J. Sci. Educ.* **24** 369-87 http://doi.org/10.1080/09500690110110142
[20] Drechsler M and Schmidt H J 2005 *Chem. Educ. Res. Pract.* **6** 19-35 http://doi.org/10.1039/B4RP90002B
[21] Bergqvist A, Drechsler M, Jong O D and Rundgren S N C 2013 *Chem. Educ. Res. Pract.* **14** 589-606 http://doi.org/10.1039/c3rp20159g
[22] Taber K S and Watts M 2000 *Chem. Educ. Res. Pract.* **1** 329-53 http://doi.org/10.1039/B0RP90015J
[23] Coll R K and Treagust D F 2002 *Res. Sci. Technol. Educ.* **20** 241-67 http://doi.org/10.1080/0263514022000030480
[24] Anderson L W and Krathwohl D R 2001 *A Taxonomy for Learning, Teaching, and Assessing: a Revision of Bloom's Taxonomy of Educational Objectives* (New York: Addison Wesley Longman, Inc)
[25] Li M C and Tsai C C 2013 *J. Sci. Educ. Technol.* **22** 877-98 http://doi.org/10.1007/s10956013-9436-x
[26] Oyelekan O S and Olorundare A S 2009 *Int. J. Educ. Develop. using Inform. Com. Technol.* **5** 88-104
[27] Squires D and Preece J 1999 *Interact. Comp.* **11** 467-83 http://doi.org/10.1016/S09535438(98)00063-0
[28] Zoller U and Tsaparlis G 1997 *Res. Sci. Educ.* **27** 117-30 http://doi.org/10.1007/bf02463036

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