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# Interactive Chemical Bond Electronic Module Based on Nature of Science (NoS) to Improve Scientific Literacy Knowledge

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## ABSTRACT

PISA 2018 to improve literacy skills involves three competencies: 1) explaining phenomena scientifically, 2) evaluating and designing scientific literacy, and 3) interpreting data and evidence scientific literacy. These competencies require scientific literacy knowledge, namely content, procedural, and epistemic. The research presents the results of the interactive chemical bond e-module based on nature of science to improve scientific knowledge of scientific literacy. The method uses Multimedia Development Life Cycle (MDLC) The results of the e-module validity of each component, such as: material, scientific literacy, Nature of Science (NoS), presentation and language, are categorized as very feasible. The results of the e-module practicality of each component, such as: material, scientific literacy, Nature of Science (NoS), presentation and language, are categorized as very practical. The results of the e-module effectiveness obtained from the literacy test questions used to test the scientific knowledge of students with varying N-gain values, namely 0.81 at content knowledge, 0.84 at procedural knowledge, and 0.84 at epistemic knowledge.

## INTRODUCTION

At the end of 2019 until now, the pandemic Covid 19 affects the education process in the world, including Indonesia. The government has issued many policies to anticipate the spread of the Coronaviruses in school. One of them is through Circular Number 3 of 2020 concerning the Prevention of Covid 19 in the Education unit by the Ministry of Education and Culture (2020). Based on this, both the teachers and students must do online learning. This phenomenon demands to improve and make changes to the education method. The educational method that must be applied in the pandemic era is using internet networks and integrated with technology (Sabtiawan, et al., 2020) (Suastrawan, et al., 2021).

The positive effect of online learning is that both teachers and students are closer to the use of technology, because technology and education have become increasingly fundamental and inseparable elements for standards' living in the twenty-first century (Cubukcuoglu, 2013). In addition, there are negative impacts, such as the interaction between students and teachers being disrupted because they cannot meet in person, affecting psychological and physical health as a post-traumatic stress disorder, anger, and emotional disturbances (Brooks, et al., 2020), and also during the learning, students will get bored and learn less because they only look at a single screen for a longer duration (Yuzulia, 2021). This negative effect will worsen if the teacher does not use materials or media to motivate and stimulate students' curiosity.

The results of pre-research observations conducted in SMAN 19 Surabaya showed that the chemical bond course makes students bored, affects physiological and physical health, because the material is very large, and there are no interactive media so that students cannot imagine how an atom is bonded. The research conducted by Mezia, et al (2018) that 58.31% of the factors that influence students learning on chemical bond courses to come from internal factors, namely lack of motivation and 60.00% comes from media used by teachers is less interactive.

One of the effective media that is considered effective to be used during a pandemic and can increase students' motivation is an interactive electronic module (e-module) (Sani, et al., 2020). The e-module can be defined as from of self-learning presentation material that is arranged systematically so the users can achieve certain learning goals, and by being integrated with technology so that it contains interactive things, such as: video, audio, animation, images, links, and navigation (Mulyadi, et al., 2018). With the characteristics of e-module is self-learning, implementation the e-module in learning process can train students to self-regulated learning, and the objectives of the 2013 curriculum of Indonesia, which emphasizes the scientific approach, can be achieved. The scientific approach is defined as learning activities that must emphasize creativity and innovative thinking to students in the learning process by carrying out various stages so that students' abilities in scientific learning can be improved (Sofianti & Afrilianto, 2021). In the 2013 curriculum, the stages that must be passed by students when teachers use a scientific approach are: 1) observing, 2) questioning, 3) experimenting, 4) associating, and 5) communicating (Sufairoh, 2016). The objectives of the scientific approach in the learning process, including: improving thinking skills, solving abilities, training in expressing ideas, forming character building, and improving the student learning outcomes. Nevertheless, applying scientific learning in the learning process during a pandemic is difficult due to lack of time, does not use varied media, and teachers only give assignments to students without knowing whether students understand or not (Izzuddin, 2021). This is in line with the results of observations at SMAN 19 Surabaya that generally in learning process teachers only use PPT media and put more teacher-centered learning.

The emergence of various problems in the world of educating during this pandemic must find a solution. It's because what is instilled today will continue into the future. One of the serious problems in Indonesian education that is still not resolved is the quality of student literacy. The Organization for Development Economic Co-operation (OCED), through the Program for International Student Assessment (PISA), which is engaged in literacy skills, divides literacy into several domains, including reading literacy, mathematical literacy, financial literacy, and scientific literacy (OECD, 2019). The PISA 2018, to improve scientific literacy skills, involves three competencies: 1) explaining phenomena scientifically, 2) evaluating and designing scientific literacy, and 3) interpreting data and evidence scientifically. All these competencies require scientific literacy knowledge (Fardan, et al., 2016) (OECD, 2019). The scientific literacy knowledge, such as: content knowledge, procedural knowledge, and epistemic knowledge (OECD, 2019). The three of scientific literacy knowledge is very important because it will affect students' scientific literacy skills, draw a conclusion based on evidence, cultural and economic productivity, and make decisions (Fakhriyah, et al., 2017).

Based on OECD research in science literacy skills through PISA 2018, Indonesian students are ranked 74$^{th}$ from 79 participating countries. The scores are below standard, 396 points compared to an average of 487 points in OECD countries. The results of the pre-research scientific literacy test conducted at SMAN 19 Surabaya on chemical bond course, the scientific literacy knowledge is in the very low category. The content knowledge got 23.25%, procedural knowledge got 22.94%, and epistemic knowledge got 15.68%. One of the best ways to overcome the literacy problems is to train knowledge of scientific literacy in the learning process and to realize good learning based on the 2013 curriculum, it is not only students who must be prosecuted, but the teachers must be required to develop learning activities (Lutfi & Hidayah, 2017). The implementation of nature of science (NoS) learning is the best idea.

NoS learning will be very good if combined with a scientific approach, because the pedagogical practice of NoS accommodates students in reading, discussing, studying independently or groups, conducting experiments, analyzing data, and testing the abilities that have been obtained (Wenning, 2006). In addition, NoS learning is one of the importance of scientific literacy (Widowati, et al., 2017). The learning-oriented NoS learning will refer to the characteristics of scientific knowledge derived from how the knowledge develops (Lederman, 2006). The principle of NoS learning essentially involves many aspects, including philosophical, sociological, and historical. Consequently, the NoS learning cannot be separated from its empirical, creative, imaginative, and relationship with the social sciences (Lederman, et al., 2002), and also NoS learning close to social sciences and epistemology of scientific knowledge, it will bring good changes to students, and the students not only understand the material but also know what they are learning and easy to solve social problems.

Wenning (2006) introduces a NoS learning model that teachers can use so that students receive NoS learning well. The pedagogical practice of NoS, such as: background readings, case study discussions, inquiry lessons, inquiry labs, historical studies, and multiple assessments (Wenning, 2006). Based on this pedagogical practice, the students are given the opportunity to read all reading materials related to the course to be studied to foster literacy, conduct and analyze experiments that are important components in scientific approaches. The implementation of NoS in the learning process will be able to foster literacy and support learning achievement in the 2013 curriculum, and at the same time when the NoS efforts are combined in an interactive module to overcome learning difficulties in chemical bond courses during a pandemic. Research conducted by Wardhana, et al (2021) shows that the development of e-module based on NoS in atomic theory can improve students' literacy skills at every cognitive level. Based on these problems, research is needed to develop a chemical bond e-module based on the nature of science (NoS) to improve the scientific literacy knowledge.

## METHOD

This research method in development interactive chemical bond e-module based on nature of science (NoS) to improve scientific literacy knowledge uses the Multimedia Development Life Cycle (MDCL), the stages of this method are: concept, design, material collecting, assembly, testing, and distribution (Sutopo, 2003). Each stage of MDLC can swap positions, but the content stage must be the first stage, figure 1 shows the MDCL stages. This research was conducted at SMAN 19 Surabaya, and the experimental design used the one-group pretest-posttest design. This research is reviewed from the validation, practicality, and effectiveness.

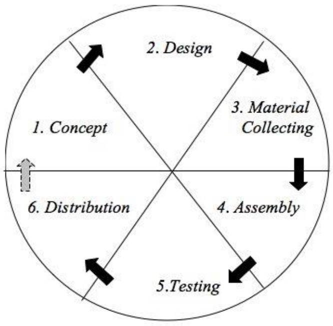


Figure 1. Multimedia Development Life Cycle

The Validation was carried out by three validators and the results obtained through the validity sheet based on the Linkert scale calculations are shown in table 1 (Vagias, 2006).

Table 1. Likert Scale

| Score | Categories |
|---|---|
| 1 | Poor |
| 2 | Fair |
| 3 | Good |
| 4 | Very good |
| 5 | Excellent |

The percentage of validation results is used to determine the feasibility of the electronic module. The interpretation scores as shown in Table 2.

Table 2. Score Interpretation

| Presentation (%) | Criteria |
|---|---|
| 0 – 20 | Very less |
| 21 – 40 | Less |
| 41 - 60 | Enough |
| 61 – 80 | Valid |
| 81 - 100 | Very Valid |

Practicality is obtained through student questionnaire responses using the Gutman scale, as shown in Table 3.

Table 3. Gutmann Scale

| Answer | Score |
|---|---|
| Yes | 1 |
| No | 0 |

The result of percentage practicality is used to show whether or not an electronic module can be run or not. The interpretation scores as shown in Table 4.

Table 4. Score Interpretation

| Presentation (%) | Criteria |
|---|---|
| 0 – 20 | Very less |
| 21 – 40 | Less |
| 41 - 60 | Enough |
| 61 – 80 | Practical |
| 81 - 100 | Very Practical |

The effectiveness obtained from a science literacy test. To calculate the science literacy scores using the formula as follow:

$$\text{Score} = \frac{\text{Total Score of answer}}{\text{Maximum score}} \text{ x } 100\%$$

Scores that have been obtained will be tasted with normality to determine the effect of using the module was analyzed by paired sample t-test formula (Gerald, 2018). The data can be concluded to be normally distributed if the value of sig. (2-Tailed) is smaller than 0,05, or there is an effect of using the module on literacy scores. The increase of student science literacy knowledge can analyze by normalized N-gain formula:

$$(g) = \frac{\%\,[Sf) - \%(Si)]}{[100\% - \%(Si)]}$$

(g) : N-gain Score
(Sf) : Final post-test averages
(Si) : Initial pre-test averages

With the criteria of the category is $g \geq 0.7$ is a high, $0.3 \leq g < 0.7$ is a medium, and $g < 0.3$ is a low (Hanke, 1998).

## RESULT

Research on development of interactive chemical bond e-module based on Nature of Science (NoS) to improve scientific literacy knowledge has obtained some of necessary data that can be analyzed to determine the feasibility of e-module based on validity, practicality, and effectiveness.

**Validity**

The validation data were obtained from two lecturers and one chemistry teacher. Components of validity are including material, scientific literacy, presentation, Nature of Science (NoS), and language. The validity result interpreted as in Table 5.

Table 5. Validation Results

| Component | Score (%) | Categories |
|---|---|---|
| Material | 91 | Very Valid |
| Scientific Literacy | 88 | Very Valid |
| Presentation | 89 | Very Valid |
| Nature of Science | 89 | Very Valid |
| Language | 83 | Very Valid |

Based on the Table 5, known that the validity data based on whole components can be concluded that e-module is very valid categorized. Material component gets the highest score which is 91%. The aspect that assessed in that component including: 1) the suitability of the material contained in the e-module with the 2013 curriculum, 2) learning objectives, and 3) accordance with the achievement of competence. The material was compiled based on 2013 curriculum needed, which is refer to Permendikbud number 37 of 2013. In the chemical bond e-module that has been developed there are consist three sub material, namely ionic bond, covalent bond, and metallic bond. The reading material presented in each sub-material emphasizes more on natural phenomena, to motivate students in learning, and increase student's interest in reading. Therefore, students can do the implementation of the material in real life and they will be able to find a solution about social problems and also the literacy skills will be increase.

The presentation of scientific literacy knowledge is spread equally in pedagogical of NoS learning. First, content knowledge is generally present in the background readings stage, case study discussions, and inquiry lessons. At that stage, students are required to explain the phenomenon, recall and use theory, also explain facts and ideas. Second, procedural knowledge is generally present in the inquiry lessons stage where the students are required to conduct simple experiments, create a workflow, and make a report. Third, epistemic knowledge is mostly on the historical studies stage which is the students are required to understand their own role in procedural justifying and ensure the data that obtained based on the concepts which have been studied.

The score of scientific literacy is 88% with very feasible categorized. The e-module that developed have accommodated activities which can improve student literacy, such as: 1) explaining phenomena, 2) knowing the applications of sub-material in daily activities, 3) scientific evaluation and investigation, 4) interpreting data and scientific evidence, 5) concluding data, and 6) solving problems based on scientific evidence. These activities can improve students' scientific literacy skills because scientific literacy not only about the ability of students reading but understand, apply, and solve the problems based on scientific concepts (Jufrida, et al., 2019). To achieve these activities, it can be implemented some questions and reading materials that contained on the developed e-module.

The activities implementation of developed e-module cannot be separated from the NoS pedagogical. In the developed e-module, each sub-material contained 6 NoS pedagogic practices, such as: 1) backgrounds readings, 2) case study discussions, 3) inquiry lessons, 4) inquiry labs, 5) historical studies, and 6) multiple assessments (Wenning, 2006). In the background readings stage, reading materials are provides to increase students' motivation in learning. In the ionic bond sub-material, reading material present the process of $CaCO_3$ formation. In the covalent bond sub-material there is acid rain, and in the metallic bond there are conductivity thermal and the advantages of metal alloys. After students read it, students are required to answer the questions of case study discussions stage that can be bridge also provide an overview of the information that will be studied.

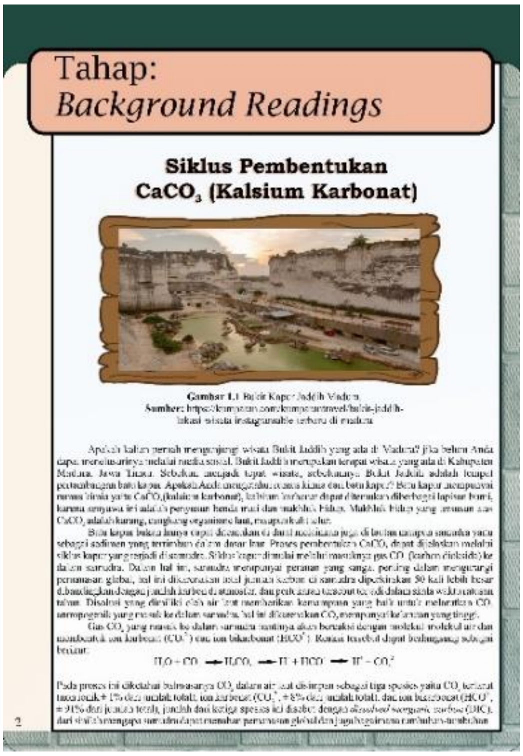


**Figure 2. The Display of the Background Readings on the ionic bond sub-material**

In the inquiry lessons stage, there are some content of each sub-material that will be studied. In the inquiry labs stage, students are required to prove the facts that have been studied at the inquiry lessons stage by conducting simple experiments (Wenning, 2006). In the sub-material of ionic bond and covalent bond, students are required to conduct experiments in the form of electrical conductivity and for the metallic bond they are required to observe the metal purifications process. The historical studies stage provides students to present and communicate the data which were obtained (Santayasa, 2006). And the last stage is multiple assessment which is to see the ability of students, in this stage there are some questions that students must do in each sub-material. The questions consist of 10 multiple choice and 3 essays. Students can be considered complete or understand about the sub-material if they get a score above the KKM, which is 78 (Kemdikbud, 2017).

The presentation component got an 89%. Assessed aspects in this presentation component, such as: 1) serving order, 2) interaction between students and the media, and 3) layout include font, type, and size that must be proportional and not disturbing. In the developed e-module, there are many futures that can train students' scientific literacy knowledge. These features, including: 1) ChmeFact, which provides an explanation of the facts of the application and uses of some compounds based on the bonds they form. The language component got the lowest score that is 83% because the language that used in the e-module is still not efficient, and there are some spelling mistakes. 2) The Scientist, which present biographies of scientist who have succeeded in making discoveries in the chemistry or education fields. 3) ChemTest, which presents questions to train students' understanding. 4) ChemFo, contains information on the use of chemicals that are integrated with technology developments that can functions to increase student knowledge. 5) ChemVid, is a feature that contains simple experiments videos or some video that support sub-materials that will be studied. 6) ChemEx, a feature that requires students to simple experiments, and 7) ChemReport, a feature that aims to train students in communicating data from simple experiments that have been carried out. The language component is very important component because with easy language, students will understand the concept.


**Figure 3. Display of ChemFo Futures**

**Practicality**

The results of practicality obtained through student response sheets and the observations sheet. The practicality result interpreted as in Table 6.

Table 6. Practicality results

| **Component** | **Score (%)** | **Categories** |
|---|---|---|
| Material | 81 | Very Practical |
| Scientific Literacy | 92 | Very Practical |
| Presentation | 92 | Very Practical |
| Nature of Science | 92 | Very Practical |
| Language | 90 | Very Practical |

Based on the Table 6, it shows that each e-module practicality component is categorized as very practical. The material component gets the lowest score, which is 81%. Generally, students feel burdened when using developed e-modules because they are not being independently which this action is different from the characteristics of e-modules namely self-learning (Mulyadi, et al., 2018). However, on the other aspects such as: 1) increasing knowledge, 2) adding insight and learning experiences, and 3) increasing motivate, the students gave a positive response. It because the material component contains of student's need. This aspect was previously obtained from the result of pre-research observation.

The components of scientific literacy and NoS get a percentage of 92%. Assessed aspects in the scientific literacy components are to train scientific knowledge, such as: 1) students can relate each sub material in real life, 2) students can solve problems based on scientific evidence, 3) students can design experiments, 4) students can interpret and present data, and 5) students can communicate data. Assessed aspects in the NoS components, such as: 1) reading materials at the background readings stage can motivate and increase curiosity towards the sub-materials that will be studied, 2) questions in case study discussions stage can develop understanding, 3) the phenomena presented can be found in real life, 4) experiments conducted at the inquiry labs stage can clarify the concepts that have been obtained at the inquiry lessons stage, and 5) overall pedagogical practice helps to apply chemistry in real life.

The component which supported by the results of the observation sheet in students learning activities are very enthusiastic in reading material in the background readings stage, they asking many questions when the discussions sessions is opened in case study discussions stage, and in the inquiry labs stage students are very interested and active when conducting simple experiments, namely testing the physical properties of covalent compounds. The results of the simple experimental portfolios were also very good, during the presentation sessions of the experimental results all group members always listen and asking questions.

Figure 4. The Students Conducting Simple Experiment

The presentations component gets a percentage of 92%. Students are very enthusiastic when using developed e-module. Pictures, videos, and animations make it very easy to understand the concepts for students. The size and type of font that used also appropriate so the students do not have obstacle when using the e-module. The composition, color, and layout also good for the material. The language component gets a percentage of 90%. Students assume that the language which used is clear enough and the sentences in the developed e-module are effective. It's also support the observation sheet where the students are not find difficulties when using e-modules.

**Effectiveness**

The data on the effectiveness results were obtained through a scientific literacy test, namely pre-test and post-test. Scientific literacy test includes types of scientific knowledge, such as content knowledge, procedural knowledge, and epistemic knowledge. The test given is in the form of essays totaling 15 questions. To improve students' literacy skills, PISA 2018 proposes specific frameworks, such as 1) explaining phenomena scientifically, 2) evaluating and designing scientific literacy, and 3) interpreting data and evidence scientifically. These competencies can be obtained with scientific knowledge. The first competency is to explain scientific phenomena that require knowledge of science content, namely content knowledge. The second and third competencies require knowledge that has been possessed; these competencies depend on an understanding of the scientific knowledge that has been built and how scientific knowledge is established, and the degree of confidence with which it is held; these competencies are referred to as procedural knowledge and epistemic knowledge (OECD, 2019).

Content knowledge is familiar knowledge, this knowledge relates to facts, concepts, ideas, and theories about the natural science world has established (OECD, 2019). The questions of content knowledge tasted as many as six questions, such as: applying the Lewis structure to the tendency of an elements to reach stability, identifying the types of bonds that occur in $SO_2$ and $SO_3$ compounds and their solubility in water, and analyzing the electrical conductivity of paper clips (mild steel). Procedural knowledge is the knowledge that becomes the standard in the scientific investigation process; because it can function as the data collector, analysis and interpretation data, retreating measurements to minimize error and reduce uncertainty, and standard procedures for representing and reduce communicating data (OECD, 2019) (Roberts, et al., 2010). The questions of procedural knowledge tasted as many as four questions, such as: determining the type of bonding of a compound based on data, compiling experimental procedures based on the tools and materials provided, and compiling electrical conductivity experimental procedures on paper clips (mild steel).

Epistemic knowledge is the ability to understand constructs and aspects contained in science as hypotheses, collecting theories and supporting data, and justifying the results of the data that has been obtained. This knowledge requires more than what is known (Fardan, et al., 2016). Students who understand epistemic knowledge will explain by example, distinguish between theory and law, and understand the role that peers review plays in establishing knowledge that can be trusted (OECD, 2019). The questions of epistemic knowledge were tested as many six questions, such as; making graphs showing the relationship between double covalent bonds with the lengths bond and binding energies of $N_2$ and $O_2$ compounds, making hypotheses and variables, and confirming data from scientific experiments. Thirty-six students assessed the questions. The result of hypothesis testing can see in the Table 7, Table 8, and Table 9.

**Table 7. The Result of Content Knowledge by Paired Sample T test**

| | | Paired Differences | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 95% Confidence Interval of the Difference | | | | |
| | | Mean | Std. Deviation | Std. Error Mean | Lower | Upper | T | df | Sig. (2-tailed) |
| Pair 1 | Pre - Post | -62.71368 | 9.67867 | 1.61311 | -65.98847 | -59.43888 | -38.877 | 35 | .000 |

**Table 8. The Result of Procedural Knowledge by Paired Sample T test**

| | | Paired Differences | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 95% Confidence Interval of the Difference | | | | |
| | | Mean | Std. Deviation | Std. Error Mean | Lower | Upper | T | df | Sig. (2-tailed) |
| Pair 1 | Pre - Post | -69.44444 | 10.87446 | 1.81241 | -73.12383 | -65.76506 | -38.316 | 35 | .000 |

**Table 9. The Result of Epistemic Knowledge by Paired Sample T test**

| | | Paired Differences | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 95% Confidence Interval of the Difference | | | | |
| | | Mean | Std. Deviation | Std. Error Mean | Lower | Upper | t | df | Sig. (2-tailed) |
| Pair 1 | Pre - Post | -76.79739 | 12.00959 | 2.00160 | -80.86085 | -72.73393 | -38.368 | 35 | .000 |

Based on the Table 5, 6, and 7, each type of scientific knowledge of scientific literacy gets a value of Sign. (2-tailed) is 0.000 < 0.05, the meaning is that there is significant difference between the pre-test and post-test scores or there is an effect of using e-modules on students' literacy skills. To see the increase in learning outcomes in scientific literacy, the N-gain score calculation used. The result of the N-gain score can be seen in the Table 10.

**Table 10. Pres-test, Post-test, and N-gain Results**

| Scientific Knowledge | Presentation (100%) | | N-gain score | Criteria |
|---|---|---|---|---|
| | Pre-test | Post-test | | |
| Content | 22.5 | 85.2 | 0.81 | High |
| Procedural | 17.6 | 87.0 | 0.84 | High |
| Epistemic | 8.3 | 85.1 | 0.84 | High |

Based on the Table 8, it can be seen that each scientific knowledge of scientific literacy experienced a high increase in learning outcomes with the N-gain score of 0.81 at content knowledge, 0.84 at procedural knowledge, and 0.84 at epistemic knowledge. Based on the table, generally, students can only work on questions with content knowledge type, namely with a percentage of 22.5%. The content knowledge is familiar, namely, the knowledge that teachers often teach so that students' procedural and epistemic abilities get a low percentage of 17.6% and 8.3%. The content knowledge is included in the low category; this is because the teacher in the learning process does not relate the concepts of chemistry in real life and is only limited to the transfer of theory without developing the students' ideas. So that the ability of students, such as: observing, classifying, formulating hypotheses, defining variables, experimenting, and interpreting data is still low, even though these abilities are as much as required by students (Kruea-in & Thongperm, 2014). In addition, students' abilities of content knowledge depend on the formation possessed by students. The information can be long or short, and the recollection depends on the instruction's association during learning (Zakaria & Rosdiana, 2018).

The highest protest results in the type of procedural knowledge are 87.0%, content and epistemic knowledge have a percentage of 85.2 and 85.1%, respectively, each of scientific knowledge is a good percentage. This high ability is because the developed e-module material is related to real life, requiring students to explain scientific phenomena, experiment, interpret and communicate data. The high value of procedural knowledge is also affected by content knowledge, if students understanding scientific knowledge (content knowledge) makes it easier to master procedural knowledge because they already have the initial understanding needed (Zakaria & Rosdiana, 2018). According to (Sudarmin & Samini, 2015), learning using integrated e-modules provides an opportunity for students to act in scientific learning. Therefore, the concepts received by students will be easy, and the literacy skill will improve (Setiawan, et al., 2017). Based on the N-gain values presented in the table, it can be concluded that the e-module developed can improve the scientific literacy knowledge.

## Conclusion

Based on the result of data, an interactive chemical bond e-module based on NoS to improve scientific knowledge of scientific literacy is developed is feasible. Based on the validity of the material feasibility component is 91%. The feasibility of scientific literacy is 88%. The feasibility of presentation and NoS is 89%, and the feasibility of language is 83%. Based on the practicality of the material practicality is 81%, scientific literacy, presentation, and Nature of Science (NoS) is 92%. Based on the resulting student scientific literacy knowledge test with a value of the variation of N-gain 0.81 at content knowledge, 0.84 at procedural knowledge, and 0.84 at epistemic knowledge, respectively with high categories.

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