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JPII 5 (2) (2021) 247-255

Jurnal Pendidikan IPA Indonesia

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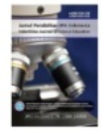

Learning with Leaflet of Electronegativity (LoEN): Enhancing Students' Understanding on Electronegativity, Chemical Bonding, and Polarity

DOI:

Accepted:... .Approved: ... . Published: ...

ABSTRACT

Previous research has reported that many high-school and undergraduate students have difficulty explaining the relationship between polarity and electronegativity even though they may be familiar with the concept of polarity. This study aims to address these misconceptions using a leaflet and assess its effectiveness using questionnaires and concept testing. A simple, colorful printable leaflet was produced and distributed to students in Indonesia. The Leaflet on Electronegativity (LoEN) provided students with an overview of the theoretical basis of the concepts and guidance on applying these principles. The leaflet format is cheap and easy to mass-produce, which is an important factor given the limited access to other types of appropriate learning resources in Indonesia. The leaflet formed the basis of a classroom discussion activity. Visualization is known to play an important role in constructing students' conceptual understanding, so the leaflet made extensive use of diagrams to explain relevant concepts. The leaflet was printed in full color to make it visually appealing and facilitate student learning. Students were tested before and after learning with the LoEN. A *Paired-sample t-test* using SPSS is used to compare the pretest and posttest scores to measure the effectivity of the LoEN. A statistically significant improvement in scores (p = 0.000) was achieved, which indicates that using the LoEN in the classroom helps students understand the topic. Also, students' positive responses signify that the LoEN provides an engaging way to learn the concepts.

Keywords: leaflet, electronegativity, hands-on learning, misconceptions, enrichment.

INTRODUCTION

Electronegativity is the central concept to many other basic concepts in chemistry curricula, including chemical bonding (Nicoll, 2001). Some undergraduate students have misconceptions about electronegativity and bonding, as reported by Nicoll (2001), such as the contribution of electronegativity to explain why some types of bonds are more prone to attack than others. Moreover, she/he reported that while some students may be familiar with the concept of polarity, they have difficulty explaining the relationship between polarity and electronegativity. According to Peterson et al. (1989), some eleventh and twelfth-grade students held misconceptions about the influence of electronegativity and the unequal sharing of an electron. This study demonstrated that some students thought that the unequal sharing of an electron was not affected by electronegativity.

Another study by Ardiansah et al. (2014) reported that 5 out of 12 participating chemistry teachers in Bengkayang District (one of the Districts in West Borneo, Indonesia) experienced misconceptions about the determination of bond types based on the difference in electronegativity of the bonded atoms. The authors reported that these misconceptions might be caused by several factors, including prior knowledge, associative thinking, and the format used to present this content in commonly used textbooks. Associative thinking is thinking by associating something with others (Syah, 2007). The thinking process includes connecting knowledge and environment, associating one idea to another idea, and connecting previous knowledge with the existing knowledge.

Another finding reported that around 40% of college students (out of 75 students who participated in this study) in Indonesia who already studied chemical bonding experienced misconceptions about identifying the bond types of a range of sample molecules from an online test (Aljunid, 2018). Moreover, he reported that some of the participants involved in this study predicted the bond type based on the metallic or non-metallic character of the bonded elements. These findings suggested that the relationship between electronegativity, bond types, and polarity taught in Indonesia may need to be reconsidered.

Chemistry textbooks are one of the main teaching and learning resources available to many educators and students. Despite this, the availability of textbooks is extremely limited in some geographical locations. This condition forces some students to rely on their high school chemistry textbooks as the main learning resource for studying General Chemistry course. The primary disadvantage of these high school textbooks is the little explanations of the main concepts. Based on a review of the three most popular high school chemistry textbooks from different publishers in Indonesia (Er, Yd, and Gr), none of them explain the relationship between electronegativity, chemical bonding, and polarity that would be suitable for a university-level course. This topic can only be found in Indonesian chemistry textbooks written specifically for university students. Moreover, the unreliable/limited access to high-speed internet connection means that most students have a greater dependence on books than in some other geographical locations (e.g., the USA and other developed countries). Therefore, there is a need to explain these concepts and the relationships between them in a more widely accessible format that would allow Indonesian students to learn the relationship between them effectively.

Booklets or leaflets are the two formats considered in this research. A booklet is a small, thin book with paper covers, typically giving information on a particular subject (Efendi & Makhfudli, 2009; Indriana, 2011). Meanwhile, a leaflet is a printed sheet of paper containing information and is usually distributed for free. If two formats are compared, a leaflet is cheaper and easier to produce than a booklet. There is a need to keep costs minimum to ensure that the leaflet could be widely distributed in institutions with minimal budgets for books and limited/unreliable internet access. The concepts presented in this topic could be explained in two paper pages, so a leaflet is the best option. The advantages of leaflets include their effectiveness for providing concise summaries of information, their simple and cheap production, and the fact that they are cheap enough for students to have their copy to learn (Ewles & Simnett, 1999). In addition, Gani et al. (2014) stated that the information presented in the leaflet could be in the form of sentences, figures, diagram, pictures, or combination of both.

Students can read leaflets anytime and anywhere and use visual representations of concepts that may be difficult to explain verbally. Students and educators may decide to integrate leaflets in learning sessions as a prompt for discussion or teamwork. Besides, the leaflet can be recycled after use. The disadvantages of leaflets are they are easily lost or damaged and that an educator is not always ready to provide further explanation if needed (Indriana, 2011; Arsyad, 2002)).

Despite its limitations, presenting the topic using a leaflet has numerous advantages. It helps overcome the limited availability of chemistry textbooks in some locations and the lack of reliable high-speed internet access. Therefore, a leaflet would be developed as a teaching and learning resource (TLR) focused on the concepts of electronegativity, chemical bonding, and polarity, as well as the relationships. The leaflet would be developed as the focus of a classroom-based activity.

DESCRIPTION OF THE ACTIVITY

Design of the Leaflet

The development process of the Leaflet on Electronegativity (LoEN) consisted of two stages: design and development, as presented in Figure 1.

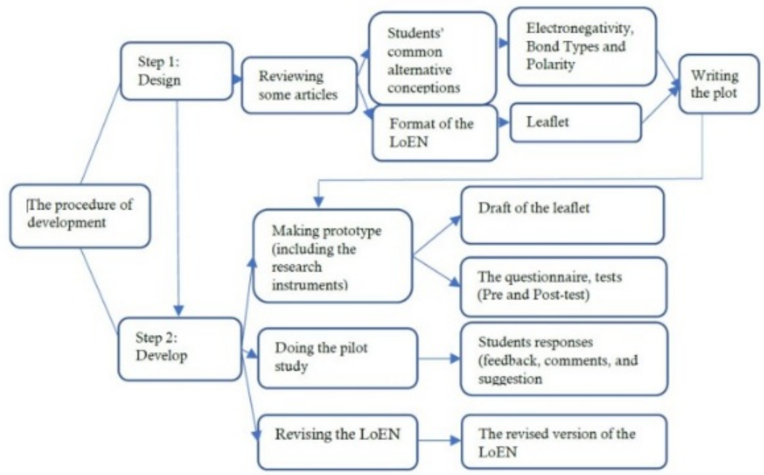

Figure 1. The procedure of developing the LoEN

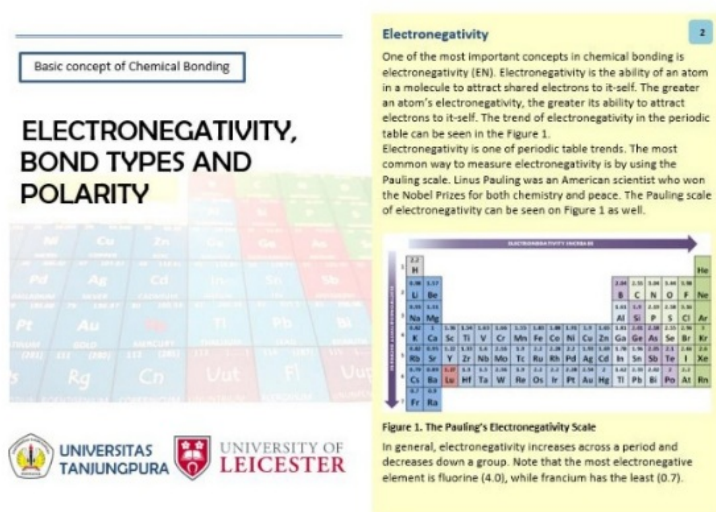

Figure 2. The performance of the LoEN

The figure shows the appearance of the LoEN by presenting the Cover and the First page as an example.

The first stage (design) is deciding topics/concepts to be presented in the Teaching and Learning Resources (TLR) and the format of the TLR. Both of these decisions were informed by reviewing the relevant literatures (Brown & Clement, 1989; Goh, 1993; Keig & Rubba, 1993; Ayas & Demirbas, 1997; Kozma et al., 1997; Birk & Kurtz, 1999; Ewless & Simnett, 1999; Bodner & Domin, 2000; Nicoll, 2001; Efendi & Makhfudli, 2009; Ardiansah et al., 2014; Aljunid, 2018). The review started by identifying the relevant studies reported in published papers to find students' common misconceptions in chemistry core concepts. The review process was conducted by considering multiple sources (online and printed papers) to identify the topic focus and the format of the TLR, which is a leaflet in this case.

Finding the relevant papers through online searches was done by inserting the relevant keywords such as misconceptions or alternative conceptions in chemistry (Zoller, 1990; Nakhleh, 1992; Taber, 2002; Özmen & Ayas, 2003; Özmen, 2004; Unal et al., 2010; Taber, 2011; Taber, 2013; Winarni & Syahrial, 2016), approaches used to overcome these misconceptions (Yezierski & Birk, 2006; Taber, 2009; Tasker & Dalton, 2009), the role of representations in chemistry education (Treagust & Chittleborough, 2001; Wu et al., 2001; Treagust et al., 2003; Yakmaci-Guzel & Adadan, 2013).

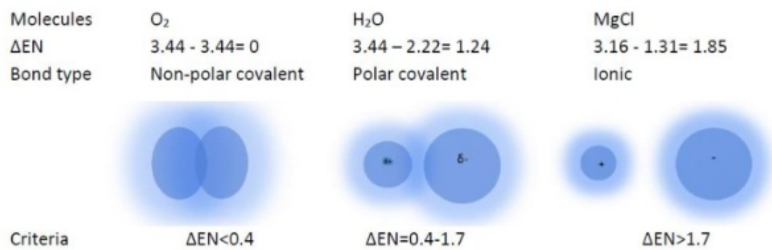

Figure 3. An example of an image included in the LoEN.

The figure describes the relationship between the Electronegativity (EN) difference with bond types and polarity of sample molecules.

Figure 3 shows an example of an image used in the LoEN, which describes the relationship between the Electronegativity (EN) difference of bonded atoms and the bond types between those atoms.

The first section is the cover that consists of the title of the leaflet. The second section is the explanation. The explanation begins with the definition of electronegativity and is supported with a diagram illustrating the trend in electronegativity of elements in the periodic table (Figure 2). The explanation is then followed by describing the bond character. The next section presents an overview of the relationship between electronegativity difference and bond character in the form of a table. The next section is the description of bond types. Two approaches to identifying the bond types between two atoms are explained in this section: identifying the type of elements involved in a compound and using the electronegativity difference. The first is the common way teachers teach to identify the bond type, while the second is the less common way in Indonesia. Both approaches are considered to complement students' understanding of the concepts. Then, a definition and explanation of the polarity of diatomic molecules are presented. These explanations also referred to the relationship between bond character, electronegativity, and polarity. An image was included to illustrate the relationship (see Figure 3). The LoEN ends with a summary in a scheme of the relationship between electronegativity, bond types, and polarity. It also presents an example of the molecule for each bond type to facilitate students' understanding of the concepts (see Figure 4).

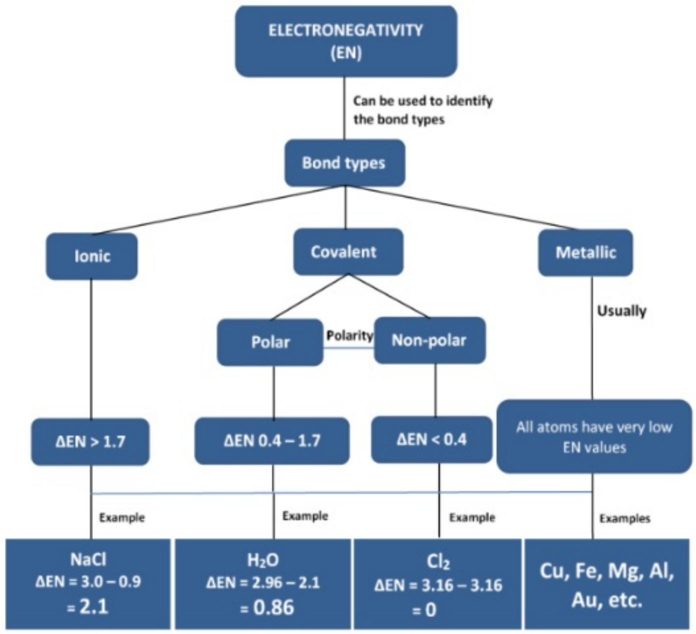

Figure 4. Diagram presented in the LoEN.

This diagram was used to summarize the concepts discussed in the LoEN. The diagram shows the relationship between EN, bond types and polarity.

Aims of the Activity

The leaflet is used to support a classroom session and as part of students' guided independent study.

This activity was designed, tested, and revised to allow students to achieve the following learning objectives:

- To understand the relationship between electronegativity, bond character, and bond type.
- To apply the concept of electronegativity and bond character to identify the polarity of the molecule.

METHOD

The study was conducted in the Faculty of Teaching and Education (FKIP) University of Tanjungpura, Pontianak. Participants of this study were divided into two groups for the pilot study and the implementation of the LoEN. Twenty students participated in the pilot study, and 33 students in the implementation of the LoEN. Both participants were first-year students of the Chemistry Education Study Program in the Department of Mathematics and Science Education, Faculty of Teacher Training and Education, University of Tanjungpura, Pontianak, Indonesia. All students involved in the study took the questionnaire, pretest, and posttest.

This research aims to develop a leaflet to support students' understanding of electronegativity and assess its effectiveness. The two-stage iterative process used to develop the leaflet is described in Figure 1. The methodology for the analysis of the effectiveness of this approach is described below.

Data Collection

Two methods were used to collect data in this study: questionnaires and tests to measure students' understanding before and after treatment.

The first data collection method was questionnaires to gather students' responses, feedback, comments, and suggestions related to the appearance, content, and value of the learning experience of the LoEN. According to Cohen et al. (2017) and Harris (2014), a questionnaire effectively collects someone's views, perceptions, feedback, response, and comments. The questionnaire used in this study consists of two sections. The first section was based on closed-questions using a five-point Likert scale (strongly agree, agree, neutral, disagree, and strongly disagree). The second section of the questionnaire used open-response questions to gather students' views, perceptions, comments, and suggestions in their own words. The questionnaires were distributed to participants at the end of each study, after implementation of the LoEN.

The second data collection method in this study was concept testing. This approach used pretests before and posttests after the intervention. These tests were designed to measure the conceptual understanding of participants before and after the implementation of the LoEN. Both tests use open-questions. The open-type question is an examination question that requires an answer in a sentence, paragraph, or short composition (Merriam-Webster Online Dictionary). It requires the student to recall the relevant factual information, organize the ideas, and write an extensive response. One of the advantages of using open-type questions is students have a chance to demonstrate their knowledge, skills, and abilities in various ways. The test used in this study is aimed for students to show their understanding related to the topics presented in the LoEN. The posttest used similar questions in the pretest to ensure that level of difficulty of each test was consistent.

Prior the implementation both instruments were validated using content validity. Two lecturers of Chemistry Education Study Program were act as the validator. After gained the approval from the validators, the instruments were tested to 20 first-year cohort students of Chemistry Education Study Program in the pilot study.

Data Analysis

Data from pretest, posttest, and questionnaires were analyzed quantitatively. The score of both tests was analyzed using IBM SPSS Statistics 24. A *Paired-sample t-test* is used to compare the pretest and posttest scores. *Paired sample t-test* was used as data of students' pretest and posttest scores. According to Bryman and Cramer (2009), a related *paired sample t-test* can be used to compare the same participants' means in two conditions or at two points. Questionnaire data were tabulated and analyzed using Microsoft Excel. Microsoft Excel was chosen based on two reasons. First, Microsoft Excel offers exclusive features to analyze the questionnaire data, such as the mathematical formula, graph, chart, and others. Second, it is easy to use as Microsoft Excel is familiar to the researcher. Microsoft Excel was used to show the percentage of students' perceptions and views based on the questionnaire data. It was also used to tabulate the pretest and posttest data before the SPSS analysis.

Procedures of the study (pilot study and the implementation)

Before the implementation, the pretest was administered to all students to collect students' prior understanding of electronegativity, bond type, and polarity. The pretest consisted of three questions that allowed students to determine the bond type and polarity of given molecules using the Pauling scale. The pretest was 15-minutes long. After the pretest, the LoEN was given to each student. They had 10 minutes to read the LoEN and 5-10 minutes to discuss the topic with friends who sat next to them. In the next 10 minutes, the lecturer explained the topic to all students.

They had the opportunity to ask some questions to the lecturer related to the concepts. In the end, students were given a questionnaire similar to the pilot study to gather their perceptions, comments, and suggestions related to the LoEN. A posttest was scheduled two weeks after the implementation due to students having another class and laboratory work for the following few days. Step by step of the procedure is illustrated in Figure 5.

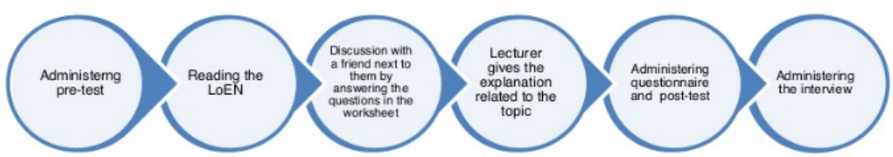

Figure 5. Procedure of the Implementation of the LoEN
The figure illustrated the 6 steps of the procedures when implementing the LoEN in the classroom in the first cycle of the evaluation.

Pilot Study

A pilot study was conducted before the implementation of LoEN in the General Chemistry 2 classroom. It aims to evaluate the feasibility, the amount of time spent on the task, and the leaflet's quality before the implementation. Twenty first-year students of the Chemistry Education study program of the Department of Mathematics and Science Education at the University of Tanjungpura voluntarily participated in the pilot study during the 2015/2016 academic year. The pilot study was in the second semester of their first year.

The LoEN and a worksheet were given at the beginning of a chemistry class. A feedback questionnaire was given to each student after they learned with the LoEN. The majority (19 out of 20 students) agreed that the LoEN supported their concepts learning. Some changes were made to the LoEN based on the feedback generated by this pilot study. The first change was the addition of page numbers to clarify the structure. The second was a reduction of the text to improve students' engagement with the LoEN. The last change was the development of a worksheet that contains questions to guide students' discussion when using leaflets in class.

RESULTS AND DISCUSSION

Following the pilot study, this activity was carried out with 33 first-year students from the Chemistry Education Study Program of the Department of Mathematics and Science Education at the University of Tanjungpura, Pontianak, Indonesia. Students completed the classroom activity and then filled out an evaluation questionnaire at the end. Students were tested both before (pretest) and after (posttest) the activity to assess their understanding of the concepts.

Both pretest and posttest have two questions. The first question asked the students to rank the given bonds to increase polarity based on Pauling's scale of electronegativity. The second question asked the students to predict the bond type that will form between the given pair of atoms. Both tests can be seen in the supporting information. All students' scores increased with the average increase at 19.58 points (maximum score = 100). Students' average pre-test and post-test were 56.03 and 75.61, respectively (n = 33). Pretest and posttest data were analyzed using a paired sample t-test, and the result was significant (p = 0.000). The results indicated that the LoEN effectively supports student learning of the concept. Irwan et al. (2017) also found a similar result where 32 tenth-grade high school students in Galing, Sambas District, Kalimantan Barat scores increased after studying with the booklet of Chemical Bonding. Afridah et al. ((2018) also reported a similar result. They used leaflet as learning media to promote the learning outcome of grade 11th students. Details of the t-test results are shown in Table 1.

Table 1. Comparative Paired Samples Result

Test	Mean	*n*	SD	*t Value*	*p Value*
Pre	56.03	33	9.299	-19.465	.000
Post	75.61	33	9.630		

One possible reason for why the majority of students' scores increased after studying with the LoEN is the figures presented in the leaflet. The figures in the LoEN were designed to emphasize the important concepts of electronegativity, bond types, and polarity. Besides, the figures allow students to visualize the polarity process and its relation to the electronegativity difference scale proposed by Pauling. Visualization is a key to chemistry understanding (Jones & Kelly, 2015; Vavra et al., 2011; Rayan & Rayan, 2017; Akaygun & Jones, 2013).

As shown in Figure 6, the majority of students also responded that they agree or strongly agree with the following statements:

1. The contents of the leaflet are clear and understandable.
2. Learning with a leaflet help students understand the topic.
3. Students know how to predict the bond types and polarity through the concept presented in the LoEN.
4. The concepts presented in the LoEN are complete.
5. Students enjoyed learning with the leaflet.
6. The presentation of the LoEN is interesting.
7. Learning with the LoEN is effective.
8. LoEN is easy to use and practical.

Figure 6 shows the results of the questionnaire containing these eight questions. The vast majority of responses either agree or strongly agree with the statements, suggesting that the students found the leaflet was good learning support. These data were taken together with the significant increase between the scores of pretest and posttest, confirming that this approach to teaching electronegativity is effective.

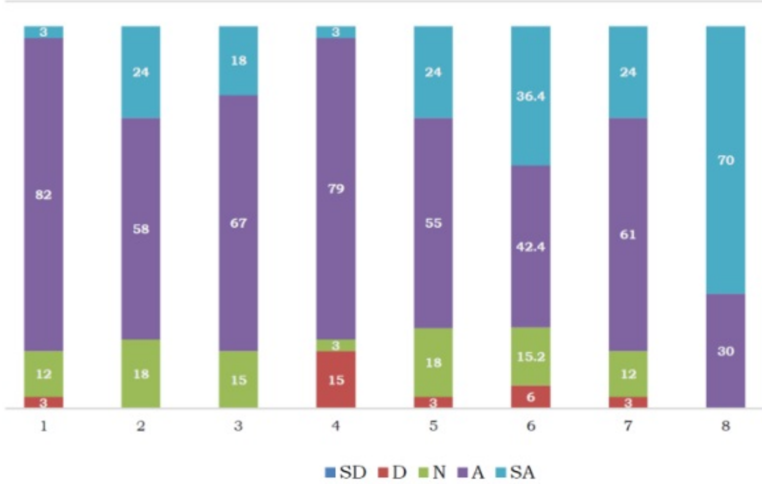

Figure 6. Distribution of responses of first-year Indonesian students (n = 33) to the statements numbered 1–8 listed previously in the text.

Students' comments and suggestions on section 2 of the questionnaire are summarized in Table 2.

Table 2. The Summary of Students' comments and suggestions on Section 2 of the Questionnaire (N=33).

Questions	Comments/suggestions	Percentage
Which part of the LoEN that is most useful?	Table, graph and pictures presented in the leaflet	27.3
	Conclusions	12.1
	The whole part of leaflet	60.6
Which part of the LoEN that is less useful?	None	100
What changes do you want to make related to the LoEN?	Colour of the Leaflet	15.2
	The cover of the leaflet is not attractive enough	3
	None	81.8

Data presented in the Table is the summary of students' comments and suggestions with the percentage in the second section of the questionnaire that consists of 3 open-ended questions.

Section 2 of the questionnaire asked three open-ended questions. The first question is about the most useful parts of the LoEN. 27.3% responded that it was the table, graph, and pictures. Meanwhile, 12.1% of them responded that the conclusion was the most useful part of the LoEN. Interestingly, 60.6% of them stated that the whole of the LoEN was the most useful. The second question concerned the less useful part of the LoEN. One hundred percent of the students agreed that there was no "less useful" part. This response indicated that the whole of the LoEN is useful. The last question asked about the changes that they would like to be made related to the LoEN. 15.2% of students suggested changing the color of the LoEN. 3% of them wanted to change the display of the cover. Meanwhile, the rest of the students (81.8%) agreed that no changes needed. The responses to the last question supported the findings on the first and second questions.

The findings of this study are consistent with previous work on leaflet-based learning activities that have shown this approach can be an excellent way to engage students and support their learning (Nugraha et al., 2013; Abdia, et al, 2020).

CONCLUSION

An activity using the LoEN and a worksheet was designed as a complementary learning resource to help students understand the relationship between electronegativity, bond type, and polarity. The activity helps students understand the basic concepts of the relationship between electronegativity, bond type, and polarity in an engaging way, to which 79% of students either strongly agree or agree, in response to statement 5. Besides, using the LoEN in the learning process helps students understand the relationship between electronegativity, bond type, and polarity as 85% of students agreed or strongly agreed to statement 7 in the questionnaire that "learning with the LoEN is effective." The LoEN might be used broader when the campus is closed due to global pandemics (e.g., COVID-19). The pdf. type of the LoEN can be sent to students for studying at home.

The discussion activity could be hosted on an online platform (e.g., Zoom, Google Meet, or Microsoft Teams).

ACKNOWLEDGMENTS

This work has been supported by The Ministry of Research, Technology, and Higher Education (KEMENRISTEKDIKTI) Indonesia, and University of Tanjungpura. We also thank the Faculty of Teacher Training and Education, our colleagues, and students who were involved in this study.

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