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Research Paper Open Accsess

Making Natural Acid-Base Indicators with a Science, Technology, Engineering, Mathematics (STEM) Approach to Chemistry Subjects During the Covid-19 Pandemic

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Abstract

This study focuses on the implementation of the STEM approach in chemistry subjects to develop natural acid-base indicators through contextual learning materials. The learning was conducted remotely using various digital services. To accomplish this, the experiment used the STEM approach with a Project-Based Learning model (STEM-PjBL), which was developed by Laboy-Rush and promoted by West Java Province Education Office in collaboration with SEAMEO QITEP in Science to develop natural acid-base indicators. The research findings were evaluated using qualitative descriptive methods to address the concerns that arose during the study. Data were collected through observations and student questionnaires regarding the implementation of the STEM approach in the acid-base indicator material. It was discovered that the STEM approach can be effectively employed in online learning during the Covid-19 pandemic. This study utilised plant parts obtained from the students' surrounding environment. However, before this experiment, students' knowledge about the nature of acid-base reactions in school snacks remain unknown.

Keywords: acid-base, natural indicator, online, STEM-PjBL

Introduction

SMAN 2 Padalarang is an eco-friendly school that has been honoured with the Adiwiyata School Awards in West Java Province. As a result, learning at school emphasised the integration of environmental awareness, issues related to the environment, and student hygiene. For instance, the type of snacks consumed by students in the school canteen is a significant consideration. While carbohydrates are necessary for proper digestion, students often opt for spicy and sour foods like *seblak* and *baslub (bakso kulub)* for breakfast. However, the consumption of these snacks can lead to gastritis due to increased stomach acid production caused by the presence of vinegar and chili sauce, which determine the acidic nature of the food. The behaviour of students in selecting snacks in the school canteen presents a contextual problem that can be addressed through chemistry education, specifically acid-base concepts.

Chemistry is a branch of natural science discipline that was initially taught as an independent subject in senior high school. Students are introduced to a "new language" starting with elemental symbols, which are then combined into chemical formulas until it becomes an equivalent chemical reaction equation. However, many students perceive chemistry as a difficult subject, in line with Wiyarsi, et al., as cited in Rahmawati, et al. (2021). This perception hinders their interest and comprehension of the subject. This marks the important role of teachers in bridging the gap and making chemistry more accessible to students.

The STEM approach can connect chemistry concepts to the daily life of students. In the context of acid-base

materials, students are exposed to various types of school snacks (food and drink) that exhibit acidic or basic properties, which directly impact human digestive health, especially stomach acid levels. By providing students with this information, they can develop the ability to identify healthy food options. According to Tsupros, as cited in Herliani, et al. (2021), STEM education employs an interdisciplinary approach, integrating rigorous academic concepts with real-world lessons, enabling students to apply science, technology, engineering, and mathematics in contexts that connect school, community, work, and the global enterprise. This approach fosters the development of STEM literacy and equips students with the skills necessary to thrive in the new economy.

In early March 2020, an unexpected event occurred—the onset of the Covid-19 pandemic in Indonesia, which necessitated a shift to remote learning. Practical work and laboratory presentations that are fundamental to learning chemistry had to be conducted online from students' homes. Padalarang 2 Senior High School has had a Distance Learning Program since 2013, allowing both teachers and students to become familiar with the use of the Learning Management System (LMS) and other applications that support online learning activities. Therefore, this chemistry study was conducted online, combining both virtual and face-to-face features.

Based on the aforementioned factors, students are expected to develop a method for identifying the acidity and basicity of food and beverages (snacks in the school canteen). To achieve this, the experiment used the STEM-PjBL approach developed by Laboy-Rush and promoted by the West Java Province Education Office in collaboration with SEAMEO QITEP in Science to develop natural acid-base indicators. The use of natural acid-base indicators aligns with the vision and mission of SMAN 2 Padalarang as an eco-friendly school, as it offers a simpler and more accessible approach. Tseng, et al., as cited in Suwadarma, et al., (2020) demonstrated that STEM-PjBL enhances effectiveness and meaningful learning, as well as supports the career of students in the future by providing practical activities that solve real-world problems in the classroom.

There are several challenges in learning chemistry:

1. Students generally think that chemistry as a difficult, boring, and even annoying subject. Therefore, it is necessary to apply a learning model that improves students' understanding of concepts easily and pleasantly;

2. Students have limited knowledge regarding the identification of acids and bases contained in snacks. Thus, it is necessary to develop a simple and easy-to-use acid-base indicator;

3. Due to the Covid-19 pandemic, learning must be conducted online. Therefore, the usual face-to-face STEM-PjBL has been changed to online. It is necessary to understand how to effectively implement online learning and assess whether STEM-PjBL was able to be used to achieve basic competencies.

This research describes the benefits of applying the STEM-PjBL approach to develop natural acid-base indicators as a variety in learning chemistry. This variation in chemistry learning was expected to make students feel a different experience, preventing boredom during online learning amid the Covid-19 pandemic. Moreover, it is also expected to improve the quality of the chemistry learning process and foster the development of scientific, technological, mathematical, and engineering skills among students and teachers. This, in turn, equips the next generation of the Indonesian nation to compete in the current era of industrialisation 4.0.

Methodology

The study was conducted to develop natural acid-base indicators through the

STEM-PjBL learning model implementation. The syntax of the STEM-PjBL learning model includes reflection, research, discovery, application, and communication. This model was used by a group of 35 grade 11 students in the second academic year of 2019/2020 at SMAN 2 Padalarang. The research used questionnaires, student project reports, researchers' notes, and tests as instruments. The collected data consisted of descriptive information in the form of words, spoken statements, or pictures of the research subjects, which were analysed to draw conclusions using specific data analysis techniques (Creswell, as cited in Purwanto, et al, 2022). The research findings were evaluated using qualitative descriptive approaches to address the concerns that had been posed.

This study was conducted in a variety of tactics, including:

1. Implementing a learning model which is different from the commonly used approach. In this case, the STEM-PjBL approach was adopted to provide students with a more engaging and enjoyable learning experience in chemistry;
2. Using materials from the environment around students to develop acid-base indicators. By using the available materials, it is expected that students can easily grasp the chemical concepts related to acid-base indicators, as it closely related to their daily lives (contextual learning);
3. Learning chemistry online using various applications so that students are accustomed to using their devices positively during the learning process.

The data were collected through observation and student questionnaires regarding the use of the STEM-PjBL model in acid-base indicator material. The gathered information was then analysed using a simple computation approach based on sample percentages.

Research Discussion

The following are some of the implementations to solve the described problems.

1. Use of the STEM-PjBL Model

STEM-PjBL model was applied to teach acid-base indicator material with the aim of bringing chemical material closer to students' daily lives; and therefore, students can easily master chemical concepts. It starts with the problem of snacks that are usually consumed by students from the school canteen. Students often buy snacks without thinking of the health of their digestive system, especially their stomach. For example, in the morning, students buy boiled meatballs with red sauce (spicy) and pungent aroma of vinegar as their breakfast. In the concept of chemistry, the food consumed by these students is acidic. If the student has not had breakfast at their home and just consumes the snacks bought at school, it will cause their stomach acid to increase and hurt the stomach.

That issue is a stimulus for students to help them in understanding more the concept of acid base in chemistry. Through cooperation in groups with their classmates, students look for more comprehensive information on how to identify substances that are acidic and basic (acid-base indicator). Students then are guided to formulate and test the ideas in designing a study of acid-base indicators. Based on the environmental conditions of each group, this study is to obtain various types of plants that can be used as indicators of natural acid base. The STEM-PjBL learning model consists of five stages, as shown in Figure 1.

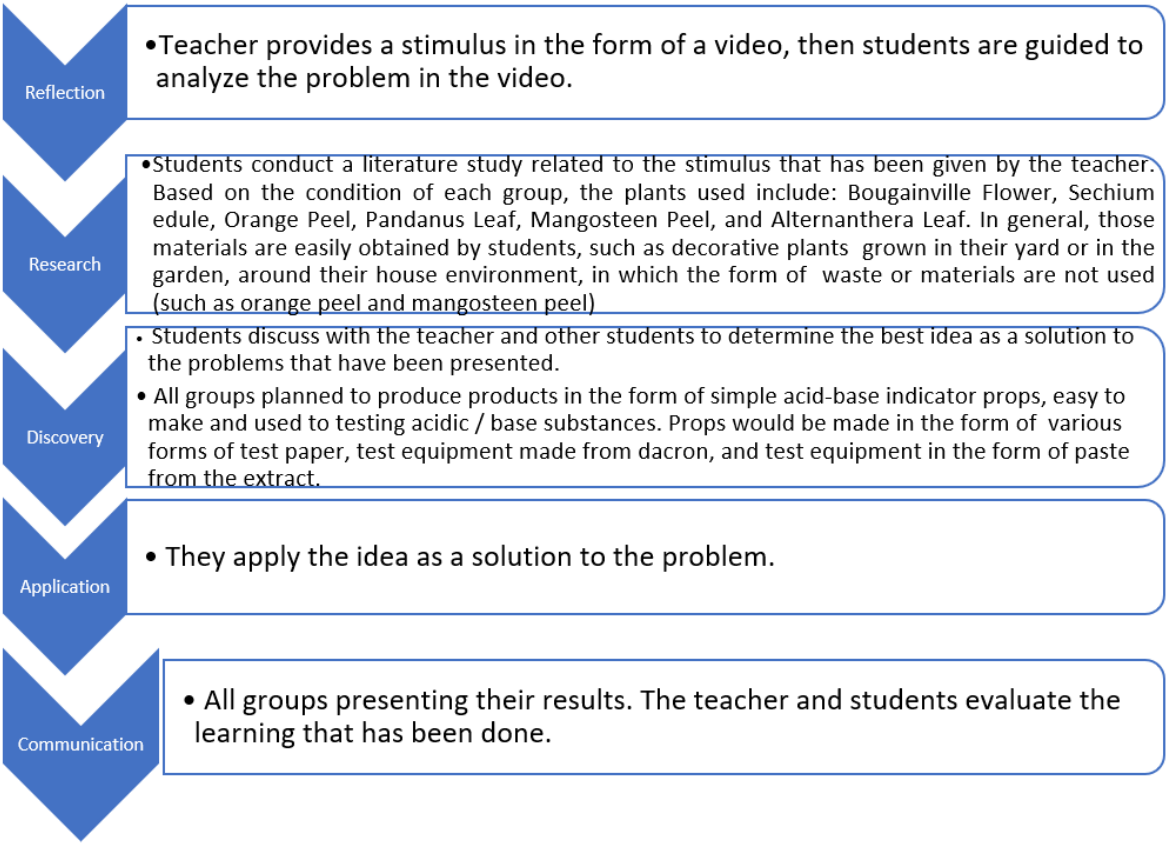

Figure 1. STEM-PjBL Learning Stages

Documentation of learning using the STEM-PjBL model on the acid base indicator material

Figure 2. Reflection and Research

Figure 3. Discovery

Figure 4. Application

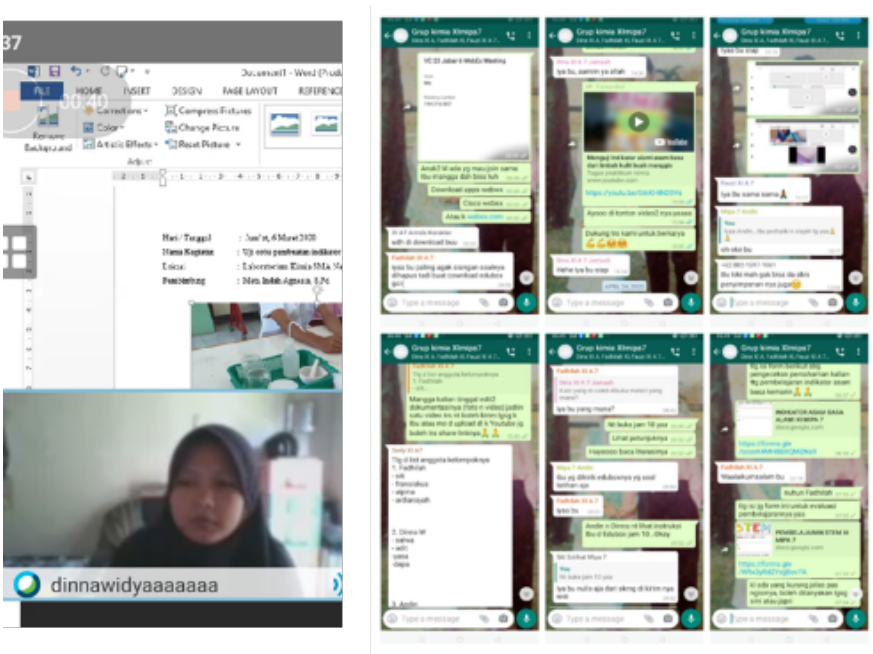

Figure 5. Communication with Webex and WhatsApp Application

Based on the questionnaires results, most of students were happy with the practice of the STEM-PjBL. It was their first experience studying chemistry with this learning model. Here are some of their responses.

> Wish: I hope learning with STEM can be applied in chemistry earlier, that is when students are still in 10th grade, so we will not be left behind from other school students.
> I was so happy because I was given the opportunity to take part in learning chemistry using STEM model, I gained a lot of experience and knowledge which could improve the ability to solve various problems. My wish is to continue this program because it really helps me through the learning process. By having a lot of knowledge, we can also be better in knowing which parts we are still lacking and how to fix them. Let's continue learning chemistry with STEM.

Most of students think that STEM-PjBL model can improve the ability to answer questions related to acid-base indicator material problems, increase understanding of scientific methods used by scientists in investigation or discovery, and improve STEM skills. This approach also aligns with the opinion of Afriana (2015), that states:

"The existence of the latest technology is needed in creating creative projects. The relationship between science, technology, and other sciences cannot be separated when learning science. STEM integrated in the PjBL will be able to cultivate 21st century skills in preparing for the golden generation of Indonesia. The STEM approach prepares students with the skills required for 21st-century competition, such as technological skills, communication skills and problem solving."

The STEM approach is suitable for exploring the topic of natural acid-base indicators because students utilise abundant natural resources in their environment, including various plan parts (flowers, leaves, fruit), as well as fruit peel waste. This approach enables them to address problems that arise, such as reducing pollution from organic waste and adding value to it, while also identifying the acid-base properties of food. In line with Herliani, et al (2021) that in addition, STEM Local Context allows students to identify problems related to the processing of natural resources that are abundant in their area, thus contributing to the welfare of the surrounding community. STEM knowledge in the topic of natural acid-base indicators includes:

- Science (S): How to determine the acid and base properties of a substance.
- Technology (T): The use of natural acid-base indicator in the form of simple test kits made from paper, dacron, or extract paste, etc.
- Engineering (E): The process of creating natural acid-base indicators from plant or fruit peel waste.
- Mathematics (M): determining the acidic or basic pH of a substance and graphing changes in pH

The majority of students also argue that learning with STEM is difficult. It was because this model was the first experience for them to be unfamiliar. In addition, due to the investigation steps in this model make the students feel difficulties, especially for students with low levels of cognitive ability. As stated by Han, et al. (2015):

"The participating teachers indicated that student readiness was a critical factor in implementing STEM PBL. In other words, teachers had difficulties in effectively implementing STEM PBL with students who were not academically ready. Students in the three participating schools demonstrated low academic achievement in mathematics on standardized state tests and came from lower economic backgrounds compare to those in other areas of the same region. Based on previous research, STEM PBL was found to be more effective in learning environments with low achievers. However, the implementation of STEM PBL with low achievers exhibiting behavioural issues was challenging for the teachers in this study. The teachers believed that the low achieving students lack familiarity with a student-driven learning environment would be another challenge in STEM PBL implementation."

In this research most students also find learning with this STEM-PjBL difficult. That's because this model is their first experience, so they are not used to it. In addition, because the investigation step in this model possesses difficulties for students, especially in students with low cognitive levels. Therefore, the learning model using STEM-PjBL in acid-base indicator material can be utilised as one of various engaging learning, methods for students. Teachers need to provide guidance and motivate students with low cognitive abilities so that they will become more accustomed to and have no difficulty in learning with other STEM-PjBL model.

1. The Use of Natural Materials from the Surrounding Environment

The mastery of student concept is also necessary for students to be able to answer the questions correctly. One way to bring students closer to their daily environment. In the concept of acid-base identification, there are 2 (two) types of indicators, those are natural and artificial indicators. Natural indicators are derived from leaves, flowers, rhizomes and other parts of plants which is exist in nature. Based on the condition of each group, the plants used include *Bougainville* flowers, *sechium edule*, orange peels, *pandanus* leaves, mangosteen peels, and *alternanthera* leaves.

In general, those materials are easily obtained by students, such as decorative plants grown in their yard or garden, or from their immediate environment. They can utilise waste materials such as orange peel and mangosteen peel. The ingredients are then processed in several ways:

a. pound the peels (e.g., orange peel, mangosteen peel) using a mortar and pestle until it is smooth, add a small amount distilled water have it filtered to get the extract;

b. boil the extract first, then let it cool at room temperature.

The extracts were then tested on several solutions, namely: HCl, H_2SO_4, NaOH, detergent water, promag drugs, tomatoes, dishwash, and vinegar depending on the choice of each group. The following are the results of each group.

Table.1. Student Observation Results

Group	Natural Materials	Extract colour	Colour in acid solution	Colour in base solution
1	*Bougainvillea*	pink	bright purple	greenish yellow
2	*Sechium edule*	green	bright green	green
3	Orange peel	yellow	yellow	bright yellow
4	*Pandanus* leaf	yellowish green	bright yellow	yellow
5	Mangosteen peel	brownish purple	pink orange	gold yellow
6	*Alternanthera* leaf	purple	pink	brownish green

Based on the results of those experiments, the extracts of natural ingredients that can be used as indicators of acid-base are mangosteen peel, *Bougainvillea*, and *Alternanthera* leaf. It is because these three extracts gave a different colour when added to acidic or basic solutions, while the other ingredients did not show contrasting colour difference. The lack of contrasting colour could be attributed to suboptimal extraction processes. In a study conducted by Wasito, et al. (2017), the extraction process for various natural ingredients begins with washing all parts of the plant, reducing its size by cutting, and subsequently drying under the sun while covered with a black cloth. The dried plants or simplicia were then pulverized and extracted to maceration using a 96% ethanol solvent for a day. However, the students did not follow this elaborate procedure and instead opted for a simpler approach in extracting the natural ingredients. Based on the results of the assessment of acid-base indicator tests, that the following observations were made:

- 82% of students demonstrated knowledge of the definition of acid-base indicators
- 45% of students were aware of the types of acid-base indicators based on their source/method of manufacture
- 42% of students understood that not all natural ingredients can be used as indicators of acid-base reactions

Hence, the students exhibited a strong understanding of the definition of acid-base indicators. However, there is a lack of understanding regarding artificial and natural indicators, as well as the types of natural materials that can be used as indicators. Indeed, it becomes an obstacle in the implementation of PjBLs, as stated by Afriana (2015), namely:

a. students who struggle with experimentation and information gathering may experience difficulties;
b. if the topics given to each group are different, the students may not be able to understand the topic.

Learning with the PjBL model is recommended in the 2013 curriculum because it effectively increase student's interest and involvement in authentic problem-solving, group work, and building solutions for real world issues (Afriana, 2015). However, when implementing the STEM-PjBL model to students who have lower cognitive levels, the teacher needs to exert extra effort to provide guidance and motivate students. This presents a challenge for the teachers (Han et al, 2015).

2. Chemistry Online Learning with the STEM Approach During the Covid-19 Pandemic

Since 2013, due to Distance Learning Program in SMAN 2 Padalarang has

commonly using Edmodo, Moodle, SIERRA and SIAJAR. Since 2019, most of teachers in the school have tried to use Edubox. In the middle of March, when the Corona virus invaded Indonesia, learning completely switched to the online system using Edubox. Besides Edubox, various digital services like *Rumah Belajar,* Kahoot, Quizizz, Browser (Chrome), YouTube, Weebex Meeting, and WhatsApp (WA) are used to support online learning at SMAN 2 Padalarang.

At that time the stages of learning chemistry with the new STEM PjBL model were implemented. Fortunately, at that time students had successfully tested the research design to create indicators of natural acid base. Due the rule of social distancing, students were unable to correct and repeat experiments, so we immediately moved to the communication stage. I guided students in analysing the results of their research trials through the WA Group. We then proceeded to the communication stage with video conference via Cisco Webex. Furthermore, learning was evaluated through Edubox and Google Forms. There is documentation of learning chemistry with the STEM approach online during the COVID-19 pandemic.

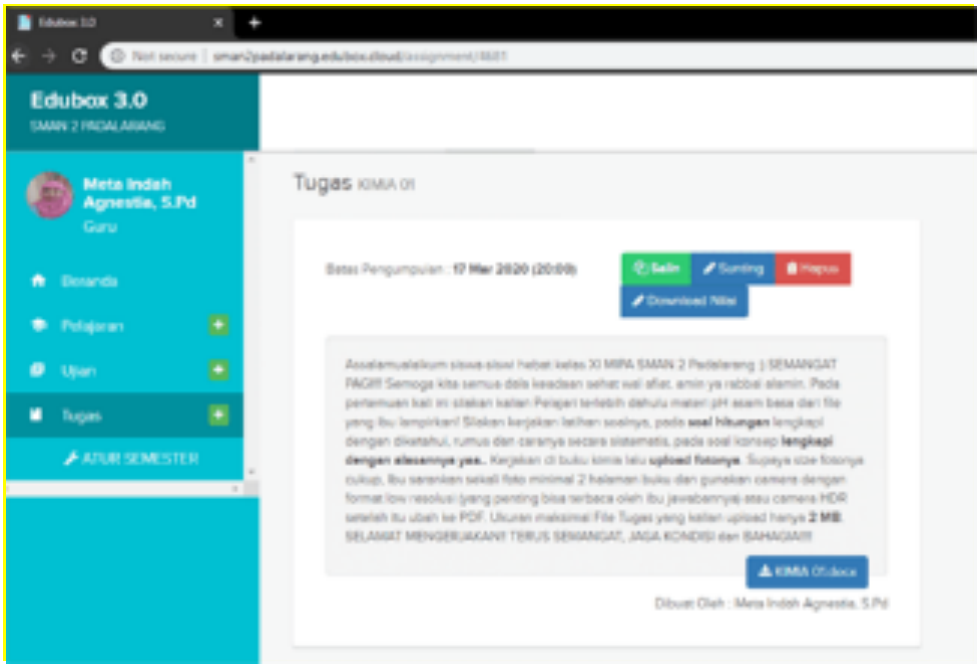

Figure 6. learning with Edubox applicatio

All groups planned to produce products in the form of simple acid-base indicator, which are easy to make and used for testing acidic/base substances. The props would be made in various forms of test paper, test equipment made from dacron, and test equipment in the form of paste from the extract.

Although the product in the form of acid-base test equipment came from natural materials has not been successfully made, students have managed to find natural ingredients that can be used as indicators of natural acid-base. Out of the six (6) tested natural ingredients, only three (3) samples can be used as indicators of natural acid base. Failure is considered a natural part of the design process and an important step towards finding a successful solution (Jolly, 2017).

Therefore, the learning phases have been achieved through the STEM approach by obtaining the output of the process and the discovery of new types of natural materials that can be used as a reference indicators of natural acid base. Besides that, students have

successfully achieved the following learning outcomes:

3.10.1 Determine natural materials that can be used as indicators.

3.10.2 Identify the colour change of the indicator in various solutions.

3.10.3 Identify several acid-base solutions with several indicators.

4.10.1 Identify problems related to healthy canteens.

4.10.2 Develop the best procedure for testing healthy foods based on pH criteria.

Conclusion

The STEM approach can be used as a variation in chemistry learning so that students feel happy and interested in mastering chemical concepts. The STEM approach can be utilised in online learning during the COVID-19 pandemic. The teacher guides students to analyse experimental and communication data uses the Cisco Webex, Edubox, and WA Group applications. Plant parts come from the environment around students can be used as indicators of natural acid-base properties, but student's knowledge about the nature of acid-base in school snacks is not yet known. It is because students cannot conduct the test due to the enforcement of social restrictions during the COVID-19 period.

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