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The Framework of RBL-STEM Learning Activity: Improving Students' Climate Change Literacy in Solving the Problem on Forecasting the Nutrition Supply of Hydroponic Plants with GNN

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ABSTRACT: This paper aims to develop the learning activity framework for the RBL model integrated with the STEM approach, especially in improving the students' climate change literacy in solving the problem on forecasting the nutritional supply of hydroponic plants using machine learning of GNN technique. It is using qualitative research which involves some bibliography study and analytical study. The findings are presented in a table containing six stages, namely stages 1-6. Each stage explains how students learn to collect data using IoT software, namely Thingspeak to collect some agriculture data, and by using Python under Google Colab platform we implement Graph Neural Networks (GNN) in RBL-STEM learning model. The main findings of this research related to RBL-STEM learning is to develop the learning activity framework in solving the problem of forecasting the nutritional needs of hydroponic plants using Thingspeak and google colab software to improve students' climate change literacy described in stages 1-6. This research also included the development of a framework in improving the students' climate change literacy in solving the problem on forecasting the nutritional supply of hydroponic plants using. The implication of the findings of this study is that the learning activity framework is ready to be continued in the process of developing RBL-STEM teaching materials to improve students' climate change literacy in solving the problem on forecasting the nutritional needs of hydroponic plants machine learning of GNN technique.

KEYWORDS: Climate change literacy, Graph neural network (GNN), Nutrition needs of hydroponic, RBL-STEM.

INTRODUCTION

Climate change is an important issue that poses a serious threat to all people on earth. As is well known, the increasing global warming has caused climate change that has adverse impacts on all aspects of human life. One thing is for sure, this issue is not a problem that can be solved by itself without efforts to take concrete actions. Moreover, the world's global temperature is getting higher and higher over time (Limaye *et al*., 2022). The Meteorology, Climatology and Geophysics Agency (BMKG) participated in the National Dialogue 'Anticipating Climate Change Impacts for a Golden Indonesia 2045' organized by the National Development Planning Agency (BAPPENAS). The Minister of National Development Planning and Head of the National Development Planning Agency (BAPPENAS), warned that the impacts of climate change threaten the economy in Indonesia. "It is estimated that in the period 2020-2024 climate change will cause economic losses, therefore a policy intervention is needed (Djalante *et al*., 2021). Paris Climate and Atmosphere Researcher Erma Yulihastin said that in January 2023 the European Center for Medium-Range Weather Forecasts (ECMWF) stated that global warming is expected to reach. In 30 years, this global warming could continue until it reaches 1,5ºC in March 2023. He explained that climate change in Indonesia has different impacts and effects in each region in Indonesia (Hong *et al*., 2023).

According to YouGov survey results, released in December 2020, Indonesia is one of the countries with the highest number of climate change deniers today. The YouGov survey results show that around 21 percent of Indonesians say that climate change is not real or that humans are not responsible for climate change. In other words, they believe climate change is not man-made. Therefore, climate change literacy needs to be promoted, especially in education. Having adequate knowledge and understanding of climate change is now necessary, among other things, to reduce the risks of climate change. Climate change literacy has become an emerging research topic, with the main focus on stabilizing the Earth's climate by 2025 (Otto *et al*., 2020). According to Limaye *et al*, (2020), climate literacy is defined as essential knowledge of the principles of climate science, in addition to basic concepts of climate change. In addition, climate literacy also includes awareness of climate change and readiness to deal with related ideas, topics and issues (Daniš *et al*., 2013). In other words, climate literate individuals are experts in the principles of climate science and can assess information and clearly communicate climate change and take responsible action to reduce unsustainable practices that negatively impact the environment. According to Anderson (2012), climate change is an interdisciplinary study that focuses on sustainable development goals. Therefore, the integration of climate topics into the education system will prepare the educated to be aware of and have the ability to solve this problem. In conclusion, climate literacy, if integrated into the education system, will help the younger generation, especially university students, to better understand the impact of climate change and its impact on humanity (Kuthe *et al*., 2019). The six key indicators of climate change literacy are shown in Table 1 (Hoydis *et al*., 2023).

Table 1. Indicators and Sub-Indicators of Climate Change Literacy

No.	***Indicator***	***Sub-Indicator***
I.	Basic understanding of climate change	Ability to explain how climate change occurs due to increased greenhouse gas emissions
II.	Realizing the impact of climate change	Awareness of the increasing frequency of droughts and floods due to climate change
III.	Ability to conduct research related to climate change	Ability to conduct research related to sustainable climate change solutions from simple to complex
IV.	Understanding the causes of climate change	Understanding some of the human activities that cause climate change to occur, such as deforestation, waste accumulation, land, water, air pollution, fossil fuels etc
V.	Understanding solutions to overcome climate change	The ability to address climate change, such as renewable energy, sustainable agriculture. Bio-technology, waste management, clean environment, sanitation, flood prevention, etc
VI.	Ability to communicate related to climate change	Ability to explain the impact of climate change to others, related parties, and the agricultural community and then discuss to develop ways or policies to reduce the impact of climate

One way that can be applied is by forecasting the nutritional needs of hydroponic plants. This activity allows students to understand how climate change can affect agriculture, including hydroponic farming. They can understand changes in weather patterns, water availability and temperature that can affect plant growth in hydroponic systems. Climate change literate students can identify relevant climate variables, such as average temperature, rainfall and humidity. They can understand how changes in these variables can impact the nutrition supply of hydroponic plants. As such, students can link the nutrition supply of hydroponic plants to a reduced carbon footprint and more efficient water use (Gonzalez *et al*., 2020). Forecasting the nutrition supply of hydroponic plants can use GNN techniques by utilizing Internet of Things (IoT) technology, google colab, and other software. Knowledge of forecasting and GNN techniques can help students plan hydroponic plant growth in climate change scenarios. They can understand how forecasting techniques and can help adapt plant growth to climate variability. Climate change literacy and an understanding of forecasting can help students formulate scientific solutions to the challenges of hydroponic farming. This could include selecting plant varieties that are more resistant to climate change or adjusting planting schedules based on weather predictions (Garcia *et al*., 2020).

The rapid development of science and technology has a major impact on human life. Many conveniences and innovations are obtained with the support of digital technology. Therefore, to take advantage of opportunities and answer the challenges of the industrial revolution 4.0, research-based learning (RBL) is needed in higher education. Research Based Learning is learning that requires students to be able to find, explore (develop knowledge) to solve the problems at hand, and then test the truth of that knowledge. The learning interaction between students and lecturers is an active interaction. Lecturers act as facilitators and mediators in order to bring students to achieve the expected competencies (Mufidah *et al*., 2023). The stages in RBL consist of the exposure, experience, and capstone stages (Dafik *et al*., 2023). These three stages can be developed into six steps, according to Dafik (in Suntusia

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et al., 2019), namely background problems, problem formulation, hypotheses, data collection, discussion, and conclusions. The utilization of technology in forecasting the nutritional needs of hydroponic plants can use the STEM approach. The STEM (Science, Technology, Engineering, and Mathematics) approach is an approach that is currently used at various levels of education to produce superior human resources and can compete in the world of education because STEM (Science, Technology, Engineering and Mathematics) can require students to study and review scientifically which can be useful for their daily lives. According to Astuti *et al*., (2021), STEM consists of four aspects of learning, namely science (Science) is knowledge that has been accumulated over time from a scientific examination that can produce new knowledge. Technology is the skills possessed in knowing how new technologies can be developed, skills in using technology and technology that can facilitate human work. Engineering is the knowledge of the design, design and creation of man-made objects in order to solve problems. Mathematics is the study of patterns and relationships between space, quantity, numbers, and structure. The challenge of rapidly growing globalization faced by teachers is to provide a platform in running the education system so as to create opportunities for students to link knowledge and skills. According to Dafik *et al*., (2023), the STEM approach is the latest learning that is currently recommended by experts to be applied at every level of education, because in the STEM approach students can gain various skills such as critical analysis, group work, creativity, collaboration, initiative, problem solving and digital literacy. These skills need to be possessed by students to be able to face the growing challenges of globalization.

The main objectives of this research are as follows: (1) Describe the structure of the RBL-STEM model learning activities to improve students' climate change literacy in solving the problem of forecasting the nutritional needs of hydroponic plants with GNN techniques, (2) Describe the framework for making teaching materials based on the model-STEM in solving the problem of forecasting the nutritional needs of hydroponic plants with GNN techniques, and (3) explain how the use of thinkspeak and google colab and teaching materials for the RBL-STEM model can improve students' climate change literacy in solving the problem of forecasting the nutritional needs of hydroponic plants.

METHOD

This research is a research and development that produces a framework of RBL-STEM learning activities. This research design refers to the R&D research design, namely ADDIE which stands for analysis, design, development, implementation and evaluation which can be seen in Figure 1 (Dick *et al*., 2015). Based on the results of the related literature review, we created an RBL-STEM learning activity design to improve students' climate change literacy in solving the problem of forecasting the nutritional needs of hydroponic plants with GNN techniques that serve to create RBL-STEM learning activities.

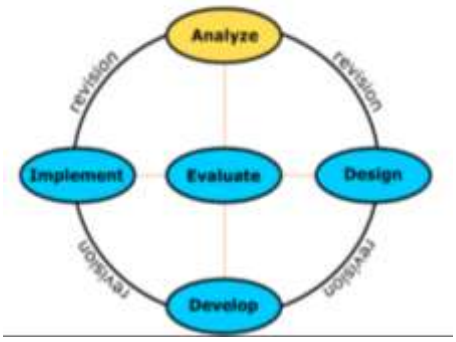

Figure 1. ADDIE Development Model (Branch, 2009).

RESEARCH FINDING

A. RBL-STEM Activity Framework

This learning activity aims to improve students' climate change literacy in solving the problem of forecasting the nutritional needs of hydroponic plants using the GNN technique. The syntax suggested by Nawawi *et al*. (2020) is the basis used to develop this activity framework. This RBL-STEM learning requires students to be more active in learning. The first stage that students must do is to

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understand the problem given and then determine how to solve the problem, followed by finding data and information through related literature. The RBL-STEM activity framework in this problem can be seen in Figure 2.

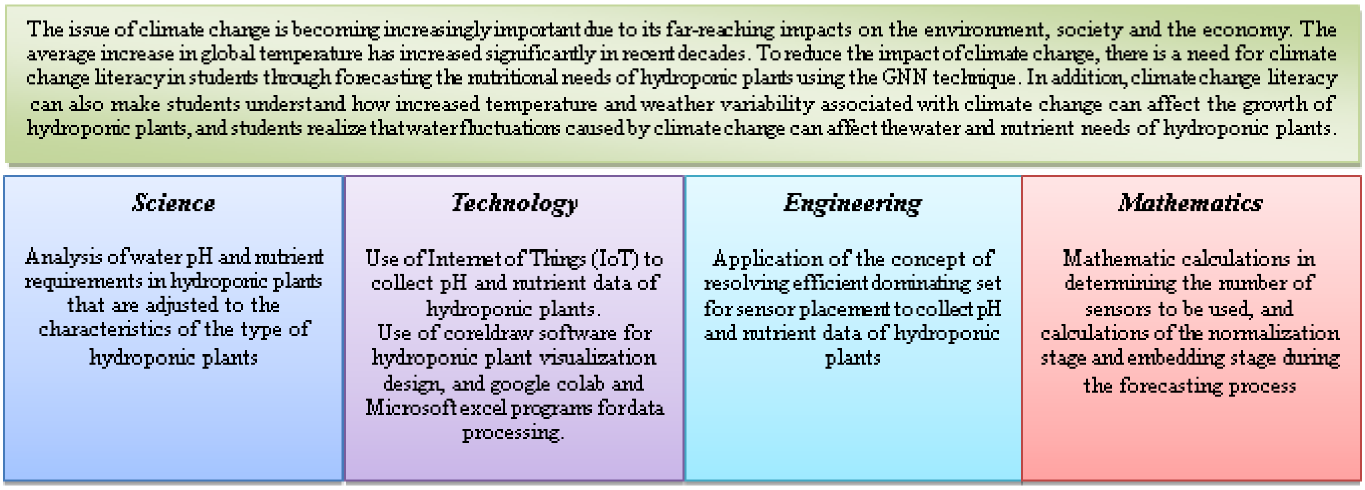

Figure 2. STEM problems in forecasting nutrition supply of hydroponic plants

B. RBL-STEM Learning Outcomes and Objectives

The expected learning outcomes are that students can predict the nutritional needs of hydroponic plants after the day of observation by utilizing the Internet of Things (IoT) and the google colab program in data processing, so that hydroponic plants are likely to grow and produce a good harvest in any current climate change The purpose of this learning is that students can gain knowledge and skills in the fields of science, technology, engineering, and mathematics through RBL-STEM learning.

1. Science - Students are expected to:
   a. Understand how climate change can affect hydroponic plant growth and its impact on nutrient availability.
   b. Understand the scientific basis of climate change and relate it to hydroponic plant growth.
   c. Be able to explain the mechanism of climate change and identify its impact on hydroponic plant growth through scientific analysis.
2. Technology - Students are expected to:
   a. Master forecasting techniques, especially GNN, and be able to apply them in forecasting the nutrition supply of hydroponic plants.
   b. Develop the ability to collect, analyze, and interpret weather data, average temperature, and water pH to forecast nutrition supply.
   c. Introduce students to advanced forecasting technologies, such as Internet of Things (IoT) and google colab to improve the effectiveness of hydroponic farming.
3. Engineering - Students are expected to:
   a. Apply the principles of hydroponic farming techniques in designing solutions that are adaptive to climate change and plant nutrition supply.
   b. Integrate hydroponic engineering principles in designing practical and efficient solutions.
   c. Determine the location of sensors using the concept of resolving efficient dominating sets for efficient and effective sensor locations.
4. Mathematics - Students are expected to:
   a. Collect, analyze, and interpret weather data and formulate mathematical models for crop nutrition forecasting.
   b. Develop their skills in collecting and analyzing weather data and formulating mathematical models for nutrient forecasting.
   c. Perform calculations at the normalization and embedding stages of the data obtained for the forecasting process of hydroponic plant nutrition supply.

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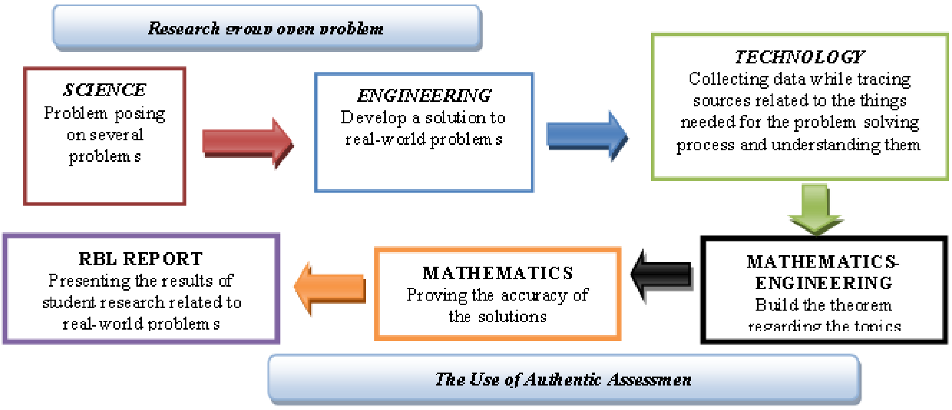

Figure 3. RBL-STEM framework in forecasting nutrition needs of hydroponic plants

C. STEM Problems

This research uses the RBL-STEM learning model to enable students to learn and develop knowledge and skills in Science, Technology, Engineering, and Mathematics. Some explanations of the elements of STEM are as follows:

1. Science elements

The issue of climate change is becoming increasingly important due to its far-reaching impacts on the environment, society and the economy. The average increase in global temperature has increased significantly in recent decades. To reduce the impact of climate change, there is a need for climate change literacy in students through forecasting the nutritional needs of hydroponic plants using the GNN Technique. Understanding the interaction between nutrients in hydroponic nutrient solutions and plants involves an understanding of chemical concepts, pH balance, solubility of mineral salts, and interactions between nutrient elements. Nutrients affect plant growth, life cycle, photosynthesis and metabolism. Plants respond to the hydroponic environment, including responses to applied nutrients and how this affects root and leaf development. Climate change affects nutrient availability, plant absorption and general plant development. In addition, the pH of the water plays a very important role in the growth and health of hydroponic plants. pH refers to the acidity or basicity of the nutrient solution or water used in a hydroponic system. It is important to carefully monitor and regulate the pH of the nutrient solution or water in a hydroponic system. The optimal pH range varies depending on the type of plant being grown. Generally, a pH range between 5.5 to 6.5 is considered optimal for most hydroponic plants. By keeping the pH within the right range, plant nutrients can be properly accessed by the roots, and plant growth can be optimized. A visualization of hydroponic plants can be seen in Figure 3.

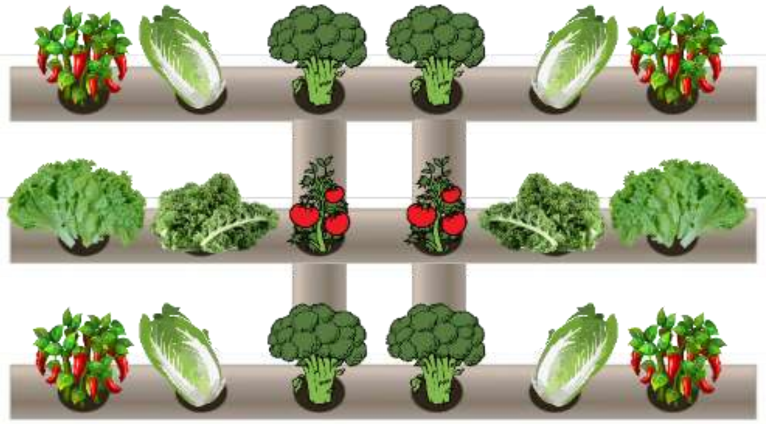

Figure 3. The illustration of hydroponic plants

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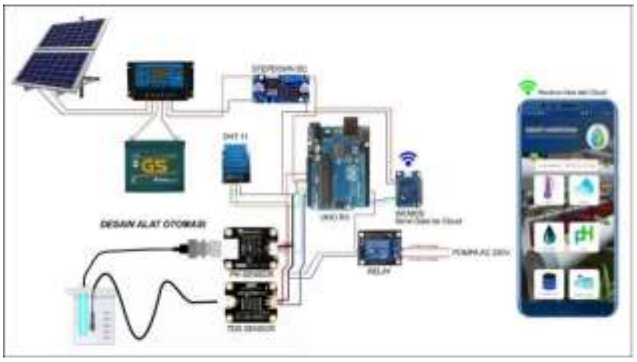

Figure 4. Sensor arrangement and how it works with IoT

2. Technology elements

The technological element associated with hydroponic plant nutrient requirement forecasting involves the use of modern technological tools, software and approaches to predict and manage plant nutrient requirements more effectively. The use of sensors connected to the hydroponic system to monitor important parameters such as pH, temperature, humidity, and nutrient levels. Data from these sensors can be used to forecast crop nutrient requirements. Technology that allows farmers to monitor the condition of the hydroponic system remotely via mobile devices or computers. This facilitates real-time monitoring and quick access to data. Furthermore, integrating sensors and devices in an IoT network to collect, share and analyze data in real time. This enables more accurate forecasting based on data from multiple sources. Special applications or software can help analyze weather, temperature, and humidity data, as well as forecast nutritional needs based on mathematical models and pre-set algorithms i.e. microsoft excel and google colab programs. An automation system that responds to changes in environmental conditions and nutrient requirements by adjusting nutrient doses according to forecasting. This minimizes human intervention and ensures consistent nutrient levels. These technologies help farmers or hydroponic farming practitioners to forecast plant nutrient requirements more precisely, optimize plant growth, and reduce potential risks due to environmental fluctuations.

The use of Google Colab and Microsoft excel software is one of the technologies used in analyzing the nutritional needs of hydroponic plants. The data used for analysis is simulative data downloaded from Kaggle, namely https://www.kaggle.com/datasets/chalimmufidah/hydroponic-plants-nutrition-data. The representation of hydroponic plants on the graph for laptop/PC display can be seen in Figure 5.

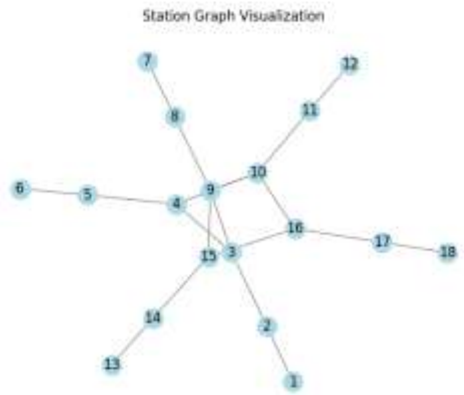

Figure 5. Graph representation of hydroponic plants

Microsoft excel is used for the normalization stage of the data that has been collected, then continued with the embedding and forecasting stage using google colab to determine the nutritional needs of hydroponic plants. The forecasting process on google colab uses 100 days of observation data, with 60% data division for training and 40% for testing. The first crop forecasting results can be seen in Figure 7, and the multi-step forecasting results for the next 14 days can be seen in Figure 8.

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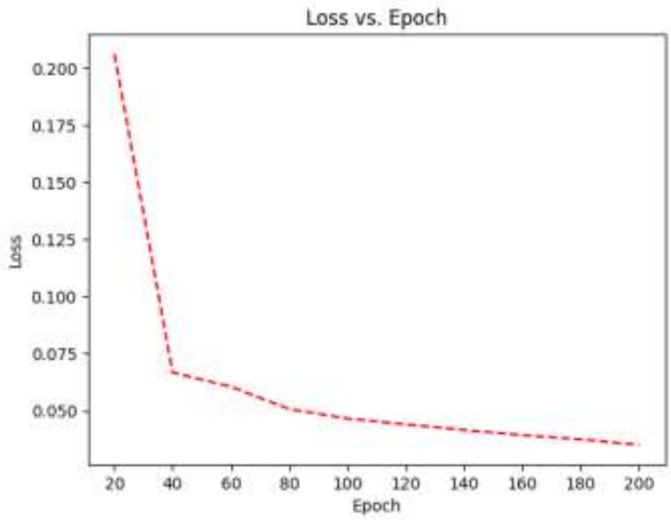

Figure 6. *Plot Loss vs. Epoch*

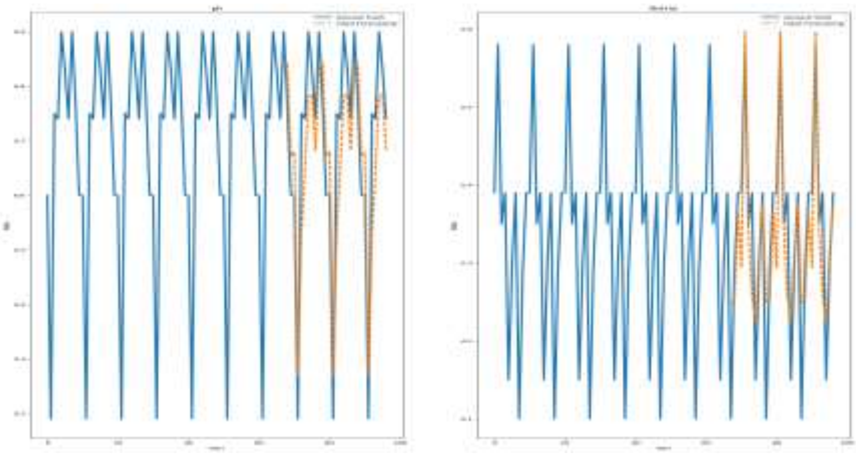

Figure 7. The first crop forecasting result

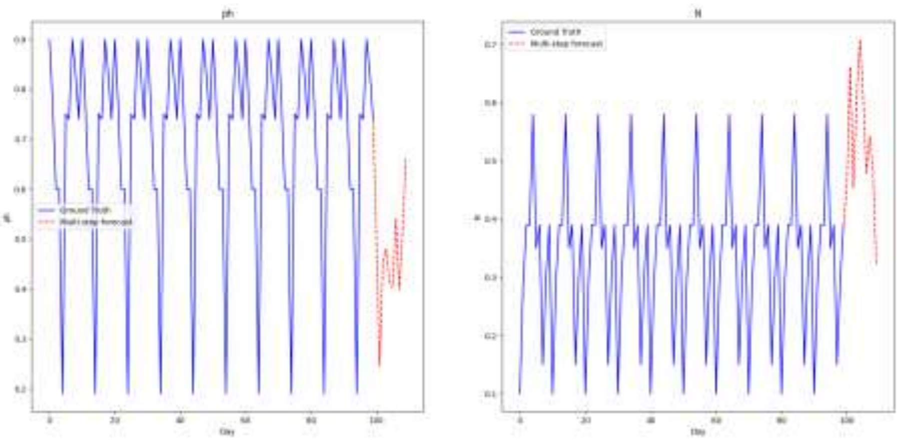

Figure 8. Multi-step forecasting results 14 days ahead

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3. Engineering elements

Engineering elements associated with forecasting the nutrient requirements of hydroponic plants involve the application of engineering principles to design, manage, and optimize forecasting systems. The technique used for sensor placement is the concept of resolving efficient dominating set. In addition, the concept is also used to group hydroponic plant types. The grouping of hydroponic plant types is obtained based on the point representation of the dominator, which can be seen in Table 2.

Table 2. Grouping of hydroponic plant types

Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
1,2,3,2,3,4	0,3,4,3,4,5	1,4,5,4,5,6	2,1,2,3,2,3	3,0,3,4,3,4	4,1,4,5,4,5
3,2,1,4,3,2	4,3,0,5,4,3	5,4,1,6,5,4	3,2,3,2,1,2	4,3,4,3,0,3	5,4,5,4,1,4
2,3,4,1,2,3	3,4,5,0,3,4	4,5,6,1,4,5			
4,3,2,3,2,1	5,4,3,4,3,0	6,5,4,5,4,1			

In Table 2, it can be seen that there are 6 types of plants that are efficiently dominating sets of differentiators, where columns 1, 2 and 3 have the same 4 sets, and columns 4, 5, and 6 have the same 2 sets. Therefore, researchers represent hydroponic plants with certain types based on the location of the set points. Researchers determine the type of plant by paying attention to current market needs and market prices that are relatively high and can be profitable. Researchers represent the types of plants in the graph, namely plant 1 as a broccoli plant, for plant 2 is chicory, plant 3 is chili, plant 4 is tomato, plant 5 is kale, and plant 6 is lettuce. An illustration of the selected plants based on the grouping of plant types is presented in Figure 9.

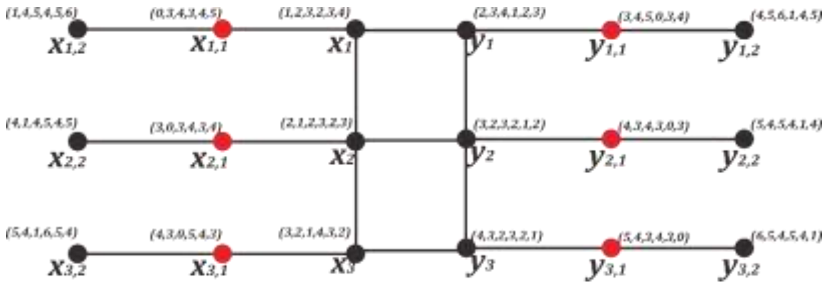

Figure 9. Illustration of the efficient completion set of the discriminator on the representation graph of hydroponic plants

4. Mathematics element

The mathematical element used in solving this problem is the calculation of the point representation of the dominators in the graph when applying the distinguishing efficient completion set to determine the number of sensors. Suppose G_A is a graph representing hydroponic plants. In this case we denote each plant to a point label x_{ij}, y_{ij} with $1 \leq i \leq 3$, $1 \leq j \leq 2$ so we get x_1, x_3, y_1, y_3 as a broccoli plant, $x_{1,1}$, $x_{3,1}$, $y_{1,1}$, $y_{3,1}$ as a chicory plant, $x_{1,2}$, $x_{3,2}$, $y_{1,1}$, $y_{3,2}$ as a chili plant, x_2, y_2 as a tomato plant, $x_{2,1}$, $y_{2,1}$ as a kale plant, and $x_{2,2}$, $y_{2,2}$ as a lettuce plant. In this math element, students prove theorems related to the topic of graphs of resolving efficient dominating set, one of which is the graph of $L_a \rhd P_b$ where the calculation is useful to solve the previous problem. Example of theorem proving on graphs $L_a \rhd P_b$ is as follows:
For every positive integer $a \geq 2$ and $b \geq 2$ so,

$$\gamma_{re}(L_a \rhd P_b) = a\left\lfloor\frac{b}{3}\right\rfloor + 1, \text{if } a \equiv 0,2(mod\ 4), \text{and if } b \equiv 1,3(mod\ 3)$$

Proof:
Calculate the cardinality of points and edges by writing down the set of points and edges first. The point set is $V(L_a \rhd P_b) = \{x_i, y_i, x_{ij}, y_{ij}; 1 \leq i \leq b, 1 \leq j \leq b-1\}$ and the set of edge is $E(L_a \rhd P_b) = \{x_i, y_i\ ; 1 \leq i \leq b\} \cup \{x_i x_{i+1}, y_i y_{i+1}\ ; 1 \leq i \leq b-1\} \cup \{x_i x_{i1}, y_i y_{i1}\ ; 1 \leq i \leq b\} \cup \{x_i x_{ij+1}, y_i y_{ij+1}\ ; 1 \leq i \leq b; j \geq b-2\}$. The cardinality of its vertex and edge is $|V(L_a \rhd P_b)| = 2ab$ and $|E(L_a \rhd P_b)| = 2ab + a - 2$. Next, write $D \subset V(G)$.

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$$D = \{ x_i, y_i; \left\lfloor \frac{1 \le i \le a}{3} \right\rfloor; i \equiv 2(mod)\ 4 \text{ for } b \equiv 1,3(mod)\ 3$$

We have $|D| = a\left\lceil \frac{b}{3} \right\rceil$, for $b \equiv 1,3(mod)3$.

Then we will prove that D is a distinguishing efficient dominating set with minimum cardinality. First, we will prove D satisfies the properties of the discriminating efficient dominating set. For every $x_{ij}, y_{ij} \in D, d(x_{ij}, y_{ij}) \ge 4$, so that $|N(x_{ij}, x_i, y_{ij}, y_i \in V(L_a \rhd P_b) - D) \cap D|$ is dominated by exactly one vertex in D.

Then we will prove that D is a distinguishing efficient dominating set with minimum cardinality. Suppose $|D_0| < a\left\lceil \frac{b}{3} \right\rceil + 1$, so we have $|D_0| = a\left\lceil \frac{b}{3} \right\rceil$ for $a \equiv 0,2(mod 4), b \equiv 1,3(mod 3)$. The possibilities that occur are as follows:

a. For $b \equiv 1(mod\ 3)$
   - If every vertex $x_1 \notin D_0 \to \exists x_1, x_i$ which is not dominated by D_0 so D_0 is not a resolving efficient dominating set.
   - If every vertex $\{x_{i,j}: 2 < i < a; 2 \le i \le b-2; j \equiv 2\ (mod\ 3) \notin D_0 \to \exists x_{i,j+1}, x_{1,j}, x_{1,j-1}$ which is not dominated by D_0 so D_0 is not a resolving efficient dominating set.

b. For $b \equiv 3(mod\ 3)$
   - If every vertex $x_{i,1} \notin D_0 \to \exists x_i, x_{i,1}, x_{i,2}$ which is not dominated by D_0 so D_0 is not a resolving efficient dominating set. set.
   - If every vertex $\{x_{i,j}: 1 < j < b-1; i \equiv 2\ (mod\ 4) \notin D_0 \to \exists x_{i,j+1}, x_{1,j}, x_{1,j-1}$ which is not dominated by D_0 so D_0 is not a resolving efficient dominating set.

Mathematics elements are also used in the calculation of the normalization stage and embedding stage. After the embedding stage, the forecasting stage is carried out which results in an MSE of 0.0320014201232412 obtained from running the google colab program as follows:

```
0%|            | 0/200 [00:00<?, ?it/s]Current epoch:0, current training loss:0.2063431739807129
10%|■          | 21/200 [00:30<02:43,  1.09it/s]Current epoch:20, current training loss:0.0667959675192833
20%|■■         | 41/200 [00:42<01:22,  1.92it/s]Current epoch:40, current training loss:0.060488417744636536
30%|■■■        | 61/200 [00:53<01:32,  1.50it/s]Current epoch:60, current training loss:0.050785891711711884
40%|■■■■       | 81/200 [01:03<01:03,  1.88it/s]Current epoch:80, current training loss:0.04658417031168938
50%|■■■■■      | 101/200 [01:14<00:49,  2.02it/s]Current epoch:100, current training loss:0.044034838676452 64
60%|■■■■■■     | 121/200 [01:26<00:44,  1.79it/s]Current epoch:120, current training loss:0.04157189279794693
70%|■■■■■■■    | 141/200 [01:36<00:34,  1.70it/s]Current epoch:140, current training loss:0.039305731654167175
80%|■■■■■■■■   | 161/200 [01:48<00:21,  1.84it/s]Current epoch:160, current training loss:0.03750203177332878
90%|■■■■■■■■■  | 181/200 [01:59<00:10,  1.89it/s]Current epoch:180, current training loss:0.03501053526997566
100%|■■■■■■■■■■| 200/200 [02:11<00:00,  1.53it/s] Current epoch:200, current training loss:0.0320014201232412
```

Figure 10. MSE of forecasting results

5. RBL-STEM Learning Activity on Forecasting the Nutrition Needs of Hydroponic Plants

RBL-STEM learning has six stages. These six stages describe the RBL-STEM learning process in solving the problem of forecasting the nutritional needs of hydroponic plants with GNN techniques to improve students' climate change literacy. More information about the stages in the RBL-STEM learning activities can be seen in the table below.

Table 3. The RBL-STEM Learning Activities in Science Aspect

First Stage	Learning Activities
Giving problems about forecasting nutrient needs in hydroponic plants whose solutions use graph neural networks and resolving efficient dominating sets	1) Lecturers ask questions to students regarding students' knowledge about the problem of providing nutritional needs in hydroponic plants. 2) Lecturers gave an overview of hydroponic plant design. Then asked students about their understanding of the problems posed. 3) Students are asked to record information about the problem posed

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Table 4. The RBL-STEM Learning Activities in Engineering Aspect

Second Stage	Learning Activities
Problem solving related to resolving efficient dominating sets.	1) Lecturers guide students to discuss solutions to solve the problems given using spatial temporal graph neural network and resolving efficient dominating set. 2) Lecturers provide an explanation of the problem of providing nutritional needs in hydroponic plants and graphs of the results of the problem representation. 3) Lecturer explains about spatial temporal graph neural network to analyze plants with the highest nutritional needs and plants with the lowest nutritional needs. 4) Students are asked to find the efficient domination number in a path graph

Table 5. The RBL-STEM Learning Activities in Technology Aspect

Third Stage	Learning Activities
Seek and collect information about problems and things that will be problem solving.	1) Students are asked to draw an illustration of the hydroponic plant system in a graph using the google colab and coreldraw programs based on the lecturer's instructions. 2) Students are given the opportunity to find information about spatial temporal graph neural networks and resolving efficient dominating sets from various reference sources. 3) Students discuss the information obtained about spatial temporal graph neural network and resolving efficient dominating set and note important things for problem solving.

Table 6. The RBL-STEM Learning Activities in Mathematic Engineering Aspect

Fourth Stage	Learning Activities
Find theorems on the topic of resolving efficient dominating set of some graphs and analyze the solution of the given problem.	1) Students select a graph and perform point labeling by labeling the points in the graph using numbers from 1 to the number of vertex in the graph. 2) Students identify the set of vertex, edges, many vertex, and many edges. 3) Students determine the cardinality of vertex and edges. 4) Students determine the dominator by selecting the vertex that dominates the neighboring vertex, provided that no vertex is dominated by at least 2 dominator vertex. 5) Students calculate the distance of the set of each vertex to the dominator such that the distance to all vertex is different from one vertex to another. 6) Students write theorems based on the observations made.

Table 7. The RBL-STEM Learning Activities in Mathematic Aspect

Fifth Stage	Learning Activities
Prove the theorem found on the topic of resolving efficient dominating set solution of the given problem.	1) Students identify the vertex set, edge set, many vertices, and many edges of the selected graph. 2) Students prove the upper bound of the theorem they wrote using the representation of the distance of each vertex by checking that all points have different distances. 3) Students prove the lower bound of the theorem written using contradiction. 4) Students create a representation table of the distance of each vertex to the dominator in the graph in general.

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	5) Students take one particular order of the selected graph, to illustrate the discriminating efficient dominating set. 6) Students analyze the potential for anomaly and no anomaly based on data processed through Microsoft excel and google colab.

Table 8. The RBL-STEM Learning Activities in RBL-Report Aspect

Sixth Stage	Learning Activities
Present the results obtained regarding problem solving and theorems obtained on the topic of resolving efficient dominating sets.	1) Students make a research report on the use of resolving efficient dominating sets to solve the problem of forecasting nutritional needs in hydroponic plants. 2) Students make a report on the process in the spatial temporal graph neural network to analyze plants with high nutritional needs and plants with low nutritional needs. 3) Lecturers evaluate and provide reinforcement regarding students' understanding obtained from the research process carried out previously. 4) Lecturers make observations of students' conjecturing skills using an observation sheet.

6. The Instrument Framework for Student's Climate Change Literacy Test

The instrument framework used to evaluate students' climate change literacy skills is presented in Table 9.

Table 9. The Instrument Framework for Student's Climate Change Literacy Test

No.	*Indicator*	*Sub-Indicator*	*Test Material*
I.	Basic understanding of climate change	Ability to explain how climate change occurs due to increased greenhouse gas emissions	• Explains what is meant by "greenhouse gases" and how increased emissions of these gases can lead to climate change. • Explain how climate change can affect the nutritional requirements of hydroponic plants.
II.	Realizing the impact of climate change	Awareness of the increasing frequency of droughts and floods due to climate change	• Express an opinion on the increased frequency of droughts considered as an impact of climate change and explain how this relates to hydroponic farming. • Explain the contribution of climate change to increased flood risk in the context of hydroponic farming.
III.	Ability to conduct research related to climate change	Ability to conduct research related to sustainable climate change solutions from simple to complex	• Explain the difference between simple and complex climate change solutions in the context of hydroponic farming. • Provide examples of simple and complex solutions to address climate change and improve the nutritional quality of hydroponic crops.
IV.	Understanding the causes of climate change	Understanding some of the human activities that cause climate change to occur, such as deforestation, waste accumulation, land, water, air pollution, fossil fuels etc	• List and explain three human activities that can cause climate change and how they impact hydroponic farming. • Provide reasons why deforestation and fossil fuel use are major concerns in the context of climate change and hydroponic farming.
V.	Understanding solutions to	The ability to address climate change, such as renewable energy, sustainable	• Define renewable energy

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	overcome climate change	agriculture. Bio-technology, waste management, clean environment, sanitation, flood prevention, etc	• Give examples of how renewable energy can be utilized to reduce the impact of climate change in the context of hydroponic farming. • Explains how sustainable agriculture can help reduce the impact of climate change on hydroponic farming.
VI.	Ability to communicate related to climate change	Ability to explain the impact of climate change to others, related parties, and the agricultural community and then discuss to develop ways or policies to reduce the impact of climate	• Explain how climate change impacts can affect the hydroponic farming community. • Conduct a discussion on steps to reduce the impact of climate change, then present it.

7. The Framework of Learning Material Development Process

The ADDIE framework (Analysis, Design, Development, Implementation, Evaluation) is a commonly used approach in the development of learning materials. The following ADDIE framework is customized for the development of RBL STEM learning materials on forecasting the nutritional needs of hydroponic plants:

a. Analysis

In this analysis stage, the first step is to determine the objectives that students want to achieve after completing the learning material. Furthermore, identifying student needs, key challenges, and skills that need to be mastered in the context of hydroponic plant nutrition forecasting, the skills to be improved are student climate change literacy. In addition, determining the type of data to be used, data sources, and technology to be applied.

b. Design

At this stage, selecting learning strategies that fit the context i.e. RBL STEM, such as simulations, case studies, experiments and discussions. In addition, it also designs the content of the learning materials, including forecasting concepts, hydroponic principles, technologies used, and mathematical models involved. Determining the software or application that will be used in learning. The final step in this design stage is to plan practical activities in learning, such as student worksheets, pretests and posttests, and climate change literacy test instruments.

c. Development

The next step is to assess the validation and effectiveness of the developed learning materials. The validation process includes an assessment of the content, format, discussion, and level of application of the instrument.

d. Implementation

At this stage is a learning session that is adjusted to the plan, involving students in RBL-STEM activities such as data collection and analysis. The RBL-STEM learning model in solving the problem of forecasting the nutritional needs of hydroponic plants with GNN techniques to improve students' climate change literacy is also evaluated at this stage, how well and effectively it is applied.

e. Evaluation

The last stage is evaluation, which assesses the extent to which students achieve the learning objectives and master the targeted climate change literacy skills based on the implementation of the RBL-STEM learning model. The evaluation is also to see the effectiveness of the technology used in learning, whether it successfully integrates data and supports learning. Based on the evaluation results, it is followed by the identification of areas that need to be improved and refined for further development.

DISCUSSION

In the changing global context of climate change, it is important for the younger generation, including university students, to have a deep understanding of the impacts of climate change as well as the ability to overcome these challenges. This article outlines an RBL-STEM learning activity framework that aims to improve students' climate change literacy through understanding and application in solving the problem of forecasting the nutrient requirements of hydroponic plants using GNN techniques. We discuss the importance of the RBL-STEM approach, the link between climate change literacy and sustainable agriculture, and the potential contribution of students in climate change mitigation. The RBL-STEM learning model allows students to connect scientific concepts with practical applications in real situations. In the context of forecasting the nutrient needs of hydroponic plants, RBL allows students to experience the challenges of modern agriculture related to climate change. This involves collecting weather data, analyzing and applying GNN techniques to forecast nutrient requirements. This process encourages a deeper understanding of the impact of climate change on agriculture as well as the importance of adjustments.

This article's discussion emphasizes that climate change literacy is not only about theoretical understanding, but also application in real solutions. By designing a learning activity that combines climate change literacy concepts with hydroponic crop nutrient forecasting, students have the opportunity to understand the impacts of climate change on sustainable agriculture. They can identify the important role of technologies and techniques in mitigating these impacts, such as renewable energy, sustainable agriculture and waste management. Through this learning activity, students not only become understanding individuals, but also potential agents of change in facing climate change challenges. By integrating climate change literacy with nutrition demand forecasting techniques, students are empowered to design sustainable and innovative solutions. This could involve improving efficiency in resource use, implementing green technologies, and more adaptive agricultural approaches to environmental change.

This activity framework was created for RBL-STEM learning activities utilizing the Internet of Things and is essential for improving students' climate change literacy skills. This framework was developed using the R&D research model ADDIE. This paper serves as a guide for researchers to take additional actions related to their research. There are two additional research outcomes in this paper, namely: (1) making RBL-STEM teaching materials using the ADDIE development model and (2) analyzing RBL-STEM teaching materials to improve students' climate change literacy skills in solving the problem of forecasting the nutritional needs of hydroponic plants. According to the results of research by Mufidah *et al*, (2023), RBL-STEM learning activities are effective in improving students' thinking skills.

CONCLUSION

The RBL-STEM learning model in order to improve students' climate change literacy through forecasting the nutritional needs of hydroponic plants with GNN techniques has great potential in producing a generation that is more aware and empowered in facing the challenges of climate change. Through deeper understanding and practical application, students have the opportunity to actively contribute to creating sustainable solutions and driving positive change in the face of global climate change. The RBL-STEM learning model shows that integrating climate change concepts with hydroponic plant nutrition forecasting techniques provides a real context for students to develop their understanding. Through a combination of problem-based learning, simulation and practical experience, students not only honed their climate change literacy skills, but also developed the ability to apply these concepts in broader situations.

In this context, this article has underscored the importance of integrating climate change literacy in STEM learning approaches. Through RBL-STEM, students can experience how scientific, technological, engineering and mathematical concepts are not only relevant in a classroom setting, but also in facing real-world challenges. By integrating climate change literacy and the application of forecasting techniques, this approach provides students with a solid foundation to face future environmental and agricultural issues.

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