Assimilation: Indonesian Journal of Biology Education
ISSN 2621-7260 (Online)
Journal homepage: https://ejournal.upi.edu/index.php/asimilasi

Using PhET simulation as guided inquiry-assisted virtual biology laboratory to enhance science literacy skills of junior high school students in West Lampung

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OPEN ACCESS

ARTICLE HISTORY
Received: 23 January 2025
First Revised: 19 March 2025
Accepted: 30 March 2025
First Available Online: 30 March 2025
Publication Date: 30 March 2025

KEYWORDS
Guided inquiry
PhET simulation
Science literacy skills
Virtual laboratory

ABSTRACT

This study aims to determine the effect of implementing a guided inquiry model with assistance PhET simulation as virtual laboratory towards improving students' scientific literacy skills. This study used quasi-experimental Pretest Posttest Non-Equivalent Control Group design. The population consisted of 134 students, while the sample was taken from 51 students using the Purposive Sampling technique by considering samples that have equivalent levels of ability. The experimental class was given treatment using a guided inquiry model assisted by Virtual Laboratory PhET Simulation, while the control class used a guided inquiry model. Data on students' scientific literacy skills were obtained from pretest and posttest scores. The results of the N-gain test showed an average increase in the experimental class's scientific literacy skills of 0.53 (moderate category) and the control class of 0.28 (low category). Furthermore, an Independent Sample T-Test was conducted to determine the effect of PhET Simulation as Guided Inquiry-Assisted Virtual Biology Laboratory on the Science Literacy Skills, obtained Sig.0.00. Based on the Independent Sample T-Test, it is known that there is an effect of implementing a guided inquiry model assisted by Virtual Laboratory PhET Simulation on improving scientific literacy skills. The effect size test was also conducted and obtained a value of 1.78 with an interpretation of the effectiveness level in the large category. Thus, it can be concluded that the implementation of the guided inquiry model assisted by the Virtual Laboratory PhET Simulation has a significant effect on improving students' scientific literacy skills.

INTRODUCTION

Scientific literacy is an important aspect that must be possessed by students in this century because someone who has scientific literacy skills will be able to think critically, solve problems, and make decisions based on scientific facts and evidence, not just opinions or myths (Bae et al., 2023; Pratiwi & Aminah, 2019). Scientific literacy enables students to understand and face global challenges such as climate change, health, and environmental pollution. Scientific literacy skills help individuals understand these issues so that they can be actively involved in finding solutions and making wise decisions regarding policies or daily actions that affect the environment and society (Jeramat et al., 2024). In addition, students will also have the ability to read and understand articles about scientific knowledge and communicate them in social conversations (Kristyowati & Purwanto, 2019).

However, in fact, the scientific literacy skills of students in Indonesia at the international level are still very low. This is stated in the PISA assessment standard data. Based on the results of PISA in 2022, Indonesian students' scientific literacy was ranked 67th out of 81 countries with a score of 383 (OECD, 2023). The data shows that Indonesia's scientific literacy ranking has increased by 6 positions compared to 2018. In 2018, Indonesian students' scientific literacy was ranked 71st out of 79 countries with a score of 396 (OECD, 2019). Although there has been an increase in Indonesia's scientific literacy ranking, this increase has not been able to reach the desired standard. Indonesia is still at the bottom.

There are several factors that play a role in causing low levels of scientific literacy. These factors include internal and external factors. Internal factors are factors from within the student who thinks that science is difficult to understand (Novita et al., 2021), while external factors are the inappropriate use of learning models, learning strategies, approaches and learning methods used by teachers in the classroom. In addition, learning media, textbooks and evaluation tools in the form of scientific literacy instruments that are less supportive cause low scientific literacy (Setyowati, 2022). Based on the results of observations at one of the schools in Lampung province, the learning process in the classroom is theoretical and still centered on the teacher, the learning resources used are only focused on printed books and there is no special learning media used in science subjects. The lack of technology integration in learning and the use of limited laboratory facilities also cause low scientific literacy (Adnan & Zakaria, 2020).

Students' scientific literacy skills can be developed by teachers by using the right learning model. The right learning model is a learning model that actively involves students in the learning process (Clark et al., 2020). One of them is the guided inquiry learning model. The guided inquiry learning model is a learning model that emphasizes the process of discovering concepts and relationships between concepts where students conduct their own experiments and the teacher only guides. The Guided Inquiry learning model is a model that can be constructive (building) for students to investigate problems and seek information about problems in the learning process (Rambe, 2020). In applying the guided inquiry model to the learning process, teachers do not let students passively participate in learning activities, but involve them actively (Pierce, 2012). Thus, students who have slow thinking skills or low intelligence can still participate in ongoing activities. On the other hand, students who have high-level thinking skills will not dominate all learning activities, thus creating an inclusive and student-centered learning environment.

The use of guided inquiry models can be integrated with various interactive learning media, such as the use of virtual laboratories. Virtual laboratories are experimental simulations that allow students to explore scientific concepts and principles in a virtual environment. These simulations can be used to complement or replace real laboratory experiences (Sellberg et al., 2024). The main purpose of virtual laboratories is to allow experiments to be conducted digitally, with an experience similar to a conventional laboratory.

One of the virtual laboratories that can be used is PhET simulation. PhET is an interactive computer simulation developed by the University of Colorado. PhET provides simulations with a

DOI: https://doi.org/10.17509/10.17509/aijbe.v8i1.80287
e-ISSN 2621-7260

variety of topics and applications of real concepts that are relevant in the fields of physics, chemistry, biology, and mathematics (Saudelli et al., 2021). PhET provides a virtual experimental experience. PhET simulation is superior to other virtual laboratories because it provides interactive, fun, research-based science learning simulations that can be used to improve learning effectiveness (Zulkifli et al., 2022). These simulations are in the form of animations and are interactive and like games. In addition to its flexibility of use in various learning models, PhET is also efficient in terms of time and cost (Perkins et al., 2006). One of the goals of PhET simulation is to provide media that can be used by students to explore when learning certain concepts (Sylviani, 2020).

Research on guided inquiry models and science literacy skills has been conducted by several previous researchers. Erdani (2020) has conducted research on the effect of using guided inquiry models on students' science literacy skills. In this study, researchers only focused on the use of guided inquiry learning models but have not integrated them with virtual laboratory learning media. The study shows that guided inquiry models make a good contribution to improving various aspects of students' science literacy. Supported by research by Gormally et al. (2009) which found that inquiry-based learning can improve science literacy skills. Qahfi (2022) has conducted research on guided inquiry learning models integrated with virtual laboratories, but in this study it is still limited to measuring learning outcomes only. Then Aina & Haryono (2023) have conducted research on the application of PhET simulations in learning science literacy skills, in this study researchers only focused on the use of PhET simulation media but have not integrated them with inquiry learning models. The results of this study prove that PhET can improve students' science literacy. Based on previous research, there has not been much research that focuses on research that integrates guided inquiry with PhET simulations in improving students' scientific literacy in Indonesia.Based on the problems described above, the researcher is interested in conducting research that aims to determine the effect of implementing the guided inquiry model assisted by PhET virtual laboratory simulations on improving students' scientific literacy skills

METHODS

This research was conducted during the even semester of the 2023/2024 academic year, specifically in May, at one of junior highschool Liwa, located on Balik Bukit District, West Lampung Regency. The population in this study consisted of seventh-grade students in junior high schools across Lampung. The sample was selected using purposive sampling technique by considering samples that have equivalent levels of ability. The experimental class used in this study was class VII-3, consisting of 25 students, while the control class was class VII-4, consisting of 26 students. The research design applied was a quasi-experimental design in the form of a non-equivalent control group design.

The types of data used in this study were quantitative and qualitative data. Quantitative data were obtained from pretest and posttest scores given to both classes during the learning process. Meanwhile, qualitative data were obtained from the analysis of observation sheets that assessed the implementation of learning using the guided inquiry model assisted by the PhET Simulation virtual laboratory. The material used in the PhET Simulation virtual laboratory is specific to the material on the interaction of living things. In the learning process, students are given Student Worksheets that must be answered after students observe and analyze the material in the PhET Simulation virtual laboratory.

The data collection techniques used in this research were tests and observation sheets. The test was used to assess students' scientific literacy skills by administering a pretest before the learning process began and a posttest after it was completed. Before using the instruments in the study, prerequisite tests were conducted, including validity testing using Pearson Product Moment

DOI: https://doi.org/10.17509/aijbe.v7i2.69055
e-ISSN 2621-7260

Correlation Bivariate, reliability testing using Cronbach's Alpha correlation technique, as well as discrimination index and difficulty level tests.

Students' scientific literacy skills data were obtained from pretest and posttest scores. The pretest and posttest scores were then used to calculate the Normalized-gain (N-gain) using Microsoft Excel. Furthermore, the researcher conducted a statistical test using SPSS for normality testing using the Kolmogorov-Smirnov test, and homogeneity testing using the Levene test. Data that were normally distributed and homogeneous were subjected to hypothesis testing using the Independent Sample T-Test. Finally, the effect size test was conducted using the Cohen formula to determine the effectiveness of using the guided inquiry model assisted by the PhET Simulation virtual laboratory in improving students' scientific literacy skills.

RESULTS AND DISCUSSION

Based on the results of the research that has been conducted, the following results were obtained:

Table 1. Results of Pre-Test, Post-Test, and N-gain Statistical Tests of Science Literacy Ability

Mark	Class	Mean ± Standard Deviation	Normality Test	Homogeneity Test	Independent Sample t-Test
Pretest	E	40.60 ± 8.33	Sig. 0.195>0.05	Sig. 0.896>0.05	
	K	35.96 ± 7.62	Sig. 0.072>0.05		
Posttest	E	71.60 ± 9.86	Sig. 0.125>0.05	Sig. 0.435>0.05	Sig. (2-tailed) 0.000<0.05
	K	53.65 ± 11.88	Sig. 0.083>0.05		
N-gain	E	0.53 ± 0.14	Sig. 0.200>0.05	Sig. 0.426>0.05	
	K	0.28 ± 0.14	Sig. 0.200>0.05		

Caption (E). Experiment, (K) Control

Based on the table above, it shows that *N-gain* The scientific literacy ability of students in the experimental class was higher than the N-gain in the control class.The results of the hypothesis show that there is an influence of the use of a guided inquiry model assisted by the virtual laboratory PhET Simulation on improving students' literacy skills. Taibu et al. (2021) research shows that the use of PhET improves students' scientific skills and scientific literacy abilities by facilitating independent exploration of scientific phenomena, but still guided by the teacher. Guided inquiry assisted by PhET simulations is very effective in improving scientific literacy, especially in the material on interactions between living things because students can manipulate variables such as predator and prey populations to see their impacts, so that abstract concepts become more concrete and easier to understand. Students' achievements in each scientific literacy indicator can be known through the N-gain value of each scientific literacy indicator, so an analysis was carried out on each indicator presented in the following table.

Table 2. N-gain of Science Literacy Ability for Each Indicator

Indicator	Class	$\underline{X}$ Score ± Sd		*N-gain*
		Pretest	***Posttest***	
Explaining scientific phenomena	E	41.10 ± 15.69	72.00 ± 20.02	0.54 (Medium)
	K	37.36 ± 15.10	53.00 ± 19.11	0.25 (Low)
Designing and evaluating scientific investigations	E	40.70 ± 19.82	69.30 ± 17.94	0.49 (Medium)
	K	35.90 ± 15.28	51.00 ± 16.44	0.23 (Low)
Interpreting data and evidence scientifically	E	40.00 ± 18.59	73.10 ± 15.38	0.56 (Medium)
	K	34.60 ± 14.87	57.00 ± 19.92	0.34 (Medium)

DOI: https://doi.org/10.17509/10.17509/aijbe.v8i1.80287
e-ISSN 2621-7260

Caption (E). Experiment, (K) Control

Based on these results, it can be seen that the indicator explaining scientific phenomena shows an average N-gain value of 0.54 with a moderate category, which is inseparable from the role of the guided inquiry model assisted by PhET Simulation. Learning using PhET Simulation can improve students' ability to explain scientific phenomena because it allows visual interaction and direct manipulation of variables, making it easier to understand abstract concepts. Learning using the virtual laboratory media PhET simulation can present complex phenomena into a context that is easier to understand, because PhET simulation is a simulation that emphasizes the correspondence between real phenomena and computer simulations and then presents them in physical conceptual models that are easy for students to understand (Salame & Makki, 2021). This simulation encourages exploration and discovery-based learning that deepens the understanding of cause-and-effect relationships in scientific phenomena. In addition, the use of simulations in group discussions can improve students' ability to convey scientific information more clearly, supporting active learning that is more effective than passive methods. All of these factors make PhET Simulation an effective medium to help students develop their ability to explain scientific phenomena better (Wieman et al., 2010).

The improvement of scientific literacy skills in the indicator of designing and evaluating scientific investigations received an average N-gain value of 0.49 in the moderate category. This is because learning uses a guided inquiry model assisted by PhET simulation. Learning using PhET Simulation can improve students' abilities in designing and evaluating scientific investigations because it allows free exploration and independent experiments, where students can control variables, set conditions, and observe the results of changes directly. This simulation allows repeated experiments quickly and easily. Visualizing abstract scientific concepts through this simulation makes it easier for students to analyze the relationship between variables and experimental results, and encourages reflection on errors that occur in the experimental process. All of these factors help improve students' abilities in designing and evaluating scientific investigations more effectively than traditional methods (Perkins & Adams, 2012). The indicator of designing and evaluating scientific investigations received the lowest N-gain value because students who are not yet familiar with technology or do not have access to adequate devices may have difficulty utilizing this virtual simulation optimally. The indicators for designing scientific investigations not only emphasize students on the process of following procedural steps, but also require a thorough understanding of cause-and-effect relationships, how to control external factors, and how to formulate logical hypotheses based on theories or initial data. Students who have not fully mastered these concepts will have difficulty in the experimental design stage. This is in line with Tillah et al. (2024) that the indicator of designing and evaluating scientific investigations is the indicator that received the lowest n-gain value. The low n-gain value is related to the lack of students' thinking ability in connecting one concept with another, limited learning time also makes this skill difficult to master.

The improvement of scientific literacy skills in the indicator of interpreting data and evidence scientifically obtained an average N-gain value of 0.56 in the moderate category. This result is different compared to the N-gain value in the control class which obtained a value of 0.34. The increase in the indicator of interpreting data and evidence scientifically cannot be separated from the role of the use of a guided inquiry model assisted by PhET simulation. PhET Simulation is able to improve students' abilities in interpreting data and scientific evidence because this simulation provides an opportunity for students to collect, analyze, and visualize data interactively. Real-time data visualization in the form of graphs and tables helps students identify patterns and relationships between variables. Students can also repeat experiments easily, allowing them to evaluate data consistency and identify anomalies, which are important in the scientific process. In addition, this simulation facilitates the understanding of cause-and-effect relationships, where

DOI: https://doi.org/10.17509/aijbe.v7i2.69055
e-ISSN 2621-7260

changes in certain variables can be directly seen in their impact on the results, strengthening students' ability to interpret data with a more critical and evidence-based approach. PhET also supports active learning that encourages students to be directly involved in analyzing data and scientific evidence.

Based on the explanation above, it can be concluded that the application of the guided inquiry learning model assisted by the virtual laboratory PhET simulation is able to develop scientific literacy skills. Through guided inquiry learning, educators act as facilitators, students will find a concept from the learning material themselves through their learning processes. Through the use of PhET simulation, students can explore scientific phenomena, the visual and interactive aspects of PhET Simulation play an important role in building students' understanding of abstract concepts. This simulation allows students to visualize phenomena that are difficult to observe directly, so that complex concepts become easier to understand. According to research, the use of PhET Simulations can improve students' understanding of concepts compared to conventional learning (Diab et al., 2024; Gani et al., 2020). In addition, the interactivity offered by PhET allows students to experiment independently, increasing their engagement and motivation to learn. Thus, PhET Simulation can be an effective tool in learning abstract concepts, complementing the conventional laboratory approach.

The percentage distribution of the N-gain criteria for students' scientific literacy skills per class can be seen in Figure 1. To determine the percentage distribution of the N-gain criteria, an analysis was conducted on the pretest-posttest values per indicator in the experimental class and the control class to determine the N-gain category in each of the two classes. Then the N-gain values obtained were grouped based on the criteria as follows.

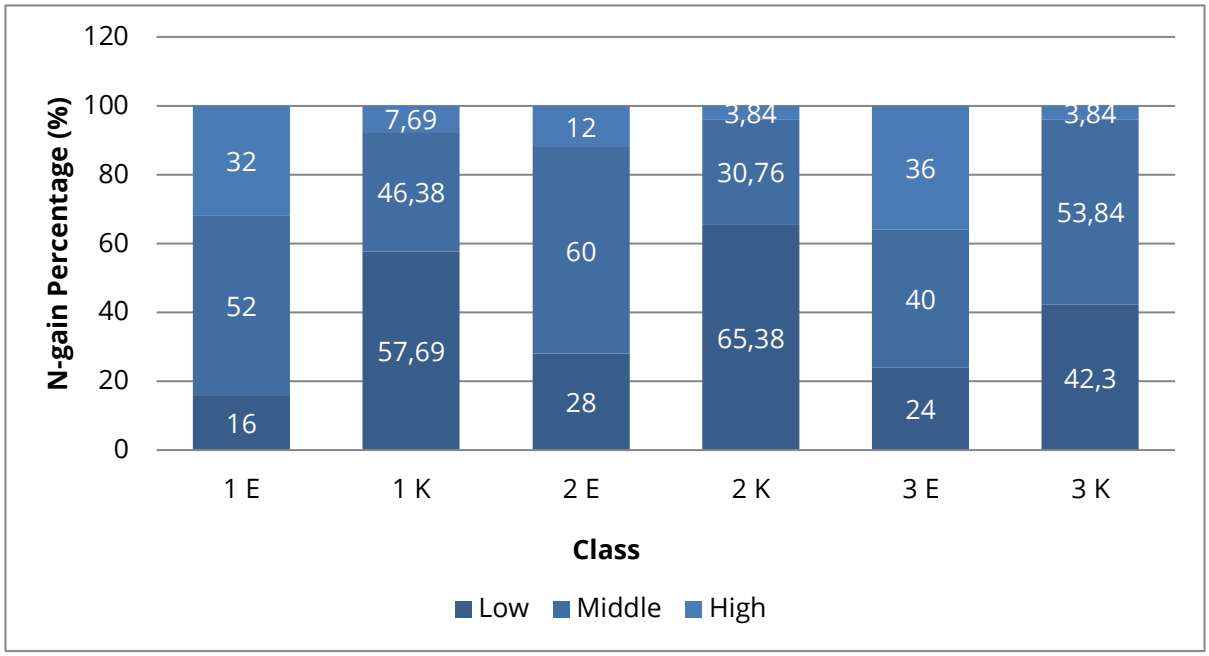

Figure 1. Literacy Ability Indicators per Class

Description: 1E: Indicator explains the scientific phenomena of the experimental class; 1K: Indicator explains the scientific phenomena of the control class; 2E: Indicator evaluates and designs scientific questions of the experimental class; 2K: Indicator evaluates and designs scientific questions of the control class; 3E: Indicator interprets data and evidence scientifically of the experimental class; 3K : Indicators interpret data and evidence scientifically control class;

DOI: https://doi.org/10.17509/10.17509/aijbe.v8i1.80287
e-ISSN 2621-7260

Based on Figure 1, it can be seen that in the indicator explaining scientific phenomena, the highest category percentage in the experimental class is in the medium criteria, while in the control class it is in the low category. The same thing also happens in the indicator evaluating and designing scientific investigations, where the experimental class has the highest percentage in the medium category while the control class has the highest percentage in the low category. However, it is different with the indicator interpreting data and evidence scientifically, where both in the experimental and control classes, the highest category percentage is in the medium criteria. Thus, it can be concluded that the experimental class tends to have a higher percentage than the control class, this is due to the application of the guided inquiry model assisted by PhET simulation in the experimental class.

Based on the data above, the average percentage of the distribution of the N-gain criteria for scientific literacy skills of each indicator in the experimental class is higher than that of the control class. This is because the experimental class applies a guided inquiry model assisted by PhET simulation in the learning process. In accordance with the results which concluded that virtual laboratories (PhET Simulations) can improve students' scientific literacy skills in 3 aspects of scientific literacy competencies (Aina, 2023). The results of this study are supported by Haerani et al. (2020) who stated that there is an influence of the free inquiry model on improving students' scientific literacy skills.To determine the magnitude of the effect of using a guided inquiry model assisted by virtual laboratory PhET simulation on students' scientific literacy skills. The results of the effect size test are presented in table 3 below.

Table 3. Results of the Effect Size Test of Science Literacy Ability

Class	Average N-gain	Standard Deviation	*Effect Size*	Category
Experiment	0.53	0.14	1.78	Big
Control	0.28	0.14		

The results of the effect size calculation in table 3 show an effect size value of 1.78 which is included in the large category. This shows that the application of the guided inquiry learning model assisted by the PhET virtual laboratory simulation is effective in its application. In line with the results of the study concluded that inquiry learning assisted by PhET simulations has been proven to be able to improve students' scientific literacy (Fitriani, 2024; Wen et al., 2020). In this study, the application of the guided inquiry model assisted by PhET simulations had a significant effect on improving students' scientific literacy because the learning process took place effectively and in a structured manner, and the core learning activities also ran as they should, this can be seen based on the results of the observation sheet analysis in table 4 below.

Table 4. Results of Observation Assessment of Learning Implementation

Activity	Achievement Score (%)		Average (%)	Category
	Meeting 1	Meeting 2		
Introduction	75	91.66	83.33	Very good
Core	100	100	100	Very good
Closing	88.88	88.88	88.88	Very good
Overall	87.96	93.51	90.73	Very good

Based on the results of the analysis of the learning implementation observation sheet in table 4. shows that at the first meeting the average score was 87.96% with a very good category and the second meeting 93.51% with a very good category. Furthermore, the average of the two meetings was calculated to get a score of 90.73% with a very good category. This indicates that the

DOI: https://doi.org/10.17509/aijbe.v7i2.69055
e-ISSN 2621-7260

implementation of the guided inquiry model assisted by PhET simulation during the learning process in the experimental class is running properly.

The results of the observation sheet for the implementation of guided inquiry learning assisted by virtual laboratory PhET simulation showed a positive response from students in the learning process. This is in line with research conducted by Pitaloka et al. (2020), the guided inquiry model is a model that can improve scientific literacy skills and improve discipline in students. The guided inquiry model is a learning model that requires students to the guided inquiry model is a learning model that requires students to be active in the process of finding concepts or understanding through exploration, observation, data collection, and analysis with guidance from the teacher. Students are encouraged to ask questions, design simple experiments, and draw conclusions based on the evidence found, thereby training scientific literacy and problem-solving skills. According to Aina et al. (2021), the use of virtual laboratory PhET simulation in the learning process is also considered to be able to improve students' scientific literacy skills. This is because by using interactive simulations virtually, students will be interested and more enthusiastic in learning so that it can make the learning process more conducive, and students will be more active in the learning process. Therefore, the use of the Guided Inquiry PBL model assisted by virtual laboratory PhET simulation is considered appropriate and can improve students' critical thinking skills.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that there is a significant influence with an effect size value of 1.78 on the application of the guided inquiry learning model assisted by PhET virtual laboratory simulations on improving students' scientific literacy skills in each indicator, both in the indicators of explaining scientific phenomena, designing and evaluating scientific investigations and interpreting evidence and data scientifically.

Guided inquiry model research assisted by virtual laboratory PhET simulation is an alternative in improving students' scientific literacy, especially in areas with limited facilities such as West Lampung. This approach encourages innovation in learning methods, increases student engagement, and is a cost-effective solution for schools with limited access to physical laboratories. Therefore, teachers need to be trained to utilize this technology, so that they can integrate it into learning to create quality science education. Further research is recommended to examine the effects of guided inquiry with PhET simulations on science process skills, critical thinking, or conceptual understanding more specifically. This can provide a more comprehensive picture of the effectiveness of this approach in science learning as well as the use of more diverse subjects.

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Acknowledgment

Researcher would like to thank the university which funded this research and the participants who were involved in this research.

Authors' Note

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

How to Cite this Article

Priadi, M. A., Lengkana, D., & Yosita, D. (2025). Using PhET simulation as guided inquiry-assisted virtual biology laboratory to enhance science literacy skills of junior high school students in West Lampung. *Assimilation: Indonesian Journal of Biology Education, 8*(1), 91-100. https://doi.org/10.17509/10.17509/aijbe.v8i1.80287