INTERACTIVE COMPUTER SIMULATION TO SUPPORT TEACHING OF BIOLOGY IN DISTANCE LEARNING

Basuki Hardjojo, Diki, S. Nurmawati and Susi Sulistiana
Indonesia Open University, Jakarta, Indonesia
dikinian@mail.ut.ac.id

In the open and distance education environment, where teacher-student interaction is very limited, there should be more emphasis in promoting student's initiatives. Interactive computer simulation can help the student gain an understanding of a subject learnt at a distance. Students can carry out their respective assignments. It simulates procedures of laboratory work efficiently. It can also visualize a complicated and even a hard-to-imagine scientific concept.

The Department of Biology of Universitas Terbuka initiated an interactive computer simulation to support student learning process. The subjects are genetics, microbiology and biochemistry. The objectives of the interactive computer simulation are to better ensure student preparedness to carry out real laboratory practice. The computer simulation presents a step-by-step procedure of a simulated laboratory practice. This simulation develops student's comprehension of the procedure and its relation to the theoretical framework.

Introduction

A characteristic of open and distance learning (ODL) is separation of teacher and student. Students learn by means of media. These media enable teaching and learning over a distance in the first place (Peters, 2003). Thus, media is a one of the most important component of ODL.

Distance university contributed to reducing the costs of studying and the establishment of mass higher education (Daniel, 1998). It spreads knowledge among people in a more cost-effective way.

Universitas Terbuka is the sole open and distance university in Indonesia. It was declared operational in 1984. It has 36 regional offices throughout the country. The number of active students are around 200000. There are four faculties, one of which is the Faculty of Mathematics and Natural Sciences.

The Department of Biology in the Faculty of Mathematics and Natural Sciences conducts undergraduate degree programme by distance learning. Since its inception in 2001, it has had around 300 students. Most students live in urban areas across Java and Sumatra. Some students even live as far away as in Batam Island (in Malacca Strait), and Papua, the easternmost part of the country.

There are 62 courses in the department. The critical components of a course are learning material, learning support and learning assessment. Most learning materials are produced by course team which includes outside subject matter expert. Besides subject matter expert, a course team includes multimedia expert and instructional design expert.

An indispensable activity of learning biology is laboratory work. In UT, laboratory practice for biology students is conducted in partner universities, which are conventional universities. The partner universities are :

- Jakarta State University in Jakarta
- Pakuan University in Bogor, West Java
- Indonesia Education University in Bandung, West Java
- Surakarta State University in Solo, Central Java
- Yogyakarta State University in Yogyakarta.

Each partner university cooperates with respective UT regional office. Each student who is registered in a regional office, should have his/her laboratory practice in partner university in the area. However,

they can also have the laboratory practice in another partner universitiy. In addition to provide laboratory facility, the partner university also provides tutor and course material writer.

There are 14 laboratory courses in the department. The student may take it after they take the theoretical courses. These courses are as follows:

- BIOL4440 Plant Structure
- BIOL4441 Animal Structure
- BIOL4444 Avertebrate Taxonomy
- BIOL4451 Vertebrate Taxonomy
- BIOL4447 Higher Plant Taxonomy
- BIOL4446 Lower Plant Taxonomy
- BIOL4448 Plant Embriology
- BIOL4452 Animal Embriology
- BIOL4449 Plant Physiology
- BIOL4450 Animal Physiology
- BIOL4442 Ecology
- BIOL4443 Genetics
- BIOL4341 Biochemistry
- BIOL4445 Microbiology

In open and distance education system, where teacher-student interaction is limited by factors as time constrain, geographic barrier and cost. There should be more emphasise in promoting student's initiative. A solution is using an interactive computer simulation.

Developments

Some distinguishing characteristics of learning process in distance university are problem-based learning, resource based learning and constructivism. Those methods of learning support using interactive learning system. This is the important reason to use computer in supporting distance student.

Problem based learning (PBL) is a learning process which students are encouraged to create and develop their own body of knowledge by analysing problems presented to them. The problem is the starting point of learning (Bridges and Hallinger in Crumpacker, 2001). By means of solving problems, students learn the subject. They will eventually understand the whole knowledge through this activity.

Another concept of learning in distance university is *resource-based learning* (RBL), which is defined by the Australia National Council of Open and Distance Learning (NCODE) as an integrated set of strategies to promote student-centered learning in a mass education context, through a combination of specially designed learning resources and interactive media and technologies (NCODE). This concept holds a view that there are many learning resources beside teacher, textbook or laboratory, these are internet and CD ROM-based resources.

The concept modifies central role of teacher (Ryan et. al., 2000). The teacher tends to be a facilitator of learning. The teacher is no longer the only source of knowledge. Instead, the teacher is focusing more on guiding the student find out the knowledge by the student's own experience in learning activity.

Constructivism holds that there are many meanings of perspectives for any event or concept (Duffy and Jonassen, 1992). The learners are building a personal interpretation of experience. By so doing, the learners develop their own understanding of a concept. Instruction process is not a process of transferring knowledge, otherwise it is a process of problem solving. A learning process should be a process of dealing with solving problems presented during the process. Those problem are structured

so that students gradually develop an understanding of a certain knowledge which is the objective of the learning activity itself.

ICS support learner-centered learning process. The computer simulation can increase interactivity, individualisation and independent learning (Peters, 2003.). It can function as game, simulation, evaluation and tutorial.

Learning occurs by active process in memory system, which is characterised by retrieving knowledge and skill from long-term memory to working memory (Clark and Mayer, 2003, p35). The retrieval process is so important that without it, a knowledge stored in long-term memory is meaningless, for it cannot be accessed and applied by the learner.

A mental management process which oversee the information processing is called metacognition (Clark and Mayer, 2003). Metacognition consists of three steps, those are defining goals, planning and monitoring. Each student define specific individual goals, based on his/her own objective in learning. These goals are translated into learning plan. The student learns according to his/her learning plan. He/she can choose any learning resources and do specific learning pathway accordingly.

Interactive computer simulation (ICS) can help student gain an understanding of a subject learned. Students will carry out their respective assignment. It simulates procedures of laboratory work.

Computer game can be used to develop a higher thinking order among students (Sherwood, 1990). Student may compare many activities which is ranked according to the level of difficulty. Once he/she achieved a certain level of thinking, he/she will be motivated to keep learning.

The computer can encourage divergent and creative thinking (Dowling, 1990). Actual laboratory practice is usually limited by time allocation and availability of facility. Yet with this simulation, student can explore some possibility of even some high-risk experiment.

Present Status

One of the most suitable mode of ICS to support laboratory practice is simulation. There are several types of simulations. Based on the educational objective there are two groups of simulations. Those educational objectives are to teach about to do something or to teach how to do something. The first group is subdivided into physical simulations and iterative simulations. A physical simulations is characterised by a physical object or phenomenon which is represented on the screen, giving the user an opportunity about it. Some examples are chemical bonding, photosynthesis or transmission of electricity through power lines. Iterative or process simulation is characterised by an interaction of learner and computer. In the simulation, time is not included as a variable.

While the groups of simulations which objective is to teach how to do something is subdivided into procedural and situational simulations. A procedural simulation is to teach a sequence of actions to accomplish some goal, like flying an airplane, performing a titration or diagnosing equipment malfunctions. The student must imitate the actual procedures of operating or manipulating physical objects. Situational simulations deal with the behaviour and attitudes of people or organisations in different situations. It incorporates role playing. (Alessi and Trollip, 2001).

There are different types of simulation, which depends on the instrructional strategy chosen by the developer. The instructional strategy is concerned with how learners are going to learn from the learning events and describes how learners are going to achieve the learning objective (Jollife et al, 2001). It can be considered at both micro- and macro-level. The micro-level concern with developing instructional strategies for an individual topic, while the macro-level with developing an overall instructional strategy for the entire learning event. At the micro-level, there are five-steps including: pre-instructional activities, information presentation, activation of learning, follow-up and remediation.

The pre-instructional activities include an introduction video, a text presentation and/or accompanying narration. The introduction is designed to encourage and motivate student to explore the preceeding session. It should also include a statement of the objective of the courseware.

The information presentation does not mean a contradiction to the abovementioned principle of constructivism, for the presentation is intended to remind the student of prerequisite knowledge. The main objective is contained in the preceeding step, which is the activation of learning.

In the step of activation of learning, the student does the interactive simulation. By doing the activity, they explore the previous learning experience from the long-term memory and combine it with the present simulation.

The next step is follow-up and remediation. The students can evaluate the result of his/her activity. They can step into higher order of learning, if they achieve a good result in the proceeding activity.

There are four types of presentations in simulations. These types are: choices to make, objects to manipulate, events to react to and systems to investigate (Allesi and Trollip, 2001).

Based on the types of presentations, basic actions of learner in the interactive simulations are:

- Moving viewpoints/changing the view
- Navigating through environment
- Selecting an object
- Moving an object (Brady and O'Sullivan, 1998)

Feedback about any action may be given immediately or at some later stage. There are natural feedback in a simulation that is similar or identical to what occurs in reality. Artificial feedback may provide the same information, but in a way that does not occur naturally. Regardless of how the real world works, simulation provides us the option of giving natural or artificial feedback, of immediate or delayed feedback, or of giving no feedback at all (Allesi and Trollip, 2001).

The ICS is neither a replacement nor an alternative to real laboratory practice. Otherwise, it is intended to be a complement. The student will have to do exercise with the computer simulation prior to an actual laboratory session. This is a tool which enable the student to imagine the laboratory procedure.

Limitations

1. Low student skill in laboratory procedure

   The procedures are presented in printed learning material, which is considered not clear enough by students. Without constant face-to-face explanation and lack of inter-students direct contacts, some students waste the laboratory session by repeating procedures.

2. Most computer simulations are not interactive enough

   Some computer-based learning material is just an imitation of traditional teaching and learning (Peters, 2003). Those are only presenting facts and procedures. It dosesn't encourage student to make a decision.

3. Low transmission rate of internet in Indonesia

   As a result of low quality of telecommunication infrastructure, the transmission rate is low. Dialing internet connection wastes student's time and cost. Unfortunately, the better the simulation software, the bigger the software, creating more time-consuming internet connection.

4. ICS cannot replace a real life laboratory practice completely

   Most biology students want face-to-face contact in their studies are not prepared to take virtual studies as a replacements (Parslow, 2005). Moreover, there are still a lot of competences that cannot be simulated by computer. Some specific skills like slicing finite specimen of plant or animal tissue must be trained in real plant and animal tissue. Placing a slide glass under a microscope to get the proper microscopic image needs special repeated training.

Innovations

In 2005, Department of Biology of Universitas Terbuka began to initiate an interactive computer simulation (ICS) to support student learning process. The topics of the simulation are genetics, microbiology and biochemistry. Selection of those topics are based on the difficulty to conduct the laboratory practice and the high cost of its facility. The objectives of the interactive computer simulation is to better ensure student preparedness to carry out real laboratory practice. Other benefits of the simulation are:

- Enable student to easily conduct the simulation anywhere and anytime, individually or collectively. The frequent simulation practice will decrease student's mistake in the real laboratory session.
- Some experiments is time consuming, such as yeast inoculation, plant breeding and even simple experiment of bacterial staining takes time. The computer simulation does not need to be conducted in full time experiment, so the student can directly jump to the expected step.
- The simulation produces required answer to problem and procedure which is presented. This feedback enhances student's motivation.
- By responding to computer answer, students can assess their level of comprehension. Students can repeat the procedure according to their need.

The ICS is a computer simulation which is designed to present a problem to solve. It is indeed preceeded by an introduction of a topics. Then, the students are to do some laboratory procedures. There are also problems to test their comprehension of the topic.

A distinguishing characteristics of the new interactive computer simulation is its high interactivity. The simulation consisted of several steps of activities and some problems. The student's answer to each problem create different kinds of computer's response.

There are two kinds of problems in computer simulation, ill-structured problem and well-structured problem. Ill structured problem does not have clear and complete informations related to the problem. It contrasted to well-structured problem which have definitive answer.

Ill structured problem can motivate active learning (Kiili, 2005). It is more suited to conceptual development and problem solving development (Oliver and Omari, 1999). The simulation is actually an ill structured problem. It contains alternative response for each possible student answer. Whether they produce the right answer or not, the computer always give further feedback. The student can create and try every possible alternative to each problem.

There are several steps in developing the ICS. The first step is planning. The plan is based on course syllabus of each course. The three courses are chosen considering their delicate laboratory procedures, expensive cost and need of sophisticated laboratory facility. We also organize, allocate budget and arrange time schedule. The products are flowchart and script for each topic.

The flowchart and scripts depicts the sequence, logic, feedback and interactivity of the resulting computer simulation. A preceeding information is always presented, prior to every interactive simulation. It means that student is supposed to recall previous learning experience and progress to appropriate level of study. He/she can choose any topics based on his/her study need.

The next step is programming, which means creating an interactive computer programme that simulate a laboratory practice. The computer programme is supported by graphic, video and audio. Graphic and video show the real and ideal procedure of experiment. Afterward, the student will have to be able to solve the problem, which is represented by the simulation.

Each simulation presents real laboratory steps and resulting circumstances. The students experience solving problems. The experience is an important way of study in which students will create their own body of knowledge. The knowledge itself is the result of their effort to solve problem.

The problem presented in the simulation enable student to achieve higher thinking order. They can relate various problem, data, and feedback. Eventually, the process will arrive at students understanding of theoretical background of the laboratory procedures.

An important advantages of any simulation is that it motivates students. By achieving any level of study, they are challenged to progress into higher level of study. Students can bypass any subtopics which are regarded as too easy or already understood. Therefore, they can study by their own need.

The ICS courseware is distributed to students in CD-ROM. It can also be distributed in the internet. Unfortunately, the low bandwidth of internet connection and even inaccessibility of internet connection in some areas will discourage students to use the courseware.

The simulation can be conducted by a group of students. Conducting the simulation in a group is a way to improve teamwork among students. Students in a group can discuss what they have already done in the simulation.

The ICS topics consists of genetics, microbiology and biochemistry. The genetics ICS topics focuses at epitasis. The biochemistry topic focus at amino acid separation by paper electrophoresis. The microbiology topics consists of morphology and staining of bacteria.

Genetics ICS program

The Department of Biology of UT offer BIOL4219 Genetics course as one of the most important courses. It is one of the prerequisite course of the student final assignment.

The programme is to describe the basic principle of genetics and to prepare the students to master laboratory procedures. The students may take the laboratory session only after they took the course.

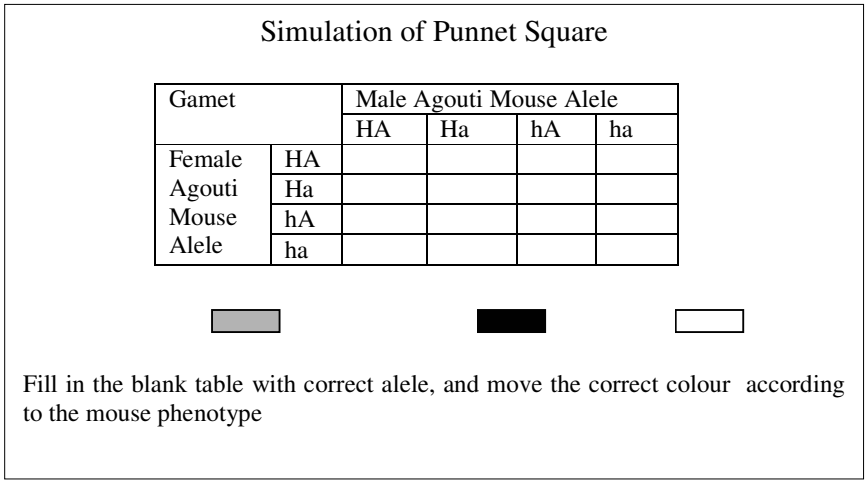


Figure 1: An example of Punnet Square

The genetics ICS programme is based on several specific competences as follows:

- Mendel's First Law
- Mendel's Second Law
- Description of Epistasis
- Recessive epistasis
- Double recessive epistasis
- Dominant epistasis
- Double dominant epistasis
- Dominant and recessive epistasis

The ICS begin with the objective of the programme, which is the specific competences themselves. It was meant to enable the student to know precisely the objectives of the activity. It was followed by the main menu and some explanation video materials of various living creatures.

The description of epistasis is followed by explanation of each type of epistasis. The explanation is not only a presentation of genetics mechanism, but also some interactive problem. The students are required to fill in a Punnet Square, which is a popular way to explain genetics equation. It is a square which has to be filled by correct genotypic formula and fenotypic trait. The way the student answer is by writing down the correct word representing each alel, and by removing a coloured block representing a phenotypic trait. If the student fill in the right answer, there will be a positive response. The positive response is a cheerful sound. The wrong answer will produce the negative response, like sorrowful sound.

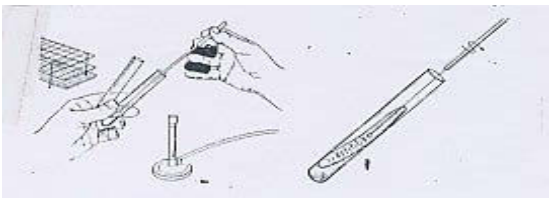
The objective of the courseware is to explain epistasis as a deviation of Mendel's Law. Another objective is to explain some details of metabolism aspect of epistasis.

Microbiology ICS program

Microbiology course deal with submicroscopic creatures which need special care to avoid contaminant. This special precautions deserves very strict procedure to be taken by students. Even some failures is resulted by simple mistake. Another important precautions is regarding the sterilization, especially in working with pathogenic microorganism.

To avoid these failures, students must be prepared to conduct steps of laboratory procedures. Beside preparing students, the animation can show model of some phenomenas in microbiology. It can bridge the laboratory practice with the theoretical explanation.

Gram Staining Simulation



1. Place the cursor on the Bunsen
2. Place the cursor on the glass slide
3. Place the cursor on the Ose stick
4. Place the cursor on the bacteria

Figure 2: Gram staining simulation

The Microbiology ICS is complementary courseware of BIOL4223 Microbiology. The topics are:

1. Morphology and size of bacteria
1. Characteristics of Gram positive and Gram negative bacteria
2. Gram staining
3. Spore staining

At first, the student can see a video of actual laboratory procedure. The video is showing actual laboratory practice. The video can show standard laboratory practice of biology students of UT for partner universities.

After the student learn some information in text and video presentation, they can try to make some simulation experiments in animation. Each student answer will result in either positive of negative response. The positive response is a cheerful sound. The wrong answer will produce the negative response, like sorrowful sound.

Biochemistry ICS program

Biochemistry laboratory practice is characterized by expensive material and tools. It limits students effort to reach satisfying result. Beside a competence in laboratory procedure and techniques, students may find it difficult to understand some basic concepts of biochemistry. The ICS is beneficial to help students overcoming it by using animated molecular model.

The program intends to present some basic concepts of amino acid structures and the related laboratory practice. The topics of the Biochemistry ICS Program are:

1. Definition of amino acid
2. Three dimensional structure and amino acid model
3. Fundamentals and method of amino acid analysis
4. Tools of amino acid identification by paper electrophoresis
5. Method of amino acid identification by paper electrophoresis

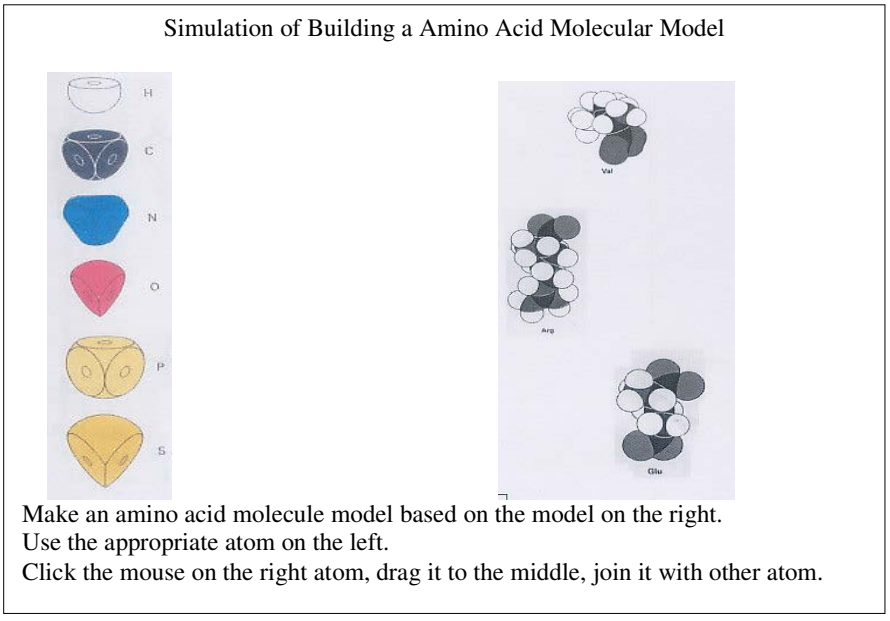


Figure 3: Simulation of building a amino acid molecular model

The concepts of amino acid structures is described by 3D animation. The student can try to develop a model of amino acid molecule by combining appropriate atom and functional groups available in the presentation monitor. The components of a molecule is presented in the monitor display. The student may choose correct molecule component based on his/her previous knowledge. If the student fill in the right answer, there will be a positive response. The positive response is a cheerful sound. The wrong answer will produce the negative response, like sorrowful sound.

The student can see a video of actual laboratory procedure, to show them the actual skill that is needed to perform the activity. Then the student will has to complete an animation of laboratory procedure.

The student can also get some information regarding the amino acid by viewing the video and photo presentation. The video describes actual laboratory practice of the similar topics.

Conclusion

The ICS can be used to prepare a student to comprehend laboratory procedure. The more a student is capable to work according to the simulated procedure, the more the student is ready to work in the actual laboratory session.

By means of ill structured problem presented to student, the ICS can also improve student's understanding of theoretical concept.

There should be an emphasis toward creating multiple-user type simulation, which can be used both on-line and off-line.

Reference

Alessi S. M., and S., R. Trollip, 2001, *Multimedia for Learning : Methods and Development*, 3rd Ed, Allyn and Bacon, New York.

Brady, S. and C. O'Sullivan, (1998), *3D Traininng Environments, VRML and its use in Interactive Task-based Simulations,* http://cuip.uchicago.edu/~joi/thesis/brady99training.pdf

Clark, R., and R. Mayer, 2003, *E-learning and Science of Instruction*, John Wiley and Sons, New York.

Daniel, J., (1998), *Knowledge Media for Mega-universities*, Scaling Up New Technology at The Open University, in: 1998 Shanghai Open and Distance Education Symposium, http://www.open.ac.uk/johndanielspeeches/chinatlk.html

Dowling, C., 1990, Exploring the Unpredictable-The computers as a catalyst for creative thinking in the classroom, in: *Computers in Education, Proceedings of the IFIP TC 3 Fifth World Conference,* Sidney.

Duffy, T. M. and D. H. Jonassen, 1992, Constructivism: New Implications for Instructional Technology, in: *Constructivism and the Technology of Instruction*, Lawrence Elbaum Associates Publishers, New Jersey.

Jolliffe, A. and J. Ritter and David Stevens, (2001), *The Online Learning Handbook, Developing and Using Web-Based Learning*, Kogan Page, London.

Kiili, K., (2005), Digital game-based learning: Towards an experiential gaming model, in: *Internet and Higher Education*, (2005), p17.

National Council of Open Distance Learning (NCODE*), Quality guidelines for resource based learning*. Report to NCODE from RBL working party, http://ncode.uow.edu.au/info/qual_guide.html

Oliver, R. and A. Omari (1999), Using Online Techonologies to Support Problem Based Learning: Learners' Responses and Perceptions, in: *Australian Journal of Educational Technology*, 1999, 15 (1), 58-79.

Parslow, G. R., (2005), Multimedia in Biochemistry and Molecular Biology Education: Virtual Universities Are Not About to Replace Face-to-Face Teaching, in: *Biochemistry and Molecular Biology Education*, Vol, 33, No. 2, p.141, 2005, http://www.bambed.org .

Peters, O., (2003), Learning With New Media in Distance Education, in : *Handbook of Distance Education*, Lawrence Erlbaum Associates Publishers, New Jersey.

Ryan, S. et al, 2000, *The Virtual University, the Internet and Resource-Based Learning*, Kogan Page, London. p,35

Sherwood, C., 1990, Computers and Higher Order Thinking Skills, in: *Computers in Education, Proceedings of the IFIP TC 3 Fifth World Conference*, Sidney.

Diki was born at April 15, 1969. Graduated from the Department of Biology, Padjadjaran University, Bandung, Indonesia in 1995. Now a lecturer at the Department of Biology, Universitas Terbuka, Indonesia. Previously worked as a laboratory analyst at the Hasan Sadikin Hospital, Bandung, Indonesia. His research interests are human genetics, and the development of online learning. Address: Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Terbuka, Pondok Cabe, Ciputat, Tangerang 15418, Indonesia, Phone: 62-21-7490941 ext 1810. E-mail: dikinian@mail.ut.ac.id