DEVELOPING ELECTRIC FIELD LEARNING MEDIA USING FINITE ELEMENT METHOD LABORATORY TO ENHANCE THE QUALITY OF PHYSICS LEARNING INSTRUCTION

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The concept of electric field should be understood by university student due to its wide applications in the information and communication technology such as integrated circuit (IC) on television, computer, printer, and photocopy machines. Based on the previous observation, most of the students were having difficulty on understanding such a concept conducted in theoretical model. Therefore several efforts have to be done to overcome the problem, especially the development of learning media by producing the electric field simulator using finite element method laboratory (FEMLAB), which is able to show clearly the pattern and the intensity of electric field around the electrical conductors. The aims of this research are: to enhance the understanding of the electric field pattern and the vector field around electrical conductors, to obtain the electric field simulator using FEMLAB as well as to enhance the quality of physics learning instruction. The simulation products resulted in this research have been carried out by development research method, including development model, development procedure as well as simulation products testing. The results of this research are suitable FEMLAB program to obtain the electric field simulation around the electrical conductors, and the application of such simulation on physics learning instruction. Finally, the conclusions of this research are (1) the electric field pattern was formed by contours which depend the value of positive and negative charge, where the highest intensity was reached by the electric field near the conductors, (2) The direction of the vector field is from the positive to the negative charge, where the same charge would repel each other and the opposite charge would attract each other, and (3) electric field simulator used in the physics learning is capable to enhance the quality of physics learning instruction.

Keywords: simulation, electric field, FEMLAB, the quality physics learning instruction

I. Introduction

Physics is one of a subject which underlies other subjects. There are many scientists who develop a subject based on physics, for instance, chemist who builds up the structure of molecular theory and paleontologist who re-constructs how dinosaurs walks. In addition, Physics is one of a subject which underlies engineering and technology subjects (Young, 2006:1). There are no engineer who can contrive a device without mastering concept and rule of Physics used formerly. To contrive the device, mastering the concept of Physics, as, boundary layer, the flux of laminar –turbulent, and viscosity is required.

The application of concepts and rules of Physics on engineering and technology makes the concepts and rules of Physics as one of requirement which has to be mastered by students of engineering program, in order to forearm them with high capability to face work realm. Nonetheless, most of students still found difficulties to fulfill those criteria. This difficult circumstance is caused by the level o0f student's ability in analyzing mathematical equation describing concepts or rules of Physics in low. Therefore, the efforts to reduce fallibility of the concepts have to be done. One of those efforts is planning and developing

the learning media. There is electric field simulation with finite element method laboratory (FEMLAB) around electric conductor which is capable to describe the form and electric field capacity factually. For instance, in the concepts of electric field, there is div operator (∇) which means partial differential electric field students call it as mass scalar. Another difficulty is student's inability to illustrate the spectrum of electric field, and to count the capacity of electric field around of the electric conductor.

This of information electric field concept is significant to be understood by students because of its application on the technology (especially for integrated electronic sequence). Electric field concept can possibly produce potential balanced concept, electrical potential energy, electrical force movement, and capacitance. Eventually, these concepts will produce the device of electronic instruments, such as television, computer, printer, and so on.

The adversity of students in understanding electric field concept is expected that is circumstance is happened because of theoretic model which is too blur, so that learning process becomes ineffective. The difficulty to understand electric field concept will take effect to the fallibility in identifying, choosing, and stringing up components to form a system of integrated electronic sequence. Even, it can create fallibility and incapability of students to detect error function system. This is an indicator of ineffective learning process and directly impacted to the quality of graduate students. It means that they are not ready to face work realm competitions.

Based on the explanation above, the efforts to reduce the fallibility of the concepts need to be held. Some of them are the necessity of devising and developing learning media, in which formed electric field simulation around the electrical conductor that is capable to clearly describe the form and the electric field capacity, and the necessity to rectify student's understanding to div operator (∇). Electric field simulation is done by using FEMLAB by means of considering the advantages of it:

a. FEMLAB is potential software for modeling and engineering problem solving which is based on partial differential equation (PDE),
b. To use FEMLAB software, we don't to need master math or numeric analysis subject. By using FEMLAB, we can create various models, only with defining physical quantity required. It can be done without defining the equations for those physical quantities.
c. By using FEMLAB, we can create various models based on the equations of mathematics and physics.

In the manner of advantages FEMLAB program mentioned above, the students' understanding enhancement to electric field concept will ensure the rich of learning enhancement. By applying this simulation, it is expected that students will conceive electric field concept more, so that they are equipped with established adaptability and creativity to enter the subject of technology. Furthermore, the efforts to fulfill the criteria of accessible and teachable in learning activities will be reached better.

The aims of this research are:

a. Providing obvious illustration about electric field pattern and force vector around electrical conductor resulted from FEMLAB simulation,
b. Producing a set of learning media, that is FEMLAB for electric field, and
c. Enhancing the quality of physics learning instruction.

II. Research Method

Electric field simulation by using FEMLAB is held with applying development research method. There are three stages of this research: development model, development procedure as well as simulation products testing.

Development Model

The resulted model of this research is descriptive procedural model. In which adapts from model that is developed by Sutopo, the model is known as computer-assisted development product (Soenarto, 2005). The stages of this development model are served below.

a. **Concept**; it is developed by identifying objective, analyzing learning needs, analyzing learner characteristics (level ability to operate computer), contriving software used as learning material.
b. **Design**; it contains two stages of designing product. There are (1) designing software; (2) developing flow chart.
c. **Collecting materials**; it is done to create electric field simulation.
d. **Assembly**; it deals with arranging paper of learning material in every frame which is usually called screen mapping.
e. **Testing**; this stage has aim to seek the effectiveness the product. In which, product ought to fulfill two criteria: learning and appearance criteria. Meanwhile, there are three times of testing: (1) tested to expert, (2) limited test, and (3) reality test. However, considering the limited time and research sample, this research only employs two kind of test: tested to expert and limited test.
f. **Dissemination and distribution**; this stage works about disseminating learning product to the real users.

Development Procedure

Some factors in making electric field simulation with FEMLAB (Comsol: 2000) have to be racked thoroughly, in order to seek the accuracy level of specified mass. Below are the stages in making electric field simulation:

a. At the beginning, enter to the MATLAB software,
b. Make sure that MATLAB program work properly, and then enter to FEMLAB software by using **graphical user interface** (GUI).
c. By clicking FEMLAB, automatically **navigator model** window appeared.
d. First, choose the dimension that will be used (for this term choose **2D**) on navigator model window.
e. Choose the model will be used, that is **physics mode**.
f. Afterward, click **electrostatics** and choose **linear stationary**.
g. Click **option** menu and choose **add/edit variables**, then enter the variable needed; electric permittivity $\varepsilon_0 = 8.854x10^{-12}$
h. Choose **draw mode** to draw a simulated object with certain electrical potential.
i. Choose **boundary mode** to enter electrical potential on the specific boundary.
j. Choose **PDE mode** to enter coefficient of electrical permittivity.
k. By clicking **plot mode**, elucidation that you wanted can be acquired; potential contour and potential flux vector.

By attending the stages above, we can develop conventional model which collocates to a branch of physics to be a multi-physics model containing simultaneous physics branches.

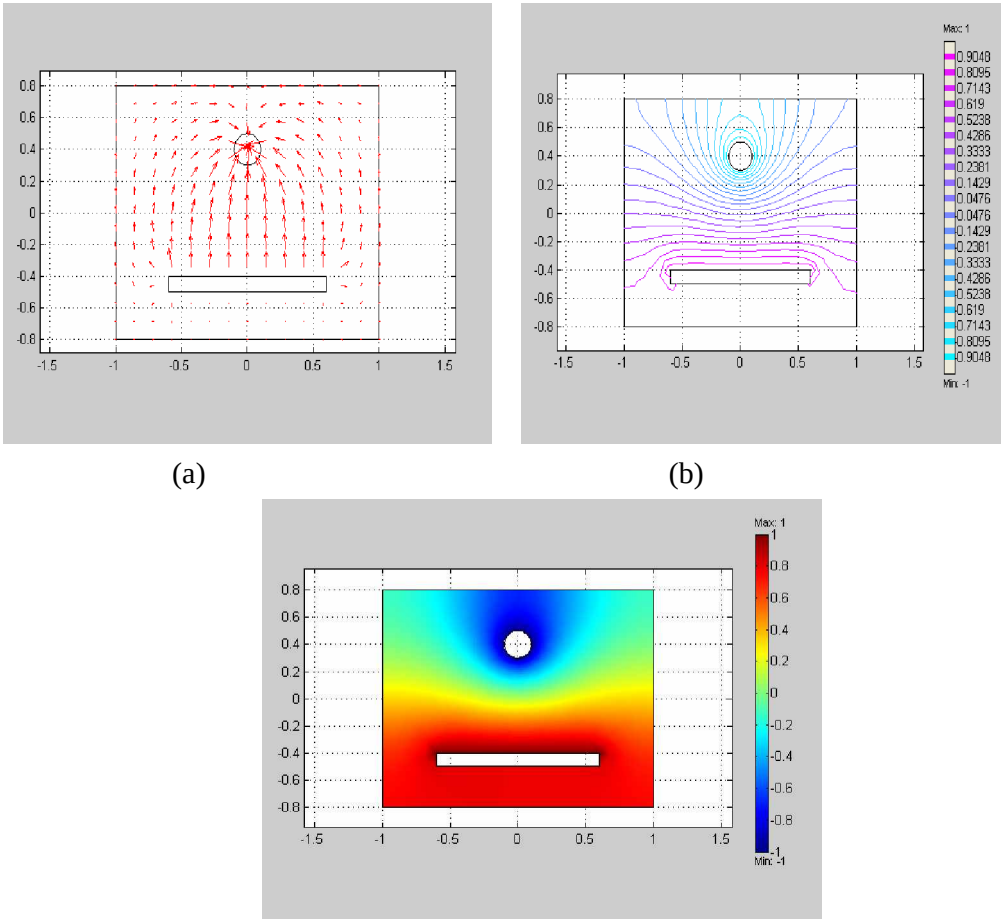
Simulation Product Testing

Simulation product testing is held to identify the level of effectiveness and product enticement in learning process. This process through three stages, there are tested to expert, limited test, and reality test. While subject for every test is shown on the table 1.

Table 1. Subject of testing and sampling technique for every stage

Stages of testing	Number of sample	Sample characteristics	Sampling technique	Process and result of the test
expert	2 people	Lectures of Fisika FPTK UPI	Purposive	Interview, questionnaire; first draft of the product
limited	5 people	Product users: students of JPTM who take Fisika II	Random	Interview, questionnaire, observation; the compatibility of the product to product users.

Note: 1. *JPTM = Jurusan Pendidikan Teknik Mesin*
2. *FPTK = Fakultas Pendidikan Teknologi dan Kejuruan*



(a) (b)

(c)

Picture 1. Electric field around capacitor (negative capacitor) and plat conductor (positive capacitor)

Electric Field Learning Media to Enhance the Quality of Physics Learning Instruction

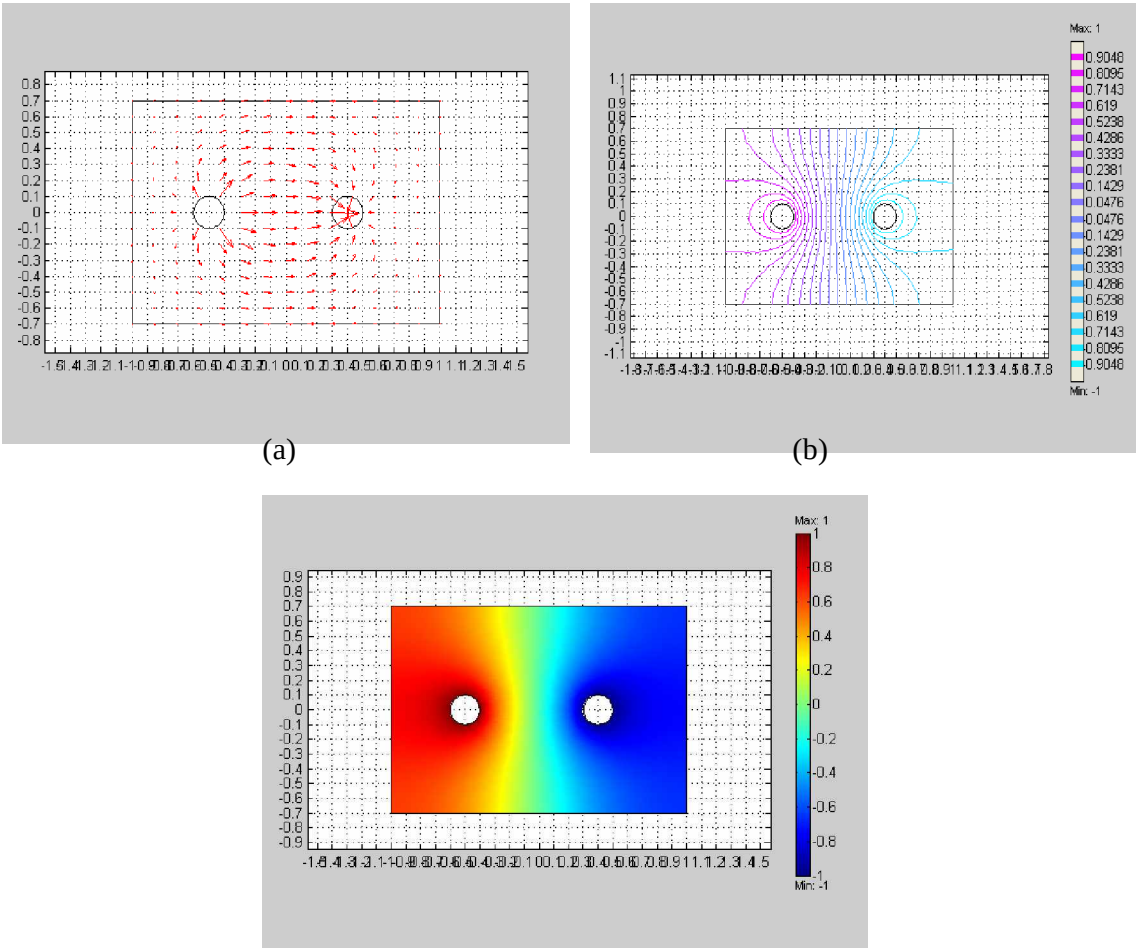
The enhancement of quality of physics learning instruction is indicated by normalized gain value (N-gain). To fulfill this aim, it has been done the quasi experiment research with pre test-post test control group design. The experiment group is the group of Refrigeration and Air Conditioning Student while the control group is the group of Production and

Planning Student and each of group is the first degree student of Mechanical Engineering Department, Indonesia University of Education.

The hypothesis of this research is: “Gain learning of the student who did not use electric field learning media as high as or equal with the student who used electric field learning media.

$H_o = \mu_1 \leq \mu_2$

$H_1 = \mu_1$ ¤ μ_2



(a) (b)

(c)

Picture 2. Electric field around point capacitor (positive capacitor) and plat capacitor (negative capacitor)

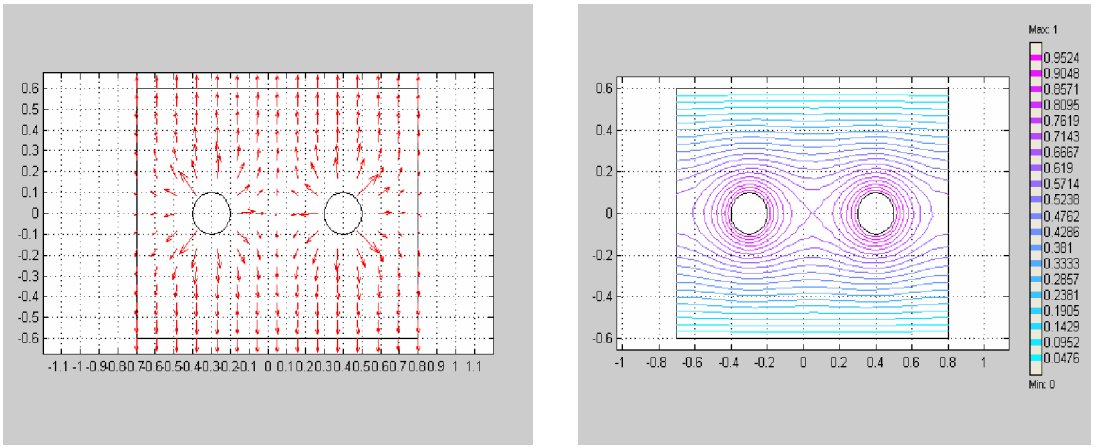
III. Results and Discussions

a. Electric Field Pattern

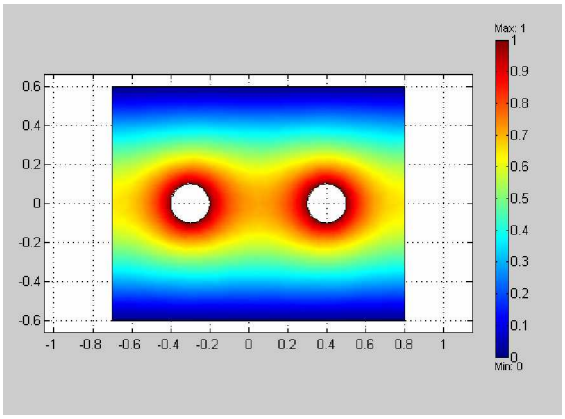
This research has produced some pictures of electric field and force vector pattern around electrical conductor that is produced from FEMLAB simulation as follow:

1. Electric Field around Point Capacitor and Plat Capacitor

Picture 1 show that around point capacitor and plat capacitor which is carrying different types of capacity (positive and negative) appeared electric field whose direction is from the positive to the negative capacitor (picture 1a). The scales of picture 1a only show the size of the point capacitor and the plat conductor, it does not show the power of the electric field. Contour of electric field shown in picture 1b and 1c, where the blue color shows relatively negative capacitor while the red one shows relatively positive capacitor. The same pattern also happens to electric field around the point capacitor and straight conductor, but there is interchange between positive and negative capacitor (picture 2).



(a) (b)



(c)

Picture 3. Electric field around two different types of point capacitors

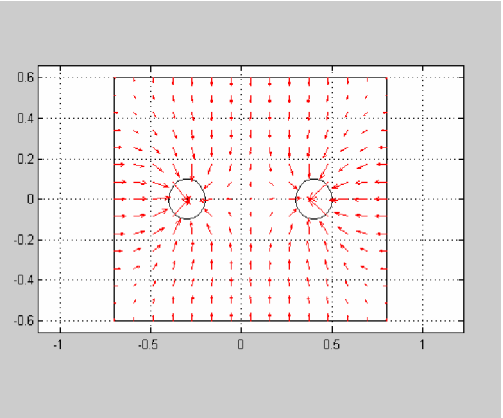
2. Electric Field around Two Types of Point Capacitors

Two types of point capacitor that is situated close to each other will produce electric field, with the direction as it is shown in picture 3. The direction of the electric field will begin from the positive capacitor to the negative capacitor (picture 3a). Its contour is shown on picture 3b and 3c.

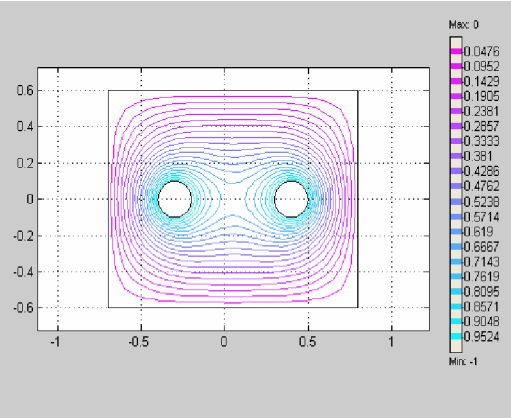
3. Electric Field around Two Types of Point Capacitors

The case of electric field on two different types point capacitors has different pattern with the case of electric field on two similar types point capacitors. Electric field on two different types point capacitors shows no “empty” area between the two capacitors (picture

3b) while electric field on two similar types point capacitor shows that there is “empty” area between the two capacitors (picture 4b and 5b). The empty area on electric field between two similar types’ capacity is existed since each capacitor rejects the other. Picture 4b shows the rejection from two positive capacities while on picture 5b there is rejection of two negative capacities.



(a)



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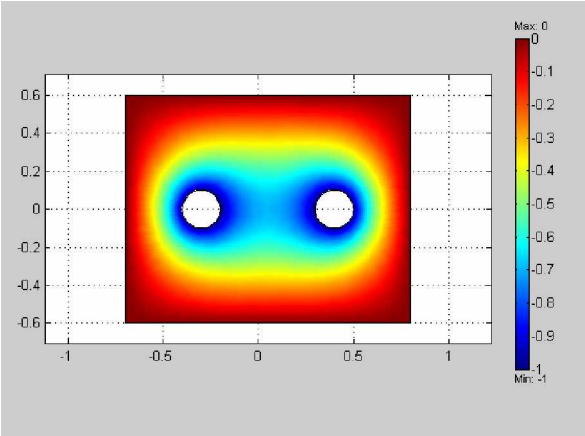


(c)

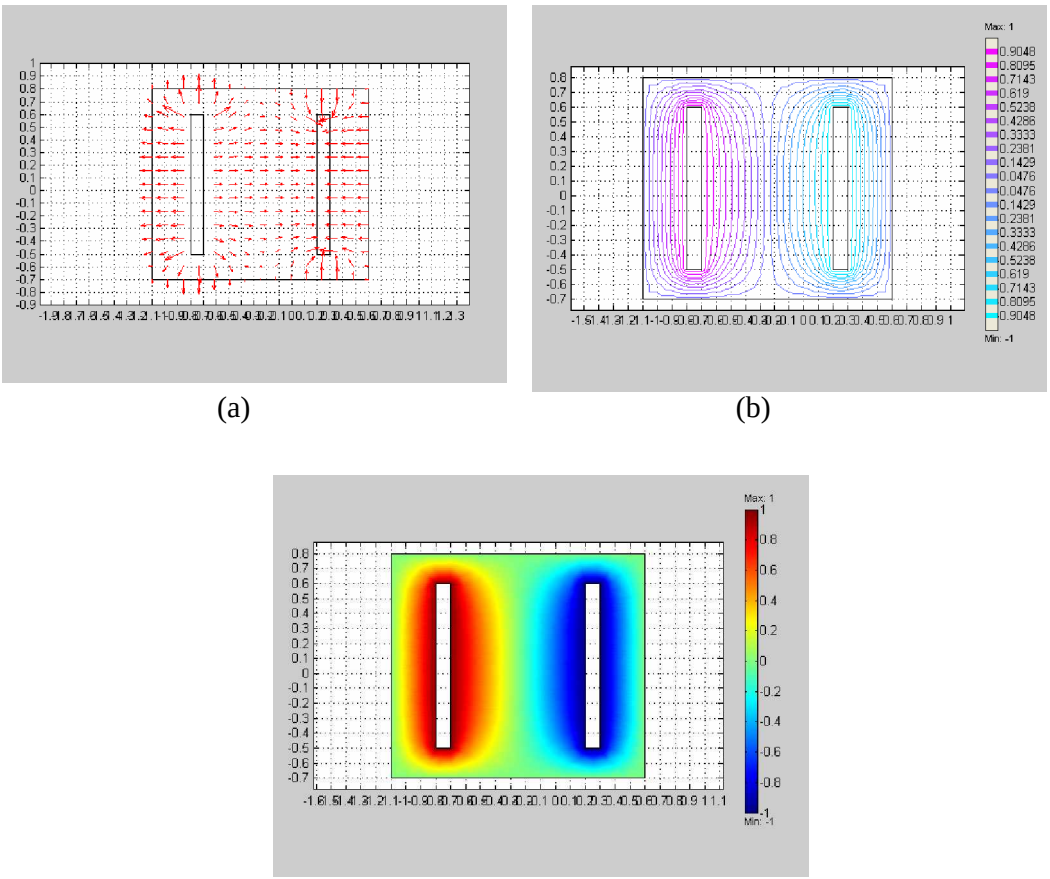
Picture 4. Electric field around two negative point capacitors

4. Electric Field around Two Plat Conductors with Different Types of Capacity

Electric field around plat conductor with different types of capacity will show similar pattern with electric field that exist on two different type point capacitor. The area between the two conductors obtains the effect of the electric field, since different type capacitors have the characteristic to pull and draw each other.

Electric field around two conductors with different type capacity has diverse pattern with dielectric field on two conductors with similar capacity. It shows that there is no “empty” area between the two capacitors, while the other one shows that there is an “empty” area between the two capacitors. The empty area on electric field between two conductors with similar capacity is caused since each capacitor rejects the other, while electric field on two conductors with different type capacity has the characteristic to pull and draw each other. The direction (force vector) of electric field for all types of capacitor has the same tendency,

that is always out (making distance) to positive capacitors and always in (getting closer) to negative capacitor. This characteristic is applicable to all types of conductor, no matter what shape the conductor is; whether it is a point, round, cylinder, or plat conductor.



(a) (b)

(c)

Picture 5. Electric field around two different types of plat capacitors

b. Students' and Lecturers' Degree of Satisfaction in Using Electric Field Simulation by Applying FEMLAB

1. Lecturers' Degree of satisfaction

The data regarding lecturers' satisfaction of the electric field simulation using FEMLAB is taken through interview method. From the interview some standpoints are found; the readability of program on the presentation of electric field simulation, especially related to the meaning of colors that available on the simulation program. Input from physics lecturer then become the reference to revise the presentation of the simulation program before is finally applied to students' process of learning.

2. Students' Degree of satisfaction

Based on the questionnaires which are shared to some students, it explains the degree of satisfaction related to usage of FEMLAB as the electric field simulation instrument. The data are served as follow:

Table 2. Students' degree of satisfaction to the simulation product

No	items	No. Queso.	VA (%)	AG (%)	DB (%)	DA (%)	VD (%)
1.	Simplicity of using the program	1-7	14	23	63	-	-
2.	Clarity of program presentation	8-22	37	57	16	-	-
3.	Motivation of learning electric field	23-26	40	30	30	-	-
4.	Motivation to use FEMLAB for other materials	27-30	20	70	10	-	-

Note: VA = very agree, AG = agree, DB = doubt, DA = disagree, VD = very disagree

Based on the analyzed answers questionnaire given to students, it can be assumed the degree of satisfaction regarding the application of electric field simulation by using FEMLAB as follows:

a) Simplicity of using the program

Most students cannot give opinion toward the simulation product which is produced on this research. It is proved that 63% of the students choose doubt. This circumstance is happened since they, in this case, do not get enough opportunity to directly (interactively) use the program. This is because the available computers in Mechanical Engineering an Electrical Engineering Department are not compatible for FEMLAB. Students are only given the opportunity learn the final presentation of electric field produced by various conductors.

b) Clarity of program presentation

Students consider that the presentation of the electric program using FEMLAB is intelligible. It is proved by the answers of the questionnaire where the total of those who agree and very agree reach 94%. The clarity of this program presentation is one of imperative factors to find the effectiveness of learning process, since students can logically analyze the factors related with electric field.

c) Motivation to learn electric field

Students' statement in regard with the clarity of FEMLAB on electric field which are quite appreciative, gives the impact to their motivation to learn electric field further. This can be seen from their answers to continue learning electric field.

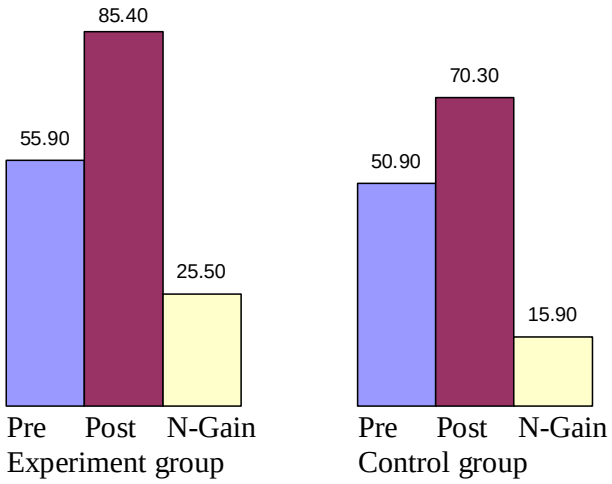
d) Motivation to use FEMLAB for other subjects

Although students can not interactively use the program, from the clarity of FEMLAB program presentation on electric field, students are motivated to try to use FEMLAB program to other subject above and beyond electric field. Finally, considering the simplicity to create the simulation program of electric field by using FEMLAB, it is recommended to physics lecturers to apply this program in learning process.

3. Enhancing the Quality of Physics Learning Instruction

The data about pre test, post test, and N-Gain values from the experiment and control group are showed at the picture 6.

Using statistics examination, it is revealed that the value data for the experiment and control group are the normal-homogeneous data, so the next hypothesis examination is done by t-right hand examination for two samples. Using hypothesis examination, it is revealed that H_o is rejected or H_a is accepted, it means that gain learning of the student who used electric field learning media higher than gain learning of the student who did not use electric field learning media. With the other word, using electric field learning media can enhance the quality of physics learning instruction.



Picture 6. Pre test, post test, and N-Gain values from the experiment and control group

IV. Conclusions and Suggestions

Based on the result of analyzed data and discussion, some conclusions are acquired as follow:

a. The illustration about electric field pattern and force vector around electrical conductor has been resulted from FEMLAB simulation.
b. By using electric field learning media can enhance the quality of physics learning instruction

Researchers have bear down to produce high quality research, but we realize that this research and its results are still far from perfect. Some advises that we can expose are:

a. It is needed limited experiment involving some samples and field test for produced model validity.
b. It is needed extension research to investigate the effectiveness of the model in reducing fallibility concepts of electric field around electrical conductor to students.

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