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Building Critical, Tenacious, and Confident Characters through Application of APOS Model:

Case study in integral calculus learning

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***Abstract*—APOS Model is a model of Mathematics Learning Based on APOS Theory, which is student-centered and has syntax with phases: Orientation, Practicum, Small Group Discussion, Class Discussion, Exercise and Evaluation. The Worksheet is designed to support the APOS model, which is contain activities for each phase. In the practicum phase, the Worksheet contains a command from one of the appropriate computer application programs. In the small group discussion phase, the Worksheet contains questions related to the results of the lab work and new questions that are solved manually by the students. In the class discussion phase, the Worksheet contains a command to present the results of the discussion. In the Worksheet training / evaluation phase the worksheet contains about the Calculus questions. The APOS model has been applied to integral calculus courses by students of class A mathematics study program S1 FKIP UNIB 2017/2018 TA. The aim of the article is to explain that the APOS Model can build critical, tenacious, and confident characters. Data was collected through: observations, open questionnaires, interviews, and results of the Midterm exam and Final Exam. The results show that there was a better change in character after several meetings especially after the Midterm exam. When it came to the integration technique chapter, the topic was difficult but many students were able to study it well. This is indicated by the value of the Final exam. The result which is included in the effective category. There are 5 selected students who are able to complete the Worksheet in Chapter Integral unnaturally, without the guidance of lecturers. It can be concluded that the APOS model can help building critical, tenacious, and confident characters.**

Keywords—component; APOS model; APOS model based worksheet; critical; tenacious and confident

I. INTRODUCTION

APOS is a learning theory that is specially for mathematics learning at the college, which integratedwith computer use, learning in small group, and paying attention to mental constructions carried out by students in understanding a mathematical concept. These mental constructions are: action, process, object and schema abbreviated as APOS [1-3].

- **Action**: A transformation is first conceived as an action, when it is a reaction to stimulatean individual perceives from external. It is require specific instructions, and the need to perform each step of the transformationclearly [1-3].
- **Process**: As an individual repeats and reflects on an action, it may be interiorized into a mental process. A process is a mental structure that performs the same operation as the action, but wholly in the mind of the individual. Specifically, the individual can imagine performing the transformation without having to execute each step explicitly [1-3]
- **Object**: If one becomes aware of a process as a totality, it realizes that transformations can act on that totality and can actually construct such transformations (explicitly or in one imagination), then we say that the individual has encapsulated the process into a cognitive object [1-3].
- **Schema**: A mathematical topic often involves many actions, processes and objects that need to be organized and linked into a coherent framework, called a schema. It is coherent in that it provides an individual with a way of deciding, when presented with a particular mathematical situation, whether the schema applies [1-3].

The APOS Model is a Mathematics Learning Model Based on APOS Theory [4]. The APOS model is a refinement of the Calculus Learning Model Based on APOS (MPK-APOS) Theory [5,6]. The syntax of the APOS Model consists the phases: Orientation, Practicum, Small Group Discussion, Class Discussion, Exercise, and Evaluation [4-6]. The characteristics of the APOS Model are: learning that includes: (1) knowledge constructed by students through APOS mental construction; (2) using a syntax with phases: Orientation, Practicum, Small Group Discussion, Class Discussion, Exercise and Evaluation; (3) using computer; (4) students study in small groups [4-6].

The APOS model is a student-centered learning model, which is effective for improving: activity, motivation, student learning outcomes, and positive response from students [4-12].

To support the APOS Model, a Worksheet is designed that contains activities for each phase, namely: The Orientation Phase is the phase when the lecturer preparing

students to take part in learning with the APOS Model. The main activity is to direct students to be ready to receive learning with the latest subject matter [4-6,13,14].

The Practicum Phase is the phase of students carrying out commands for a computer application program such as Maple, which is on a Worksheet. The results of Maple's execution are copied back to the place provided. The purpose of the practicum phase is to introduce students to a new situation or information (new concepts) [4-6,15-19].

Small Group Discussion Phase is a discussion activity in small groups, to answer questions, or solve integral calculus questions, manually. The questions that asked will help students to find the concept of integral calculus. The small group consists of students with heterogeneous abilities, namely there are high, moderate, and weak students. It is hoped that smart students help weak students. This is consistent with the concept of Vygotsky's social constructivism and Slavin's cooperative learning model [4-6,20,21]. Class Discussion Phase is an activity where the selected group of students presents conclusions or presents the completion of one of the questions in the small group discussion phase or other questions in front of the class [4-6].

Exercise Phase is the activity of solving the questions that given. Problems that are difficult to make given for homework; The goal is for students to learn calculus books at home [4-6,14,22].

Evaluation phase is the activity of lecturers to determine the effectiveness of the APOS Model [23]. Alternative assessment is an effort to integrate learning outcomes measurement activities, with the entire learning process. Assessment is an integral part of the whole learning process [23]. The APOS model has been implemented in Integral Calculus learning in the Mathematics Education Program FKIP UNIB TA 2017/2018. Are there instructional impacts or companion impacts such as: Critical, Tenacious and Confident in students after applying the APOS Model?

II. METHOD

A. *Research Subject*

The sample in this study were all students who take the class of Integral calculus in the Mathematics Education Program Semester III Class A FKIP UNIB TA 2017/2018, which is amount 37 people. Students' abilities according to the test results, and other information are: 24.32% high, 40.54% moderate, and 35, 14% weak [9].

B. *Data Type*

The types of data in this study are: quantitative data and qualitative data. Quantitative data is obtained from the result of the midterm Exam, and Final exam. Qualitative data is obtained from observations, interviews and open questionnaires.

C. *Research Instruments*

The instruments used in this study are:

- Documentation of Midterm Exam and Final Exam Score
- An open questionnaire about the impact of the accompanying APOS Model

D. *Data Analysis Technique*

Learning outcomes from the result of Midterm exam, and Final Exam, and result if the questionnaire is open for a single answer, are processed by using descriptive statistics. Percentage of student learning outcomes using the following formula. Value (%) = (Score obtained by students) / {Maximum score) x 100%. Achievement rate (%) and category are: if 0 <value ≤ 20, it is not effective; if 20 <value ≤ 40, is less effective; if 40 <value ≤ 60, is quite effective; if 60 <value ≤ 80, effective; if 80 <value ≤100, is very effective [24]. The answer to the open questionnaire is a summary of the student's statement.

III. RESULT AND DISCUSSION

A. *Figure 1. Graph of Midterm Exam and Final Exam Score*

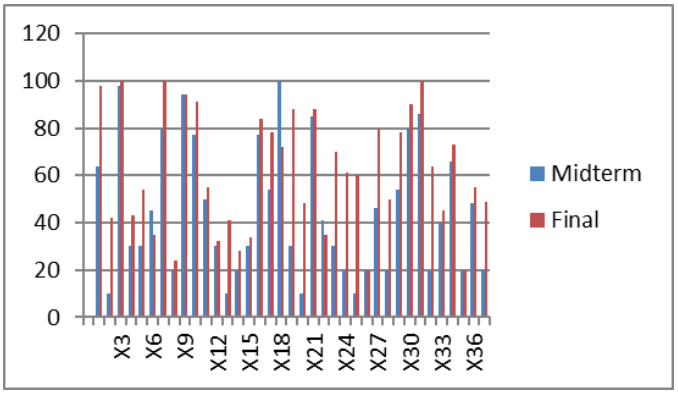

Fig. 1. Graph of midterm and final exam score of Integral Calculus.

Figure 1 shows that, some students have a Final Exam score higher than the score of the Midterm Exam. The average of the Midterm Exam is 45, and the average of Final Exam score is 61,595. The difference between the average of midterm and final exam is 26,595. From the results of the observations during the learning, the student attitudes change better after midterm exam. Students learn more seriously. The midterm exam score is very low, after being analyzed, it turns out that students have difficulty drawing a graph of a function, so it's difficult for student to solve midterm exam questions about the area, and the volume of rotating objects [9,19]. After midterm exam, students no longer draw graphs. This has an effect on students' learning motivation which is increases.

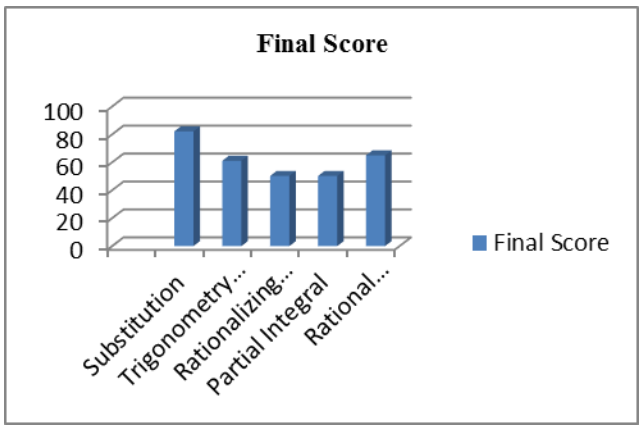

Fig. 2. Graph of final exam score for each integration technique.

Figure 2 shows that the highest value is in the substitution integration technique. This is show that students generally understand the substitution integration technique. The graphical value of the rationale integration technique is rationalizing, and the partial integral is in the lowest. This topic is the most difficult among integration techniques because it involves trigonometry. Trigonometry is a mathematical material that is difficult for students to understand. The graph value rises for the Rational function integration technique. The Rational functions is not containing trigonometric functions. This is reinforced by the results of the study [25]. The students' learning difficult is in Integral Calculus are evidently based on the weak procedural knowledge of Trigonometry by the sample of one hundred (100) students. The participants find difficult whenever the given integral is expressed in non-algebraic form, regardless of the required integration process. It was concluded based on statistical finds that learners experienced the same level of difficulties in calculating integral applying either the integration formulas or the integration techniques. The count index revealed that the difficult items identified in the use of any of the two integration process both require the students' capability to operate and simplify non-algebraic functions.

Practicum using computers has motivated students to be active to learn calculus. The results of the study Zakari and Salleh support the statement the results obtained from exploring students' perceptions towards calculus and their readiness to use computers in learning provides a new perspective on the teaching and learning of this topic [26]. Integrating computers in the learning of calculus should be seriously considered as many studies have shown a positive impact of this strategy on students' understanding. Thus, the new strategy has to be carefully planned to improve students' learning outcomes in calculus

B. Interview Results and Open Questionnaire Results

Before the idea of giving an open questionnaire to students who had attended integral calculus in class A TA 2017/2018, on September 22, 2018 researchers interviewed Ahbi, the best student in the Integral Calculus class.

Lecturer: Ahbi, may I know, compared to conventional learning, what is the different that you feel, in the APOS Model learning, last year? Are there critical, tenacious and confident characters that felt, due to learning with the APOS Model?

Ahbi: According to me, the most felt is the formation of tenacious and critical characters, and of course the confident follows when we have reached the tenacious and critical characters. When studying calculus given the APOS Model learning last semester, I used to explore questions independently and look for integral work methods that have various forms of questions. Because I was used to the phase of group, class discussions, and the training, working on the questions was already not too heavy and I had enjoyed it Based on Ahbi's answer, came the idea of giving an open questionnaire to Ahbi's friends. On September 25, 2018, an open questionnaire was given to students of the 3rd semester of Grade A FKIP Mathematics Education study program who had taken the Calculus course for 2017/2018. The distance between the final exam and filling out the questionnaire was 9 months. Students who returned the questionnaire numbered 30 people. Questionnaires are returned anonymously. After the data is processed, the following information is obtained.

a. ***Question 1. Are there critical, tenacious and confident characters that occur as a result of learning Integral Calculus with the APOS Model?***

The number of students who answered "yes" was 96.7%. Their reasons are as follows. To complete the Worksheet based on the APOS model, accuracy and perseverance are needed. We have to find the material by ourselves, to solve the problem, if we are not critical, not tenacious and not confident, we will not be able to complete the material on the Worksheet. To do the work in a Worksheet in groups, make a tenacious character, and be critical of ourselves we are more honed every time we learn from the APOS model in the class. Our confidence is honed by presenting the answers to the questions in front of the class

b. ***Question 2. Are there any influences of characters formed, in the next lecture?***

The number of students who answered "Yes There Are" is 80%. The reason is like the following summary.We are used to being critical, tenacious and confident, so that we continue to get used to / transmit to the next lecture. We are more careful, curious about solving problems in the problem. We are becoming more tenacious, and critical, and more independent in the next lecture / outside the lecture. Our independent character is formed, due to learning to use the APOS Model based on the Worksheet

c. ***Question 3. Which knowledge lasts longer, searched by yourself, or explained by the lecturer?***

The number of students who answer "search by myself" is 80%. The reason is like the following summary. Find your own knowledge, last longer, because we are more active in learning. We will always remember what we have done.
Previously, there were 5 best students selected to complete the Unreasonable Integral Worksheet. December 19, 2017, a week before the final exam, the five chosen were made

into a new group. . They are given an Unreasonable Integral Worksheet. Other students make exercises at home for the subject of rational function integration. They do it outside the classroom. Worksheets that have been answered are collected at the final exam on December 26, 2017. After the holiday is over, then on February 6, 2018 the five students working on the Integral Worksheet are unnaturally asked to answer the test questions consisting of three questions taken from practice questions, with time 90 minutes. After checking the results were obtained that: Two people managed to answer all three questions correctly. One person answered correctly for two questions and wrong operation for another. Two people do not remember the integral principle is not fair, but remember the integration technique. The test is given without prior notice. They do not carry the Integral Calculus book. So they have to remember the material they learned two months before outside the classroom without lecturer guidance, without class discussion. Integral Unqualified material is the most difficult of the other Intergral because students should have to know about unlimited limit and limit in infinite and advanced integration techniques. This proves that Learning with the APOS Model can shape the character of students to be critical, tenacious and confident and independent [10,11].

In the practical phase students work using the Maple application program. The results of the study Awang et al. concluded the integration of Maple activities in integral calculus tutorial classes was found giving positive effects on enhancing engineering technology students' understanding in this topic [10,11,27]

The results of this study indicate that the theory about the cone of learning Dale proved true. If students are involved in hands-on workshops they are able to recall 70% [28,29].

Because mathematics is activity (doing mathematics), math activities not only focus on the final solution sought, but in the process which includes, among others, the search for patterns and relationships, conjectural tests, and estimation of results. In such activities, children are required to use and adapt existing knowledge leading to the development of new understandings [30].

The results of the study Munafo concluded we believe that teaching activity based on a constructivist view of learning can bring forth more engaged students with deeper awareness of real and more prepared to face every day decision-making situations within the Project for Life [30].

Mattar states that work is also needed to explore the application of connectives in educational technology and distance education [31]. Of specific interest is the development of reflection on the reconfiguration of Vygotsky's zone of proximal development and its potential uses in education. Research results Muniyappan, social constructivism encourages the learner's own version of the truth that is influenced by his or her background, culture or knowledge of world [32]. Social constructivism which assumes that cognitive growth first occurs on a social level and later individual level, emphasizes the role of ZPD (Zone of proximal development). The learner's background also helps to shape the knowledge and truth that the learner creates, discovers and attains in the learning process. Social constructivist teaching approaches emphasize reciprocal teaching, peer collaboration, cognitive apprenticeships, problem- based instruction, web quests, anchored instruction, and other methods that involve learning with others. Instructional models based on the social constructivist perspectives highlight the need for collaboration among learners and with practitioners in the society.

IV. CONCLUSION

The APOS model has a syntax with phases: Orientation, Practicum, Small Group Discussion, Class Discussion, Exercise and Evaluation. The APOS model is supported by the APOS Model Based on Worksheet. The impact of applying the APOS Model on Integral Calculus learning is the formation of critical, tenacious, confident and independent characters. Independent is meant to be able to find information from books or from lab results or from other sources to solve the problem of Integral Calculus being studied

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