DEVELOPMENT OF *COGNITIVE APPRENTICESHIP INSTRUCTION* MODEL IN MATHEMATICAL PHYSICS LEARNING TO IMPROVE REFLECTIVE THINKING SKILLS

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ABSTRACT

Cognitive Apprenticeshi- Instruction (CA-I) models are modified from cognitive apprenticeship learning in businessfield with emphasis on the development of reflective thinking skills that are important for physics teacher candidates. This study is a mixed methods research with embedded experimental design involving three physics education study programs of three universities in Semarang. Quantitative data from pre and post test were analyzed and triangulated withdata from observation, questionnaire, and interview results. Based on the data analysis, the CA-I model which has syntax of modeling-coaching-articulation-reflection-exploration can make a significant contribution in enhancing the students's reflective thinking skills.

Keywords:*cognitive apprenticeship; reflective thinking; mixed methods*

1 INTRODUCTION

Mathematical Physics subject in the Physics and Physics Education study program is a compulsory subject for students in a higher education. In some colleges, curriculum for this subject is varied; they are placed in the second and the third semester.Some are placed on the third and fourth semester in a row. The placement of this subject is designed to provide a precondition preparation for students since its inception in mastering the techniques of mathematical analysis of the physics concepts for the next semesters.

In the other hand, higher education students are adult learners. At this level, higher level thinking skills has become imperative to be developed and need the right strategy to be trained. A wide variety of high-level thinking skills had proposed by educational experts in preparing prospective professional teachers. One of them is adopted in this study, it is reflective thinking skills. Based on the results of preliminary studies, training the reflective thinking skills to the prospective teachers insolving physics problems especially in the mathematical physics lecture is urgent (Ellianawati etal, 2013a). Physics problems that are constantly evolving dynamically require proper, effective, and efficientcompletion strategy. In the other hand, this strategy also requires the ability of solving problems critically and creatively. Reflective thinking processes are accommodating critical and creative thinking processes that are interwoven and interdependent. It is mean that when the process of critical thinking occurs in the activities of problem solving, the process of creative thinking will play a role in developing the idea of the results of critical thinking, and vice versa when the process of creative thinking happens then justify the feasibility of execution is determined by the process of critical thinking (Ellianawati et al, 2015). Thus, training the reflective thinking skills in mathematical physics learning will encourage students to think critically and creatively simultaneously in solving physics problems.

The mathematical physics learning process in buliding the concept of mathematical analysis should be able to provide supplies of skills to students in operating the basic techniques of mathematical analysis used in mathematical physics, identify the circumstances analysis techniques are applied, and manage the techniques of this analysis to solve physics problems that arise in new situation. These three important skills areactually task of cognitive apprenticeship-based learning (cognitive apprenticeship, CA) as described by Collins et al (1991). Therefore, it is important to apply this CA based learning in physics teaching mathematics.

Cognitive Apprenticeshipwas originally a model of new employees' job training in a company that is common in the business field. This model is now widely applied in education and training to produce candidates as professional labors, as in vocational training and professional education, including teacher education. Several studies on the implementation of this CA have been carried out. They are significant contribution in improving the performance of students on the lecture web-based (Liu, 2005); CA develops in collaborative systems to improve the performance of teachers (Glazer, et al 2005; Glazer &Hannafin, 2006); and effort ofimproving student math problem solving ability (Johnson &Fischbach, 1992; Schoenfeld, 1992, pp.334-370).

Cognitive apprenticeship model in education according to Dennen& Jonassen (2004) essentially aims to encourage students' participant to observe the performance of an expert chosen. During this orientation activities scaffolding process also occur when experts explore opportunities to improve the ability of learners. In the next stage, learners are challenged with tasks that are a little more difficult than they can achieve themselves and the completion of these tasks are conditioned so that they can learn to collaborate with others. In other words, learners must work with diverse experience and in line with the complexity and diversity of the assignment, then from time to time, learners will become more skilled and will move from the position of the observer becomes an active part in the activities. It is mean that the pattern of coaching an expert should be able to train professional candidates understands their duties gradually and simultaneously in order to achieve success in their new duties.

From the results of the initial study on opportunities for developing reflective thinking skills through the study of mathematical physics, it is obtained significant data that cognitive apprenticeship-based learning can accommodate efforts to improve reflective thinking skills student teachers of physics (Ellianawati et al, 2013). However, although the CA model in accordance with the characteristics of mathematical physics subject to develop reflective thinking skills for prospective teachers of physics, it needs a further empirical studies in applying this model. To distinguish the models CA in the profession field with the modifications CA in education prospective teachers,the use of Cognitive Apprenticeship-Instruction (CA-I) term is determined. The basic term that distinguishes is the specific implementation strategies of the models related to the characteristics of physical education lectures. One of the goals of education in physical education lectures is to provideteacher candidates that have pedagogic competence, personality, social, and professional. Therefore, the touch of pedagogical learning became primary.

In the other hand, the characteristics of MathematicalPhysicssubject that need almost all hand task, careful, thorough, and focus in solving problems require a strategy that tactically so that students can master the content well, enjoy the learning process in the classroom and outside the classroom, and gotpositive experiences that can be adopted when they pursue their study or when become a teacher. Based on the background mentioned above, the purpose of this study was to obtain a model of CA-I that most suitable to the characteristics of Mathematical Physics subject in improving students' reflective thinking skills.

2 METHOD

The development of CA-I model in mathematical physics subject for improving physics education students' reflective thinking skills was designed using the technique of mixed method with embedded experimental model (Creswell, 2007: 71). Quantitative data from pre and post test were analyzed and triangulated withdata from observation, questionnaire, and interview results. Therefore, data obtained from this study is a blend of quantitative and qualitative data. The preliminary stages of CA-I model development is the collection of qualitative data in the form of a preliminary study of needs assessment and analysis of curriculum Mathematical Physics subject followed by a test of content and construct validity.

Results of the preliminary design are then tested on gradually number of participants using RnD stages. The qualitative data research in this preliminary stage further processed in drafting CA-Ibased Mathematical Physics learning programs. At this stage, the measurement to obtain quantitative data derived from pre-test and post-test.

During the learning program, qualitative data collection about learning activities using observation sheet checking and video recording were also conducted. The final stages of collection and processing of data performed qualitative data analysis of student responses to the development of learning programs, both through questionnaires and interviews sesions. Once all the data were obtained, then interpretation of qualitatif data emphasis on the quantitatif data was doneto describe the students' reflective thinking skills profileswhich was developed through CA-I based MathematicalPhysicssubject.

This study is involving187 students and 5 lecturers from threephysicaleducation coursesofthreedifference universitiesthat organizesphysics education studyprogramin Semarang, Central Java, Indonesia.

3 RESULTS AND DISCUSSION

The CA-I model syntax is modeling, coaching, articulation, reflection, and exploration. Stage of modeling, is the stage where students observe, select, and sort the information presented by the lecturer according to their needs. Stage of coaching, is a lecturer activity in assisting andsupporting student cognitive activities. Stage of reflection, is the activity of students in giving meaning to their own learning and self-improvement through the completion of structured tasks. Stage of articulation is verbal responses to the results of assignments collected by students. The exploration stage is a further assignment with a slightly more complex task to train the students' reflective thinking skills.

The development of CA-I model in giving a meaning to each of the teaching materials in this study was done by using certain strategies. They are providedthe assignmentof daily life physics problems that isnon-routine, open ended, andintermediateproblemswhich aregiven simultaneouslyandcontinuously; assessedstudents progress eitherindividually or in groupsbothin the classroomand outside the classroom; provide tutors guidance inscaffoldingprocess throughreflectivedialogue; supporting situation based teaching materials which can be studiedindependently. These strategies were done in order toimprove the studentsability to solve more complexphysics problems.

3.1 Model Development

The developed CA-I model has been through three revision phases. The first revision was an improvement after the draft model adopted from the CA model was trailed to six remedial students who had previously studied mathematical physics. Based on the observation result, in the first development stage, the lecturer has prepared adequate teaching materials, but still lack of problems that support the development of reflective thinking skills.

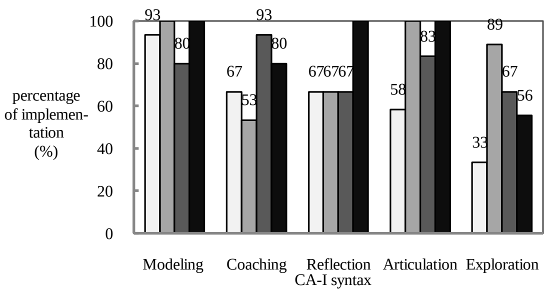

Figure1. Implementation of first trial of CA-I based MathematicalPhysicslearning (= first meeting; = second meeting; = third meeting; = fourth meeting)

This is in accordance with the theory of Marsh (2008: 21) that in the development of thinking skills of learners should be devised strategies that match their level of thinking and learning. The result of observation at the first stage of development gives information that the modeling and articulation stages have been done well, the coaching and reflection stage is enough to meet the criteria, but the coaching stage is still weak.

According to the result of questionnaires and interviews analisys, it come to the conclussion that the scaffoldingstrategy which was expected to occur during the coaching stage cannot be implemented optimally. The more often incomplete reflective assignment done by the students caused the lecturers to play more roles in the discussion at the articulation stage. The application of material that has not been discussed in the modeling stage has caused the exploration stage not to run as expected.

Evaluation results and syntax improvements from the first trial were implemented in the larger classes of class A and class B. The lecture syntax in the second trial in both classes experienced simultaneous changes. That is, when the first meeting in class A gained new experience from the evaluation and discussion between the researchers and lecturers, it is directly applied in class B and so to class A.Compared to the first syntax trial results with 3 credits and a second trial with 2 credits obtained results as in Figure 2.

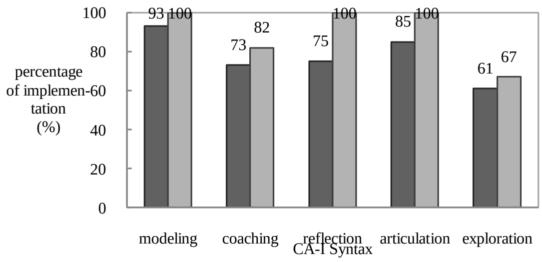

Figure 2. Implementation of the CA-I Mathematical Physics Learning Syntax of firsttrialresults () compared to the second trial in class B () for the first four meetings

The comparison of the secondtrial result syntax is selected class B because the syntax executed in class B is the bestevaluation result syntax. Based on the results of this second trial is recommended syntax of CA-Ibased Mathematics physics lecture to improve students' reflective thinking skills with the weight of 3 credits per meeting. This is because at the weight of the 4 credits courses that are held each 2 credits on different days or those that are weighted 2 credits as in the second trial, the lecture syntax is divided into two stages. In the first meeting its implementation was cut into modeling-coaching-reflection and articulation-coaching-exploration at the second meeting.

Implementation of CA-I based Mathematics physics learning in the experimental class is independent. That is, lecturers implement the CA-I model only based on the guidance sheet. This stage is important since it can be seen how the commitment of implementing the CA-I model in the field.

Based on the observation result, it appears that the lecturer in the experimental class is still trying to find the most appropriate format to match the class condition. This is evident from the fluctuation of the score of the syntax implementation of the lecture in the first two weeks. In the third and fourth weeks, all the syntax stages have been performed, as well as in the seventh week. Almost all aspects achieve maximum score, meaning that the lecturer is accustomed to perform the syntax stages.

However, since the materials to be completed are still numerous and require more intensive training for final semester exam preparation, the lecturers focus more on the modeling and coaching activities after the 8th week. The results of observations in the experimental class are as in Figure 3.

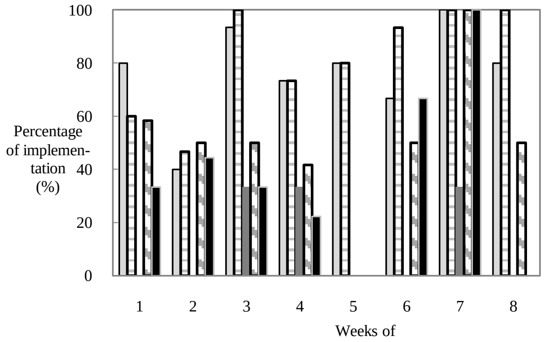

Figure 3. Observation Results on the Implementation of CA-I Syntax in Experiment Class for the First 8 Effective Meetings

3.2Reflective thinking results

The development of CA-I model in improving reflective thinking skills in problem solving are measured by reflective thinking skills test consisting of three post test questions about the application of Mathematical Physics concepts on wave, mechanics, and electrical problems. The first trial obtained by the data as in Figure 4

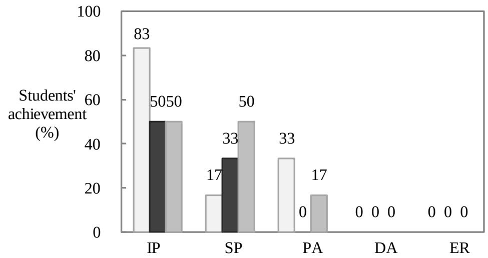

Figure 4. Students' achievement in solving Mathematical Physics problems (☐ = wave,■ = mechanics,☐ = electricity) reflectively (identify the proplems = IP, state the problems = SP, propose alternative solutions = PA, develope ide = DA, and evaluate the results = ER)

In Figure 4 in general, students have been able to identify and try to formulate problems and propose alternative solutions. However, it seems that the skills of developing ideas and evaluating answers have not yet emerged on the three questions. The three questions presented basically they have learned in BasicPhysics subject because all students who follow the remedial class has been taking the course of Basic Physics 1 and Basic Physics 2. It seems four times face-to-face sessions have not helped the students to be able to bring the ability they develop ideas and evaluate answers.

According to the criteria proposed by Kember etal (2000) about the level of reflective thinking, the answers given by students through the means of solving the problemsare still in the stage of understanding. Physical concepts that they should have, in the sense of not just rote, but will appear by itself when met with similar cases apparently not much done in the solution of the problems presented. The same thing on the concept of Mathematical Physics 1 in the form of approach of topics of series number, complexnumber, and differential that should appear in problem solving is also not yet widely used by students (Ellianawati, 2014). This situation indicates that the student has not been able to interpret the learning experience in Basic Physics and Mathematics Physics 1 related to problem solving Mathematical Physics 1.

Based on the observation data and triangulated using the questionnaires and interviews,students have tried to write mathematical formula related to physics concept presented, but not yet concocted to find the variable in questions. That is, students have partially understood the concepts of physics and its practical formula, but have not been able to comprehensively understand the problem solving by using mathematical approach they have learned in Mathematical Physics.

Next, on the second trial, each of the five indicators used in the first trial expanded into two indicators the total became ten indicators. This is done to get more detailed data so that it can describe every problem solving process completely. In this second trial, the research was conducted in two experimental classes, namely morning and afternoon classes. This is to see the effectiveness of the learning process of Mathematical Physics using the CA-I model related to learning time.The achievement of students' reflective thinking skills in the second trial is presented in Figure 5.

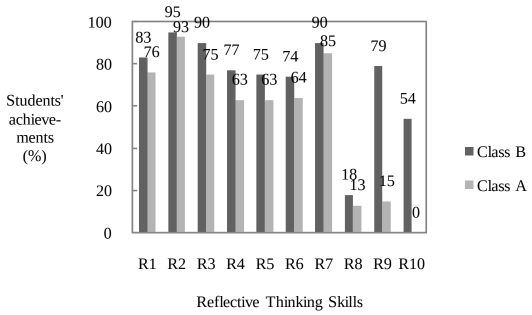

Figure 5. Average Score of Reflective Thinking Skills Components of the Second Trial (R1 = identify problem, R2 = identify the physics concept of the problem, R3 = formulate the problem, R4 = apply the exact mathematical equations, R5 = explain the procedure, R6 = connected the procedure with physics concept, R7 = consider alternative solution, R8 = analyze accurately, R9 = explain the significance of the answer, R10 = evaluate the answer through verification)

Components R1 to R7 have been mastered quite well by students of class A and class B. Learning in class A is evaluated and performed improvements, especially in the syntax then applied in class B. After the revision, components R9 and R10 are able to be trained properly. However, there is still an obstacle of increasing the R8 component that is the ability to analyze accurately. The problem used in this second trial is still similar to the problem given in the first trial. Each problem is a mixture of questions about mathematical analysis techniques and physics contexts.

The data in line with the observations, questionnaires and interviews results, there are still many of them who have not been able to apply mathematical equations. It is because they have not been able to relate the procedures of mathematics and physics concepts. Students also have not been able to complete accurately, and if this happens the student tends to end the learning process and stuck too long on one problem that cannot be solved. This result is in line with the Ayush&Elby(2011)findings.Once the students encountering contextual questions,they tend not to translate the cases into mathematical equations and tend to be trapped in their epistemological attitudes that stop at the definition problem.

Based on the data obtained in the second trial then performed improvements both in syntax and learning strategies. The final results of this model development are then implemented in the experimental class with two control classes.The experimental class is a class that is taught by the model lecturer using the CA-I learning model but without continuous guidance, namely E. Model lecturerlearns the guidance on CA-I that has been prepared but uses the teaching materials that hechooses. The first control is a control class with a direct learning model but is taught by a senior lecturer with a learning module compiled by a Mathematics Physics Teaching team, namely C1. The second control class is the class that is taught by the lecturer who has the same educational qualification as the model lecturer but uses the direct learning model with the more varied teaching materials, namely C2.

The improvement profile of students' reflective thinking skills in the experiment class compared to the other two control classes was obtained by comparing the average grade of the final grade of each class. Since the three samples were have different approach of learning, then the statistics calculation used was ANOVA test. Based on One Way ANOVA test result toward the final semester test results obtained data as in Table 1 and Table 2.

Table 1. Description Test Results using One Way ANOVA Analysis

Class	N	Ave	DS	Lowest	Highest
E	34	61.9	15.1	49	88
C1	35	63.1	10.3	36	85
C2	26	62.8	8.4	52	81

Table 2. Description Test Results using One Way ANOVA (Multiple Comparisons Dependent Variable: final_test, Tukey HSD)

(I)	(J)	(I-J)	Std. Error	Sig.
E	C1	- 1,23	2,84	0,90
	C2	-0,90	3,08	0,95
C1	E	1,23	2,84	0,90
	C2	0,34	3,06	0,99
C2	E	0,90	3,08	0,95
	C1	-0,34	3,06	0,99

Based on the information in Table 1 it appears that there is no significant difference from the mean of the three classes. More clearly in Table 2 above it appears that the value of Sig(p) of the final test value of all three classes> 0.05. That is, there is no significant difference between the final grade of the experimental class and the two other control classes. But, the highest score of the final test hold by the experiment class. It is means that the CA-I model provide better result in problem solving capability.

The data is accordancewith the observations, questionnaires and interviews result of experiment class students. The learning of CA-I based mathematics physics appears to have a significant impact on the improvement of problem solving skills of Mathematical Physics. They experience a dishtinguish learning model that help them to solve probems more handy and more easily. This data is consistent with the results of Katz et al (2003) research on reflective dialog strategy that enhances students' cognitive abilities. The results of this study are also in line with Cardelliniresearch finding (2006) that collaborative learning can improve students' intuition skills. In this study, collaborative learning was conducted in a small group discussion format in the syntax coaching stage (Dennen& Jonassen, 2004) to solve physically critical and creative problems (Alghafri&Nizam, 2014).

3 CONCLUSION

The CA-I-based Mathematics Learning Physics that has been developed in two trials and implemented into experimental class with two control classes has resulted significantly in improving students' reflective thinking skills.Data from reflective thinking test results confirmed by the results of learning observations, questionnaires and interviews indicate that the developed CA-I syntax has given students the opportunity to practice their reflective thinking skills.

Stages of modeling have given insights and options related to analytical techniques to be studied. Stages of coaching train students in finding patterns of problem solving with scaffolding given by lecturers. Stages of articulation provide reinforcement of problemsolving exercises at the coaching stage. The reflection stage allows students to explore their ability to solve problems and find the most mastered and easiest problem solving strategies for them. This stage is then reinforced by exploration stage in which lecturer can act as mentor inproviding challenges to the studentsin order to train students' reflective thinking skills.

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