Development of the STEM ISCIT Model that Focuses on Professional and Pedagogical Improvement of Prospective Physics Teachers

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Abstract. This research aims to produce an effective STEM ISCIT learning model to improve the pedagogic competence and professional competence of Physics Education students. This research goes through the stages of development, namely define, design, development and dissemination. The trial phase involved 60 students of the Ahmad Dahlan University Physics Education Study Program and Yogyakarta State University. This research has produced an ISCIT STEM learning model to support the improvement of pedagogic competence and professional students. The measurement results revealed differences in the pedagogic and professional competency tests in the experimental and control classes of UAD subjects with an average number of 87.03 and 45.44 against the effective ISCIT STEM learning model. Furthermore, the UNY test with a total of 91.18 and 52.82. Based on the N-gain value for the experimental class, UNY subjects were 91.18% in the effective category and 52.80% in the control class in the less effective category. Meanwhile, for UAD subjects, the experimental class of UNY subjects was 87.03% in the effective category and 45.43% in the control class in the less effective category.

INTRODUCTION

Teachers have an important role as regulated in UU Number 14 of 2005 concerning Teachers and Lecturers, in which teachers and lecturers are expected to be able to oversee the achievement of national education goals so that their human resources can be efficient and have superior qualifications. Because of this situation, preparation is needed before becoming a teacher. Several studies state that prospective teachers must have qualified competencies to become educators [1]. One way to increase the competence of prospective teachers is to involve universities and training in improving competence so that they are able to improve the quality of human resources in the field of education [2], [3]. The importance of competence for prospective teachers to have to guide and educate their students well to continue the role of their parents. Based on the many studies that have been done, there are competencies that must be possessed and which are very important. These competencies are professional and pedagogic competencies [4]–[6]. Professional and pedagogic competencies are two of the four competencies that must be possessed by teachers and prospective teachers. Personal competence and social competence must also be possessed to support the professionalism of teachers or prospective teachers. However, based on the data obtained, attitude and personality only affect 26.1% and the rest affect pedagogic and professional competence, then social competence and personality competence are difficult to measure directly [7]–[9]. The ability to produce achievements and achievements will determine the quality of education. Finally, training and development are basic needs that are expected to have an effect on improving competence.

Pedagogic competence with good pedagogic abilities, prospective teachers are able to design learning tools appropriately, compile media and teaching materials that are relevant to learning objectives, prepare Student Worksheets that are in accordance with student intakes and report holistic assessment results

Therefore, pedagogic and professional competencies were chosen in this study based on studies that have been carried out by several researchers. Meanwhile, one way to improve professional competence is by following a higher level of education. To make this happen, in tertiary institutions, lecturers need to provide adaptive, innovative, and communicative learning so that professional and pedagogical competencies are adequate. Three interesting points that can be aligned to create adaptive learning are Technology, Pedagogy, and Content [10], [11]

Prospective physics teachers can develop physics learning outcomes resulting from the integration of Technology, Pedagogy, and Content in the form of Physics teaching devices that are attached to technology such as Microcomputer Based Laboratory (MBL), Video Based Laboratory (VBL), and Simulation Based Laboratory (SBL) [12]. Mastery of Technology, Pedagogy, and Content at the same time is able to give a new color, bringing physical phenomena that tend to be considered abstract to be more real. An interesting learning model to study about TPC integration is the STEM approach because this STEM-based learning method is able to solve phenomena by applying knowledge and skills simultaneously.

The STEM learning model focuses the educational process on solving real problems in everyday life by developing various aspects of attitudes, knowledge and skills as well as increasing critical thinking power and being able to form logic, able to train to get used to finding solutions. In addition, it can stimulate the ability to convey information in a straightforward manner, have patience, teamwork, and various mental abilities that can be applied to individuality and daily life [13]–[16]. Based on studies from previous research regarding the learning methods used, the STEM learning model was chosen to improve pedagogic and professional competencies, where STEM learning can motivate, educate, innovative, and communicative during the learning process. Not only that, STEM is able to apply a systematic and critical assessment of complex problems, relying on practical problems, creativity, logical reasoning and practical intelligence.

Furthermore, researchers will also collaborate with Integrative Scientific Thinking (ISCIT) with STEM learning. Then the STEM Integrative Scientific Thinking (STEM ISCIT) learning model will be developed. Improving pedagogic and professional competence through learning with the STEM ISCIT model. STEM-based learning trains students' thinking skills. In addition, STEM-based learning can motivate, educate, be innovative, and communicative during the learning process [17]. Not only that, STEM is able to apply a systematic and critical assessment of complex problems, relying on practical problems, creativity, logical reasoning and practical intelligence [18]. The ability to produce achievements and achievements will determine the quality of education. Finally, training and development are basic needs that are expected to have an effect on improving competence

METHOD

The development model uses a 4D development model. This 4D development model contains a systematic guide on the steps taken by to ensure that the products they design meet the criteria. The 4D model stands for Define, Design, Development and Dissemination which was developed by Thiagarajan (1974). The research subjects used were Physics Education students from two different universities, namely 60 Physics Education students from Ahmad Dahlan University and Yogyakarta State University. The operational field test involved two groups, namely the experimental class and the control class. This field test stage was carried out on Physics Education students who were taking the Magnetic Electricity course which would then be separated in the control and experimental classes. The data obtained is used for ability analysis in the form of pretest and posttest results to measure the competence of educational students through the STEM ISCIT learning model. Instruments to test the effect of the learning model using pre-test and post-test. data analysis technique used by calculating based on the number (percentage) of participants who answered correctly the ability indicator. Category Very low (≤ 20%); low (21-40%); moderate (41-60%); high (61-80%); very high (> .80%).

RESULTS AND DISCUSSION

Hasil tes pelaksanaan ini digunakan untuk mengukur pendidikan fisika, pendidikan mahasiswa dan kompetensi professional. Learning impact test is achieved by giving a pre-test before the implementation of learning and post-test after the implementation of learning. A summary of this test data is presented in the appendix and is presented in Table 1.

TABLE 1. Learning Impact Testing Data in the Form of Average Score Pre-Test and Post-Test During Learning Held on pedagogical and professional competency test

No	Subject	Experiment Class			Control Class		
		Pre-tes	**1st evaluation**	**Pos-test**	**Pre-tes**	**1st evaluation**	**Pos-test**
1	UAD	43.69	67.54	87.03	39.03	41.48	45.43
2	UNY	48.62	60.87	91.18	45.48	50.00	52.80

Based on Table 1, the following are indicators of achievement.

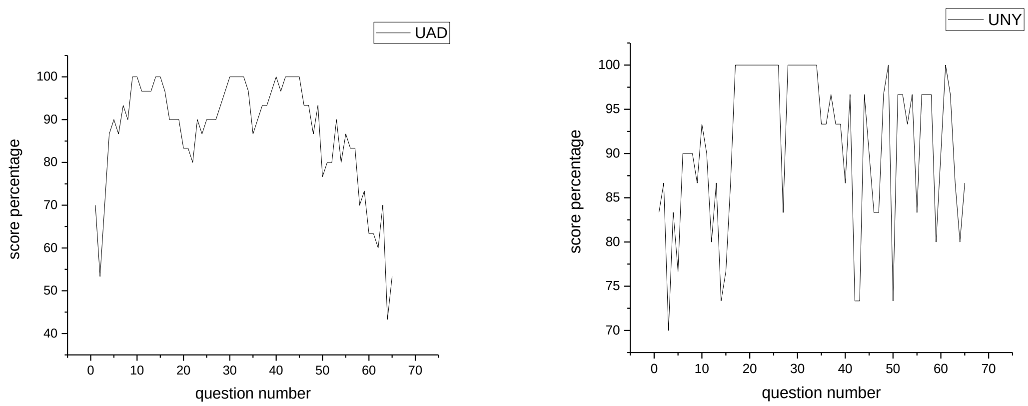

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FIGURE 1 . Achievement Indicator in each item

Professional and pedagogic competence is calculated based on the number (percentage) of participants/teachers who correctly answer the ability indicator. Category Very low (≤ 20%); low (21-40%); moderate (41-60%); high (61-80%); very high (> .80%). Based on Figure 26 the indicators contained in each item are more than 40% so it can be concluded that the indicators are achieved in the medium to very high category. Table 2 is an indicator category for each item.

TABEL 2. Indicator Category of Each Item in Experiment Class

No	Item number		Category
	UAD	**UNY**	
1	2, 64, 65	-	moderate
2	1, 3, 50, 51, 52, 54, 58,59,60, 61, 62, 63	3, 5, 12, 14, 15, 42, 43, 59, 64	high
3	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 53, 55, 56. 57,	1, 2, 4, 6, 7, 8, 9, 10, 11, 13, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 60, 61, 62, 63, 65	very high

Based on Table 2 there are 3 items or no items that have a medium category. The medium item category is an indicator of professional competence in which UAD physics education students are not entirely able to analyze the elastic properties of materials in everyday life, analyze alternating current (AC) circuits and their application, and utilize information and communication technology in communication. In addition to these indicators, items are categorized as high and very high. So that it can be concluded that the STEM ISCIT learning model is able to improve the competence of physics education students with the measuring instrument used to measure the increase in the competence being tested.

The measuring instrument or instrument that is prepared has a high level of reliability and has a balanced role to measure pedagogic and professional competence. This is also evidenced by the average score obtained at the time of the post-test which has a value of 87.03 for UAD subjects and 91.18 for UNY subjects. The average value obtained has an increase in the pre-test and evaluation of 1.

The impact test was measured by determining the importance of the difference in the average test scores of the pre-study (pre-test) and post-study (post-test) groups in the experimental class. The standard used is if the probability of error (p) of the t-test value obtained is less than 5%, the post-test and pre-test values are significantly different. Use the t-test shown in Table 41 to present the data along with a summary of the analysis results.

TABEL 3. Summary of the Results of the Learning Impact Analysis Model Using t-test with the number of subjects 30 people at every college.

	Variabel	Mean	Sig. (1-failed)	Efektifitas
UAD professional and pedagogic test	Experiment Control	87,03 45,43	0,00	efektif
UNY professional and pedagogic test	Experiment Control	91,18 52,80	0,00	efektif

Based on Table 3 above, it can be seen that the t-value calculation for each competency test produces a p-value of less than 5%. These results indicate that there is a significant difference between the scores after the competency test and the scores before the test. Table 40 also shows the post-test and pre-test scores. This means that the average of each competency test that is carried out grows significantly. Observing the results of the analysis, it can be said that the use of the STEM ISCIT model which is applied to improve ability tests has proven to have a positive impact, namely increasing student competence. Based on the N-gain value in table 37 for the experimental class, the subject of UNY is 91.18% in the effective category and 52.80% in the control class in the less effective category. Meanwhile, for UAD subjects, the experimental class of UNY subjects was 87.03% in the effective category and 45.43% in the control class in the less effective category. To further clarify the impact of the application of the developed model, a graph of the impacts that occurred during the implementation of the research is shown.

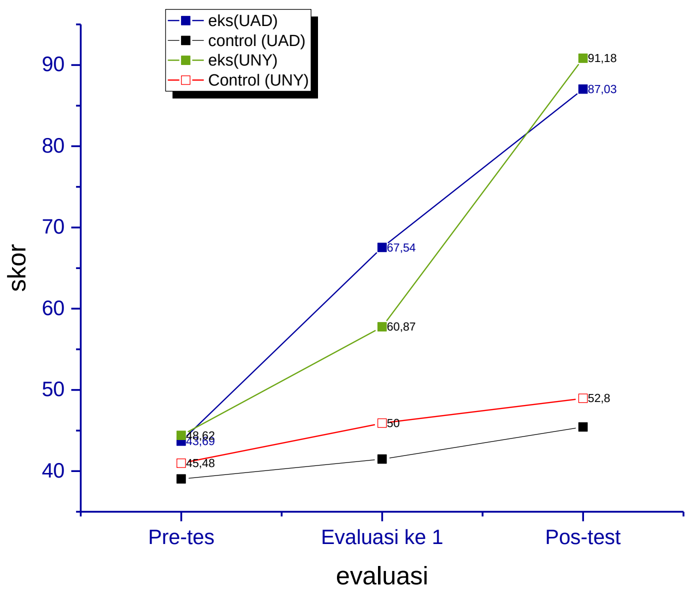

FIGURE 3. Professional and pedagogic competency test results on UAD and UNY subjects

Figure 3 shows a graph of the impact of the application of the model on improving the professional and pedagogic competence of physics education students at Ahmad Dahlan University and Yogyakarta State University. Student learning achievement as a result of the influence of the application of the developed model is very volatile. These fluctuations turned out to follow the pattern of their initial abilities which could be due to the different levels of difficulty of the materials taught in each session. Based on the analysis that has been done above, it can be stated that the implementation of the ISCIT STEM learning model developed in this study, can have a positive impact on increasing pedagogic and professional competency tests.

The model that has been successfully developed is the STEM ISCIT learning model. This model was developed with the aim of improving the pedagogic and professional competence of physics education students. There are four aspects of the general structure of the model that must be possessed to develop the model, namely syntax (stages), social system, student tasks/roles, and support system describing the conditions that should be created or owned by students [15].

The indicators contained in each item show more than 40% so it can be concluded that the indicators are achieved in the medium to very high category. The STEM ISCIT model is successful in improving the pedagogical and professional competencies of Physics Education students. The medium item category is an indicator of professional competence in which UAD physics education students are not entirely able to analyze the elastic properties of materials in everyday life, analyze alternating current (AC) circuits and their application, and utilize information and communication technology in communication. In addition to these indicators, items are categorized as high and very high.

Furthermore, all the syntax that has been done above divides each step in STEM ISCIT learning, namely Science, Technology, Engineering, Mathematics and ISCIT. Starting from Science, students are given electricity and magnetism according to the chosen material. Furthermore, the technology where students are taught to make circuits with the PhET application with electrical and magnetic materials and at the Mathematics stage students are taught to analyze the circuits that have been made with the help of the PhET application.

After all the STEM stages can be given to students, then ISCIT which is the main goal of research which is expected to increase the thinking ability of students can already be done in this study, namely when students are asked to make presentations about ideas which are then made by each project. students, in addition to presentations to convey ideas, researchers also saw that thinking skills increased when the post-test was completed. The STEM learning model used is the embedded approach. This is chosen because the material is prioritized so as to maintain the integrity of the subject. In addition, this approach will link the main material with other material that is not prioritized. Embedded approach to STEM education is material in the fields of technology and engineering as well as mathematics embedded in the magnetic electric material provided by researchers on the subject.

The findings in the research conducted are different from the research conducted by [14] in that the research results show three different cases of integration in the sample representing low, medium, and high degrees of STEM integration across curriculum implementation. The results obtained from the research of Dare, Ellis, and Roehrig, (2018) are that the degree of STEM integration that occurs in instruction may be related to the teacher's ability to make explicit connections between disciplines. This research has similarities with the research of Appianing and which also states that model components are needed in developing models.

The learning steps that are abbreviated as ONRICS are starting from Observe, New Idea, Reconstruction, Innovation, Creativity, and Society. Observation, in this stage Physics Education students are motivated to make observations on various phenomena/issues contained in the daily life environment that are related to the concepts of the subjects being taught. New Idea, in this stage Physics Education students observe and seek additional information regarding various phenomena or issues. Reconstruction at this stage, Physics Education students will practice using the materials provided by the lecturer. At this stage students are invited to think creatively which is one of the goals of STEM learning. Innovation (Innovation), the student's innovation step is asked to describe the things that have been designed in the step of planning new ideas that can be applied in a tool. Creativity, the application by Physics Education students is not in the form of actual products, but in the form of sketches and drawings. The value (society) of Physics Education students is asked to carry out two activities, namely collecting public views on product ideas through surveys and then analyzing them.

After the steps are made, then separate the STEM model starting from Science, Technology, Engineering, Mathematics and ISCIT. In this lesson, students are given electricity and magnetism according to the material chosen for research, then technology where students are taught to make circuits with the PhET application and at the mathematical stage students are taught to analyze the circuits that have been made with the help of the PhET application. After all the STEM stages can be given to students, then ISCIT which is the main goal of research which is expected to increase students' thinking skills can already be done in research, namely when students are asked to make presentations on ideas which are then made projects by each student. In addition to presentations to convey ideas, researchers also saw that thinking skills increased when the post-test was completed.

The results of the research conducted are different from the research conducted by Dare, Ellis, and Roehrig (2018) in that the results show three different cases of integration in the sample representing low, medium, and high degrees of STEM integration across curriculum implementation. The results obtained from interviews with students, in each case revealed three themes that varied among student experiences: the nature of integration, choosing between science and engineering, and student engagement and motivation.

STEM ISCIT is a learning model for students of the Physics Education Study Program. This model has the advantage of teaching students to think more critically. The model was developed with several supporting tools such as lesson plans, teaching materials, the STEM ISCIT Learning Model Book, the STEM ISCIT Model Learning Guidebook for lecturers, the STEM ISCIT Model Learning Guidebook for students, and pedagogic competency test instruments and professional competency tests. This research is in line with research.

The results of the study are: (1) there are differences in STEM and conventional learning in understanding concepts and the use of STEM learning is more effective than conventional (2) there are differences in the results of understanding concepts between male and female students where male students are higher than female students ; and, (3) there is no interaction between learning and gender on concept understanding. To support this learning, teaching materials were made in the conventional class and the experimental class. The research conducted also differs from the research conducted several distinctive themes were identified as described by teacher participants when discussing the challenges and barriers to implementing integrated STEM education, as well as support that would greatly help overcome them. Participants also provided specific advice on teacher education needed to support integrated STEM education. So that in this study there is no need for a product for STEM learning.

CONCLUSION

There are differences in pedagogic and professional competency tests in the experimental and control classes of UAD subjects with a mean of 87.03 and 45.44 on the effective contribution of the ISCIT STEM learning model with effect size values of 0.77 and 0.10 with the "Large" category. and "Small". Furthermore, the subject of UNY with a mean of 91.18 and 52.82 to the effective contribution of the ISCIT STEM learning model with an effect size value of 0.83 and 0.13 in the "Large" and "Small" categories.

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