ICT media utilization model to increase science process skills on natural science lessons in junior high school

by Agus Suyatna

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Abstract. The purpose of this research is to determine the model and utilization of the information communication technology (ICT) that effectively improve the science process skill (SPS). The method used is quasi-experiment. The sample was selected using purposive sampling technique as many as 12 classes of junior high schools in Lampung Province with average initial ability were equivalent. The material that is learned is about the measurement. Data were collected using SPS observation sheet and analysed using two-way ANOVA. The first factor is ICT media model those are the tutorial and the simulation media model of measuring instrument. The second factor is the utilization model of ICT media those are the substitute-experimental, the substitute-demonstration, the complement-experimental, the complement-demonstration, the supplement-experimental, and the supplement-demonstration. The result of the research shows that there is no difference of SPS caused by the difference of ICT media model, there is a difference of SPS caused by the different model of ICT utilization. There is an interaction between media utilization model and ICT media model in terms of SPS. The highest SPS was obtained from the learning using the tutorial media model that was learned as a supplement using the experimental method.

1. Introduction

Natural Science deals with how systematically find out about nature, so natural science is not just mastery of a collection of knowledge in the form of facts, concepts, or principles, but also a process of discovery. Science education directed to inquiry and action so that it can help students to gain a deeper understanding of the natural surroundings. Science learning has the aim of conducting scientific inquiry to foster the ability to think, behave and act scientifically and communicate. To fulfil the above objectives, science learning in junior high schools (JHS) needs to emphasize the provision of direct learning experiences through the use and development of process skills.

Based on the results of observations in schools in Lampung Province, it is known that science learning is still dominated by the lecture method. In the learning process, the teacher explains more about a scientific phenomenon than investigating it. Science learning in junior high school needs to emphasize providing direct learning experiences through the use and development of science process skills and scientific attitudes. Science process skills include conducting observations, choosing observations that are relevant to further investigation, finding and identifying new patterns and relating them to existing patterns, designing and carrying out experiments, using equipment effectively and carefully, using knowledge to carry out investigations, and use their knowledge to solve technology-related problems [1, 2]. This skill is very important to be trained so that the learning objectives of science can be achieved. However, to support this skill needs to be supported by laboratory equipment. In some cases, laboratories perceived as beneficial, but in others, they seen as too easy or time consuming for the educational result achieved. University administrators have a different set of issues related to laboratories. Laboratories encumber both space and schedules. The equipment is oftentimes costly, and needs to be maintain. Also in the economically-driven push toward web-based education, the traditional practice of hands-on physical laboratories becomes impractical or unfeasible for distance learning courses [3]. Laboratory experimentation plays an essential role in engineering and scientific education. Virtual and remote labs reduce the costs associated with conventional hands-on labs due to their required equipment, space, and maintenance staff [4].

Science process skills are very likely to be trained through learning using ICT media. This is possible because almost all of the science process skills trained in the practicum hand-on can also be practiced in a practicum in a simulation, except for taking direct measurements and arranging tools. Computer-assisted learning, including simulated experiments, has great potential to address the problem solving process that is a complex activity. It requires a highly structured approach in order to understand the use of simulations as an instructional device [5]. The use of ICT media in learning science in schools must be able to make active learning, innovative, creative, effective, fun, joyful, and weighty.

Science process skills include the ability to: a) Identify and determine independent and dependent variables; b) Determine what is measured; c) Observing skills using as many senses as possible (not just the sense of sight), gathering relevant facts, seeking similarities and differences, and classifying; d) Skills in interpreting observations such as separately recording each type of observation, and can link observations; e) Skills for finding a pattern in the observation series; f) Skills in predicting what will happen based on observations; g) Skills to use tools or materials and why they are used [6]. From the seven indicators of science process skills, only the skills to use tools or materials are likely to be difficult to train with learning using ICT media.

The selection of the right ICT media model and the use of appropriate ICT utilization models will be effective for improving science process skills. Therefore determining the right ICT media model and developing models for using ICT to build science process skills through learning science in schools is very important to do.

Research on the excellence of ICT media simulations and how to use them has been widely done [7-10]. Computer simulations (CS) on the acquisition of knowledge and cognitive load were carried out with 104 Grade 11 students in four schools in rural South Africa on the physics topic geometrical optics. In terms of the acquisition of knowledge, female students, despite having low scores on the pre-tests, showed sizable and significant increase in the post-tests when using CS. The measured cognitive load was not significantly different for the male and female students. The cognitive load initially decreased as a results of teaching both through the use of CS and without use of CS in the first week while, over time, it increased [11]. Virtual Manipulatives (VM) within a Physical Manipulatives (PM), oriented curriculum affect conceptual understanding of electric circuits and related experimentation processes. For simple circuits, PM and VM use similarly affected students' understanding. VM better facilitated understanding than PM for complex circuits: PM users, unlike VM users, encountered process-related problems that prevented development of an appropriate conceptual model because only VM afforded a view of current-flow. When students used VM before PM for complex circuits, they developed the appropriate conceptual model to use in the PM phase [12] Learning the physical concepts related to pulleys depending on the sequence of physical and virtual labs they use. Students carry out physical pulley experiment and then performed the same experiment virtually, or virtual first condition, in the opposite order. Researcher found no clear support that one sequence was better; they found evidence that participating in virtual experiments might be more useful for studying certain physical concepts, such as work and mechanical advantages. The researchers' findings support the idea that if time or physical material is limited, using virtual experiments can help students understand work and mechanical advantages [13]. The overall findings suggest that simulations can be as effective, and in many ways more effective, than traditional (i.e. lecture-based, textbook-based and/or physical hands-on) instructional practices in promoting science content knowledge, developing process skills, and facilitating conceptual change. As with any other educational tool, the effectiveness of computer simulations is dependent upon the ways in which they are used. Computer simulations are most effective when they (a) used as supplements; (b) incorporate high quality support structures; (c) encourage student reflection; and (d) promote cognitive dissonance. Used appropriately, computer simulations involve students in inquiry-based, authentic science explorations [14].

In the field there are already many ICT-based learning media available. Some are in the form of tutorial programs and some are in the form of simulations. Which form is suitable for learning physics instrumentation in junior high school, is unknown and very important to know so that teachers can choose the right ICT-based media. Likewise with the ICT-based media utilization model, in the field it is used as a substitute, complement, or supplement to physics science learning. As far as the author knows, there is no research that recommends the most appropriate form of use, especially for learning physics instrumentation in junior high schools, even though this is very important for teachers to be able to choose the right form of ICT media utilization. The purpose of this research is to determine the model and utilization of the ICT that effectively improve the SPS and to investigate the interaction between the media utilization model and ICT media model in terms of SPS.

2. Methods

This study aims to determine the ICT media model and the best ICT media utilization model in terms of SPS in measurement learning in junior high school. There are two types of ICT media models, the first is the media tutorial model and the second is the simulation media model. The media tutorial model on measurement material is measurement simulation software that is equipped with operating instructions and learning instructions. The software consists of simulation measurements using callipers, micrometre, thermometers, dynamometers, voltmeters, and ampere-meter. The simulation media model is the same as the tutorial media but is not equipped with operating instructions and learning instructions. Each ICT media model is used as: (1) substitute for the actual measuring instrument, student learning measurement only using simulation software/tutorial measuring tools only; (2) complement to the actual measuring instrument, in this case students are given learning to use some of the actual measuring instruments and some use simulation/tutorial measurement tools; (3) supplements or reinforcement of the actual presentation of measuring instruments, in this case students learn first using the actual measuring instruments, then given reinforcement using a simulation/tutorial measuring tool. There are two ways of presenting the media model, first the teacher uses ICT media using LCD projectors to demonstrate teaching materials, the second ICT media is used by students to experiment in groups using a PC or Laptop. Thus there are twelve kinds of treatment for students, each in a different class and school, but having the same initial ability average.

This research method is quasi-experimental. The population of this study was seventh grade students from 28 public junior high schools in Bandar Lampung, with 120 classes. Samples were taken 12 classes by cluster random sampling technique, with a total of 343 students. Each class receives a different learning treatment, which taught with the help of ICT media in the following ways: a) as a demonstration complement; b) as an experimental complement; c) as a demonstration supplement; d) as an experimental supplement; e) as a substitute demonstration; f) as an experimental substitute; g) as a demonstration complement; h) as an experimental complement; i) as a demonstration supplement; j) as an experimental supplement; k) as a substitute demonstration, and l) as an experimental substitute.

In each treatment, the learning outcomes measured in the form of SPS. SPS data is data on students' science skills during learning activities. SPS assessment of students during the learning process uses the SPS Observation Sheet, which consists of five SPS sub-components, namely the skills to measure, compare, create data, inferring data, and communicate. Predictors of each SPS component presented on the table 1.

Table 1. Indicator of SPS component [15].

No	Skills	Indicator
1	K1: Measuring skills	(1) using appropriate measuring instruments, (2) measuring procedures accordingly, (3) measuring results accordingly.
2	K2: Skills to compare	(1) choose the appropriate measuring instrument from two similar measuring instruments provided, (2) determine the higher accuracy of the two measurement results (3) write the accuracy of the measurement results.
3	K3: Skills for making data	capable of making complete measurement data tables
4	K4: Skills inferring data	able to make precise statements about measurement results
5	K5: Ability to communicate	(1) capable to describe data with graphs or tables, (2) write the results of discussions, (3) explain the results of data analysis orally

Note:
Scoring for K1, K2, K5 are as follow:
Score 3 = If 3 or all indicators of each sub skill are carried out
Score 2 = If 2 indicators of each sub skill are implemented
Score 1 = If 1 indicator for each sub skill is implemented
Score 0 = If none of the indicators for each sub-skill is implemented
Scoring for K3 and K4, according to the accuracy of the skills shown.

Data were analysed using two-way ANOVA. The first factor is ICT media model those are the tutorial and the simulation media model of measuring instrument. The second factor is the utilization model of ICT media those are the substitute-experimental, the substitute-demonstration, the complement-experimental, the complement-demonstration, the supplement-experimental, and the supplement-demonstration.

3. Results and Discussion

SPS of students for each model of the use of ICT media presented in Table 2.

Table 2. SPS data for each model of ICT media utilization

Media Model of	Utilization model of ICT	Teaching Method	SPS average					
			K1	K2	K3	K4	K5	Score average
Tutorial	Substitute	Experimental	2.7	2.1	2.4	1.7	2.0	2.2
		Demonstration	2.3	1.8	1.4	1.5	1.1	1.6
	Complement	Experimental	2.2	2.1	2.1	2.1	2.0	2.1
		Demonstration	2.8	2.3	2.2	1.8	1.6	2.2
	Supplement	Experimental	2.6	2.4	2.6	2.4	2.5	2.5
		Demonstration	2.5	2.3	2.3	2.1	2.1	2.3
Simulation	Substitute	Experimental	2.9	2.1	1.7	2.6	2.5	2.3
		Demonstration	1.8	2.4	2.8	2.7	1~2	2.2
	Complement	Experimental	2.8	2.4	2.3	1.9	1.8	2.2
		Demonstration	2.1	1.9	1.6	1.7	1.5	1.8
	Supplement	Experimental	2.8	2.3	2.2	1.8	1.9	2.2
		Demonstration	2.4	1.9	2.0	1.4	1.4	1.8

Information:
K1 = measuring skill K4 = inferring skills
K2 = comparing skill K5 = communication skills
K3 = making data

Based on the observations of SPS students, the highest average score was 2.5 obtained from students who learned using the tutorial media model as an experimental supplement (Table 2). This means the ICT media model of the tutorial is best used as a learning supplement by experiment or directly operated by students per group. The second best sequence, obtained from students who learned to use the simulation media model as a substitute for the experiment, obtained an average score of SPS 2.3. This means the ICT simulation media model is best used as a learning substitute by experimental method or directly operated by students per group. Both findings indicate that the ICT media is best used experimentally or operated directly by students, not demonstrated by the teacher through an LCD projector. The result of ANOVA two factors test, with the first factor being the ICT media model and the second factor is the use of ICT media, presented in Table 3.

Table 3. The result of univariate analysis of the interaction of the model of using the media with the media model

Source	Type Sum of Square	Df	Mean Square	F	p
Utilize Model	9.961	5	1.992	22.078	0.000*
Media ICT model	0.237	1	0.237	2.626	0.106
Interaction	9.984	5	1.997	22.127	0.000*

*) significantly different at 95% confidence level

Based on the results of the analysis in Table 3, it appears: (1) p value for Utilize model, 0.000 <0.05, meaning reject Ho or in other words there are differences in SPS caused by differences in the use of ICT media models. (2) Probabilities p value for ICT media model, 0.106 > 0.05, meaning that it means accept Ho or in other words there is no difference in SPS caused by differences in ICT media models. (3) p value for interaction between media utilization models with ICT media models, 0.000 <0.05, meaning reject Ho or in other words there are interactions between models of media use and ICT media models in terms of SPS. A clearer presentation of the interaction between the model of using ICT and the ICT model can be saw in Figure 1. In the figure, it appears that the best SPS obtained from learning using the ICT media tutorial model provided as an experimental supplement.

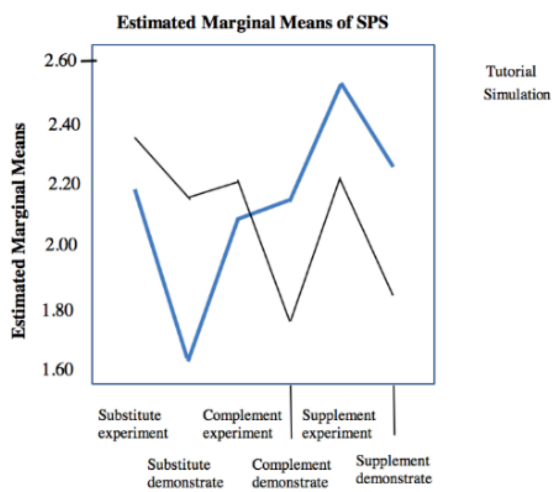

Figure 1. Graph of interactions between models of media use and ICT media models in terms of SPS

Software tutorials that contain simulations that are equipped with instructions for use and learning instructions provide more clarity for students about what to do and how to use the simulation software. However, learning outcomes in the form of SPS are not significantly different compared to students who learn to use the same simulation software, but without learning instructions and instructions for use. This is because the teacher gives the learning instructions and instructions for use orally during the learning process. The consequence is that the teacher must constantly accompany the class using simulation software during the learning process.

The use of ICT media tutorial model provided as an experimental supplement provides the highest SPS learning outcomes compared to other ways of use such as substitute and complement. This indicates that ICT media both tutorial models and simulation models, are effectively used as supplements, but cannot completely replace the riel tools.

The best presentation of simulation/tutorial ICT media is operated directly by students, not only demonstrated or operated by the teacher and aired through LCD projectors. In this way, students actively explore trying to use a variety of measuring instruments without worrying about damaging the measuring instrument. Students can also repeat the use of simulation measuring tools until they are skilled and understand well. This finding is in line with the results of the study [5], according to them, computer simulation experiments have an impact on students' academic achievement and on their mastery of science process skills in relation to their cognitive stages. The sequence of presentation of measurement material begins with the use of actual measuring instruments such as callipers, micrometre couplers, thermometers, dynamometers, voltmeters, and ampere-meters, continued with reinforcement and exercises using a virtual measuring instrument in groups, providing learning outcomes in the form of SPS, higher compared to other ways. This finding supported by the results of the study [16] about the effects of substituting a computer simulation for real laboratory equipment in the second semester of a large-scale introductory physics course. Students who use simulation equipment outperform their peers both on conceptual surveys of the domain and in coordinated tasks to assemble real circuits and explain how it works. The use of computers in groups in operating the measurement simulation software (virtual experiment), gives the highest influence on student SPS. This is in line with the results of the study [17], regarding the influence of science learning using a 1: 1 laptop on senior high school students, results were obtained the greater effect size in physics corresponded with greater use of simulations and spreadsheets by students. Computer-supported visual representations and interactions supported diverse learners' scientific understanding and inquiry and enabled more individualized and differentiated instruction. Technology-facilitated science instruction is beneficial for improving at-risk students' science achievement, scaffolding students' scientific understanding [18].

The use of experimentation strategies strongly related to conceptual understanding across tasks, but that students engaged differently in those strategies depending on what manipulative environments (ME) they used. More students engaged in productive strategies using the virtual ME for electric circuits, and vice versa using the physical ME for mass and spring systems [19]. Very important advice regarding the use of computer that is learning with computer-mediated technologies can be improved by careful design and coordination of group and individual activities [20]. The results of this study also supported by research findings that compare traditional hands-on labs, remotely operated labs, and simulations. Learning outcomes assessed by a test of the specific concepts taught in each lab. These knowledge scores were as high or higher (depending on topic) after performing remote and simulated laboratories versus performing hands-on laboratories. In their responses to survey items, many students saw advantages to technology-enabled lab formats in terms of such attributes as convenience and reliability, but still expressed preference for hands-on labs. In addition, differences in lab formats led to changes in-group functions across the plan-experiment-analyse process: For example, students did less face-to-face work when engaged in remote or simulated laboratories, as opposed to hands-on laboratories [3]. Comparing learning outcome achievement using traditional lab (TL; hands-on) and non-traditional lab (NTL; virtual and remote) participants as experimental groups. Findings suggest that most studies reviewed (n = 50, 89%) demonstrate student learning outcome achievement is equal or higher in NTL versus TL across all learning outcome categories (knowledge and understanding, inquiry skills, practical skills, perception, analytical skills, and social and scientific communication) [21]

The contribution of ICT to the improvement of teaching and learning processes is higher in the schools that have integrated ICT as an innovation factor. To attain this highest level implies that a school not only has to modernize the technological tools, but also has to change the teaching models: the teacher's role, issues regarding classroom organizational, the teaching and learning processes, and the interaction mechanisms [22]. The kind of use of ICT is a key factor for innovation, teaching and improvement of learning processes. Animation can promote learner understanding when used in ways that are consistent with the cognitive theory of multimedia learning, the consensus among media researchers is that animation may or may not promote learning, depending on how it used [23]. The findings of this study are consistent for all measured SPS components, except for the K5 indicator (Table 4).

Table 4. Univariate analysis results reviewed from each SPS component

Source	p (K1)	p (K2)	p (K3)	p (K4)	p (K5)
Utilize Model	0.000*	0.000*	0.000*	0.000*	0.000*
Media ICT model	0.315	1.000	0.129	0.170	0.000*
Interaction	0.000*	0.000*	0.000*	0.000*	0.000*

* Significantly different at 95% confidence level

The results of factorial analysis, in terms of the SPS of measuring skills (K1), comparing skills (K2), data making skills (K3), inferring data skills (K4), communicating skills (K5), obtain the same results. There are differences each SPS sub-components caused by differences in the ICT media utilization model. There is no difference in each SPS component that is caused by differences in ICT media models. There is an interaction between the media utilization model and the ICT media model in terms of each SPS sub-component. The difference occurs in the results of the analysis that is for the sub-component of the communication skills, there appears to be a difference in communication skills caused by differences in ICT media models.

4. Conclusion

The result of the research shows that there is no difference of SPS caused by the difference of ICT media model, except for the component of communicating skills. There is a difference of SPS caused by the different model of ICT utilization. The highest SPS obtained from the learning using the tutorial media model that learned as a supplement using the experimental method. There is an interaction between media utilization model and ICT media model in terms of SPS.

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