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Developing Students' Science Process Skills in the Learning of Electricity

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The science process skill (SPS) is one of the skills needed by humans to face the challenges of the industrial revolution 4.0 in the 21st century. Students who have an SPS are able to understand scientific concepts including basic and complex basic electric circuits (BEC). The research objective is to develop students SPS by using teaching discovery learning methods (TDLM) and their impact on student learning outcomes of BEC (OLBEC). The research method is quasi-experiment. Participants in this research are 72 students consisting of an experimental group using the TDLM model and the control are 36 students. The research data is analysed by using the Manova statistics. The research finding obtained that students SPS and OLBEC who followed the TDLM approach are higher than students who take CTM.

Keywords: *Science process skills, electric circuits*.

Introduction

Science process skills (SPS) are important for Vocational Education of Technology (VET) students to face the challenges of increasingly massive technological advances that occurred in the industrial revolution 4.0 in today's 21st century era. Students as future generations must be able to apply science and technology (Brown, 2006). Electricity is part of the physics content classified as science. Electricity is an abstract and complex phenomenon (Jaakkola, Nurmi, & Veermans, 2011) so that many students have difficulty learning electrical subjects in physics because the electricity theory concepts need to be solved by using mathematical formulas (Bahar & Polat, 2007) (Chabay & Sherwood, 2006) (Dori & Belcher, 2005) (Korganci, N., Mirona, C., Dafineia, A., & Antohea, 2015) (Kollöffel & Jong, 2013).

In the learning process, teachers need to stimulate aspects of the affective domain of students so that they actively follow the subject matter. The affective domain is an emotional aspect which includes attitudes, interests, confidence, values, and morals (Krathwohl, Bloom, &

Masia, 1964) (Ponto, 2016) (Ponto, Tasiam, & Wonggo, 2018). In other words, affective skills are a domain that contributes to students' mentality in following lessons. The affective domain of students can be stimulated by using appropriate teaching methods (Ponto et al., 2018).

Many teaching methods that have been investigated in the science subject matter include electricity, including the discovery teaching. The results of research using teaching discovery methods are beneficial for students (Alex & Olubusuyi, 2013) (Druckman, D., & Ebner, 2017) (Kamel. Abdelrahman, 2014) (Kunsting, J., Kempf, J., and Wirth, 2013) (Riandari, F., Susanti, R., 2018). According to Brown, discovery learning can stimulate student activity in learning science, because in the learning there will be an interest of students so that they are motivated to learn to know. Discovery learning is a model to train students to discover for themselves about the concepts being learned so that they are able to solve problems in the learning process (Resmawati, F. S., Prabowo, P., & Munasir, 2018). Indicators of learning activities are learning outcomes of basic electrical circuits (OLBEC: learning outcomes of basic electrical circuits). Some preliminary studies on electrical circuits have been conducted but the focus of this study is different from this research (Jaakkola et al., 2011) (Kollöffel & Jong, 2013) (Thacker, Ganiel, & Boys, 1999). This study was to observe students' SPS and OLBEC in terms of TDLM aspects as an experimental variable compared to CTM as a control variable.

BEC material is very important for students who are studying electrical engineering. Lack of student knowledge about BEC is very difficult for them to design a series including networks and electronic devices (Buthan, M. H., & Khan, 2018). That knowledge concerns the concepts learned. In learning the concept of a subject, students often make mistakes and have misconceptions (Biber, Ç., Tuna, A. & Korkmaz, 2013). In literature it is said that conceptual knowledge refers to recognising concepts and knowing the definitions and names of concepts. Conceptual knowledge is associated with a variety of concepts that differ from one another (Baki, A., & Kartal, 2004).

In learning an electrical subject, students are challenged to understand the concepts of current, voltage, resistance, and energy (E. Y. Feyzioğlu, Akpinar, & Tatar, 2018). Some researchers found that students experienced misconceptions in learning the basic electrical circuit (James P. Becker, 2018) (Bilal & Erol, 2009) (Engelhardt & Beichner, 2004) (Harsha, Asundi, & Prakash, 2015) (McDermott & Shaffer, 1992) (Planinic, 2006) (Saputro, Sarwanto, Sukarmin, & Ratnasari, 2018).

The results of the study report students' misconception on the subject matter about electricity consists of three categories, namely: (i) not being able to transfer the concepts learned into electrical theory subject matter; (ii) the inability to draw to estimate a series; and (iii) inability to predict the phenomenon of circuit behaviour (Planinic, 2006). Other studies have found that students' thinking concepts, namely the occurrence of a voltage and the presence of obstacles if there is a current flowing in the circuit (Harsha et al., 2015). In this regard, Becker and Plumb said what interventions were useful to make students understand the concepts (Biber, Ç., Tuna, A. & Korkmaz, 2013).

In BEC learning, students are taught to analyse the quantities of electricity and energy produced by using the concepts of Coulomb’s Law, Kirchhoff's Current Law, Kirchhoff's Voltage Law and Ohm’s Law (Buthan, M. H., & Khan, 2018) (Ponto, 2016).

In today's modern world, science plays a very important role so that there is continuous technological development (Van, De, & Schure, 2017). Science is concerned with phenomena summarised in theoretical concepts through scientific processes (Mariana & Praginda, 2009), so students must have the science process skills in learning certain subjects, for example direct current electric circuits (Ponto, 2019). In era 4.0, the young generation needs to have SPS so they can create technology that is useful for human life in the future. They need to create a technology, starting from the thought process of human reasoning about science and need to be supported by cognitive intelligence skills that are integrated with the affective domain so as to produce a technology that can help humans move, for example in a job or for use in education.

SPS is an individual intellectual skill that can be practised and learned and can be developed by learning activities in the classroom and (Balfakiha, 2010) outside the classroom. SPS can influence student learning readiness (Osman, K., & Vebrianto, 2013). Students who have readiness to learn will be active and pay attention to the subject matter.

Some references say SPS concerns the thinking skills of scientists who construct science (Omar, Puteh, & Ikhsan, 2014) (Dilek Zeren Özer & Muhlis Özkan, 2012) (Özgelen, 2012). These thinking skills are able to build knowledge, formulate, and apply to solve the problems faced. Thus, students who have SPS are able to overcome BEC learning problems. They can understand the concept and calculate the electrical quantities in the circuit, so that it will have a positive impact on OLBEC.

In literature, SPS consists of 2 parts, namely basic SPS and integrated SPS (Brotherton & Preece, 1995) (Derilo, 2019). The basic SPS includes observing, communicating, classifying, measuring, inferring, and predicting. Whereas integrated SPS consists of controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, and formulating models (Karamustafaoğlu, 2011) (Lati, Supasorn, & Promarak, 2012) (Yumuşak, 2016). BEC subject matter belongs to the science category so students who have an SPS can get a good OLBEC.
In order to obtain solutions to overcome problems in learning, TDLM (Ramdhani, M. R., Usodo, B., & Subandi, 2017) (Syarafina & Mahmudi, 2019) must be used. Discovery

learning is one part of inquiry learning techniques that is suitable for subject matter that contains science (Tam & Ewe, 2018). Discovery learning is a method that can build and develop students' SPS in learning BEC. Using discovery learning methods involves various types of achievement expected during the target acquisition content, but many define that the discovery learning is inappropriate (Klahr & Nigam, 2004).

Discovery learning is a teaching method which can activate students in process-oriented learning activities to direct students to seek and obtain knowledge learned (Prince & Felder, 2006) (Surur & Oktavia, 2019) and to solve problems (Khasanah, Usodo, & Subanti, 2018). The application of this method is to carry out student-oriented or centred learning activities and to give them freedom to use intuition, to try, to carry out investigation, to obtain useful information in group discussion activities so as to find a solution through observation activities (Balım, 2009).

In TDLM, there are opportunities to provide guidance to students. Much guidance can be done, for example, manually, by feedback or an example of problems (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011) The use of examples is done based on other forms of teaching. The teaching process must provide a complete solution and practice for students (Sweller, Kirschner, & Clark, 2007).

Statement of problems

In the learning process in BEC subjects that is carried out at VET many students experience difficulties and misconceptions. This happens because teachers still use CTM so that it is less stimulating to the affective domain of students and they are less active and creative in learning activities; the impact is that students lack SPS and affect OLBEC students. These factors make it difficult for students to adapt to subjects at the next level. To overcome these problems, TDLM needs to be used in learning.

Objective of research

This study was to observe students SPS and OLBEC in BEC learning. The purposes of the research are:

1. To find out students of SPS who take TDLM with students who take CTM in learning the BEC subject
2. To find out students of OLBEC who take TDLM with students who take CTM in learning the BEC subject
3. To find out simultaneously students of SPS and OLBEC who take TDLM with students who take CTM in learning the BEC subject .

Hypotheses

Hypothesis 1: There are SPS differences between students who take TDLM and students who take CTM.
Hypothesis 2: There are OLBEC differences between students who take TDLM and students who take CTM.
Hypothesis 3: There are simultaneous differences (together) of SPS and OLBEC between student participants who take TDLM and students who take CTM.

Method

Participant

This research involved 12th grade students of the skill program of Electrical Engineering of vocational technology school aged between 14-15 years, totalling 72 students divided into two groups - experimental and control groups, each of them consisting of 36 students. Both groups are determined based on the cluster sampling technique.

Research design

This experimental research is designed as shown in Figure 1 below.

A1		A2	
Y1	**Y2**	**Y1**	**Y2**

Figure 1. Experimental design

Figure 1 shows that A1 is TDLM that carries out learning activities in the experimental class group. While A2 is the CTM activity carried out in the control group. Y1 is SPS variable and Y2 is OLBEC variable.

Instrument

Science process skill instrument

The instrument used to determine the science process skill in BEC learning was modified from several references (Aydogdu, 2015) (Kruea-In, Kruea-In, & Fakcharoenphol, 2015) (Shahali & Halim, 2010) (Zeidan & Jayosi, 2014) and adjusted or adapted to the basic electric direct current circuit material presented in Table 1.

Table 1. SPS Assessment

SPS Component	Description
Observing	Students use the senses to obtain the electrical phenomenon.
Inferring	Students provide an explanation of observing electrical phenomena accompanied by data through the learning process.
Communicating	Speaking orally or in writing by using terms, symbols, diagrams or graphs to describe the current phenomenon, potential difference, resistance, and electric power events.
Classifying	Sorting, grouping and classifying elements, electrical quantities in an electrical circuit.
Measuring	Taking measurement by using a measuring instrument to observe the phenomenon of quantitative electrical quantities.
Inferring	Explaining the result of observation and data of electrical quantities.
Predicting	Stating the results that will occur going forward based on proof that is described through the integrated process skill.
Controlling variable	Identifying current variable, potential difference and resistance, by manipulating the circuit based on an understanding of the concept.
Defining operationally	Stating the measurement results about the variable of the experimental activities.
Formulating hypotheses	Expressing the results to be obtained after conducting experiment.
Experimenting	Conducting an experiment in the laboratory to test the theory being studied in accordance with the procedure in order to obtain data on electrical quantities for verification purposes.
Interpreting data	Organising and concluding based on rational data.
Formulating	Formulating or making an electrical circuit model in accordance with an understanding of the concept.
Graphing	Using quantitative data about electrical quantities as informed in the form of diagrams or curves.

The SPS instrument consists of 13 items according to SPS components. Each item uses a scale of 0-10, so the maximum value of the SPS instrument is "130" and the minimum value is "0". The SPS instrument is validated by three experts consisting of (i) measurements and evaluation that have a scientific field on electricity, (ii) linguist, and (iii) practitioner or teacher in the field of electrical engineering of the vocational school. Based on the validation, there are three items that are revised, then it is stated that the instrument is valid.

Instrument of learning outcomes

Student learning outcomes is measured based on BEC sub-materials which include charge, current, voltage, resistance, battery relation, series circuit, parallel circuit, series-parallel combination circuit, energy and electrical power. Based on the sub-material, the instrument consists of 10 items. The scale used to measure understanding of the concept uses a scale of 0-10 for each item. Thus, the maximum value of understanding the concept is "100" and the maximum value is "0". The validation of the learning outcomes instrument performed the same procedure as the SPS variable, and this instrument is declared valid.

Data analysis

Based on the research design and hypothesis, the research data is analysed by using the MANOVA statistical technique (multivariate analysis of variance), namely an analysis to compare differences in covariance of independent variable matrices (TDLM and CTM) and dependent ones (SPS and OLBEC).

Procedure

This research involved two teachers who have had BEC teaching experience of over 10 years, where one teacher gives treatment to the experimental class (TDLM) and the other to the control class (CTM). Before the implementation of the treatment, the two teachers discussed with the researcher to discuss their respective assignments in accordance with the research design. This treatment is carried out over 8 meetings. The duration of each treatment is 90 minutes according to the schedule determined by the VTS. The implementation of the treatment is observed by the researcher to study students' activities while participating in learning activities.

Results and Discussion

The description of the research data is presented in Table 2 below.

Table 2. Descriptive Statistics

Variable	Method	Mean	Std. Deviation	N
SPS	1	106.28	5.175	36
	2	76.50	5.158	36
	Total	91.39	15.847	72
OLBEC	1	84.61	4.993	36
	2	60.22	5.172	36
	Total	72.42	13.277	72

The research data in Table 2 about the experimental group for SPP variable is M = 106.28 and OLBEC is M = 84.61. While the control group for SPP variable is 76.50 and OLBEC is M = 60.22.

The statistical output in Table 3 is a normality test for each research variable individually. The research results obtained are that the value of *sig*. = .112 (SPS experiment; *sig*. = .197 (OLBEC experiment); *sig* .097 (SPS control); and *sig*. = .240 (OLBEC control). These values are > α .050. The results of this test indicate that the research variable data is normally distributed. The results of the data analysis presented in Table 3 show that the value of *sig*. for the research variable is greater than *α* = .05 so the research variable is normally distributed.

Table 3. Normality test

One-Sample Kolmogorov-Smirnov Test					
		Experiment		Control	
		SPS	OLBEC	SPS	OLBEC
N		36	36	36	36
Normal Parameters[a,b]	Mean	106.28	84.61	76.50	60.22
	Std. Deviation	5.175	4.993	5.158	5.172
Test Statistic		.133	.122	.136	.129
Asymp. Sig. (2-tailed)		.112[c]	.197[c]	.092[c]	.137[c]
Test distribution is Normal.					

In Table 4 is the statistical output for the homogeneity test of variances for SPS and OLBEC data in the experiment and control groups. This test is a prerequisite for the test of Analysis of Variance (ANOVA), because the MANOVA test is a continuation of the ANOVA test to test hypotheses 1 and 2. The analysis results obtained by SPS and OLBEC in the experiment group (treatment of TDLM) is *sig*. = .053 and the control group (CTM) is *sig*. = .240. Both of these values are greater than α .050. Thus, the SPS and OLBEC variances in the experiment and control groups are statistically in the same category or homogeny.

Table 4. Test of Homogeneity of Variances

Levene Statistic		df1	df2	Sig.
Experiment group	**1.538**	8	18	.053
Control group	**1.457**	10	20	.240

The multicollinearity test is one of the factors that must be fulfilled in Manova statistics, namely between the independent variable data which does not affect each other or where multicollinearity occurs. The results of the analysis in Table 5 obtained the amount of multicollinearity for the experimental and control variables for tolerance values are .197 and *VIF* 5.073. Both values are greater than *α* .050. The test results state that the independent variable in this research does not occur multicollinearity.

Table 5. Test of Multicollinearity

Model		**Unstandardised Coefficients**		**Standardised Coefficients**	**T**	**Sig.**	**Collinearity Statistics**	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-7.247	12.705		-.570	.572		
	Experiment	.241	.250	.241	.963	.342	.197	5.073
	Control	.547	.251	.545	2.176	.037	.197	5.073

In Table 6 the results of Box's test analysis for the covariance matrix homogeneity test as prerequisite for the MANOVA statistical test obtained the value of *sig*. = .166, where this value is greater than α .050; then the requirement for the MANOVA test has met the requirements.

Table 6. Box's Test of Equality of Covariance Matrices

Box's M	**5.238**
F	1.692
df1	3
df2	882000.000
Sig.	.166

Table 7 is the output of levene's test of equality of error variances. This test is one of requirements of the MANOVA statistical test, namely to find out whether the dependent variable data of the research has the same variance or homogeneous. In Table 7 the SPS variable has value of *sig*. = .967 and the OLBEC variable is *sig*. = .988. Both values are greater than *α* = .050. The results of this test indicate that the multivariate variable variance value is homogeneous.

Table 7. Levene's Test of Equality of Error Variances

Variable	**F**	**df1**	**df2**	**Sig.**
SPS	.002	1	70	.967
OLBRC	.000	.000	70	.988

Table 8. Tests of between-subjects effects

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	SPS	15960.889[a]	1	15960.889	598.035	.000	.895
	OLBEC	10706.722[b]	1	10706.722	414.352	.000	.855
Intercept	SPS	601338.889	1	601338.889	22531.432	.000	.997
	OLBEC	377580.500	1	377580.500	14612.428	.000	.995
Method	SPS	15960.889	1	15960.889	598.035	.000	.895
	OLBEC	10706.722	1	10706.722	414.352	.000	.855

Table 8 presents the separate test output of analysis of variance (ANOVA) for the value of each dependent variable compared to the alpha value of .050. The results of the analysis obtained the value of the SPS variable is $F(1.70) = 598{,}035$, $\rho = .000$ and partial $\eta^2 = .895$. Thus, Ha stated in hypothesis 1 is accepted, so it is concluded that there are significant differences in SPS owned by students who take TDLM and conventional learning in learning BEC subjects.

Furthermore, in Table 8 obtained the OLBEC variable values are $F(170) = 414.35$, $\rho = .000$, partial $\eta^2 = .855$. The value of *sig*. shows 000 <.050 thus Ha stated in hypothesis 2 is acceptable, namely there are significant differences in OLBEC using TDLM and CTM in BEC learning.

Table 9. Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Teaching method	Pillai's Trace	.895	294.826[b]	2	69	.000	.895
	Wilks' Lambda	.105	294.826[b]	2	69	.000	.895
	Hotelling's Trace	8.546	294.826[b]	2	69	.000	.895
	Roy's Largest Root	8.546	294.826[b]	2	69	.000	.895

In Table 9, the output of the MANOVA quantitative statistical quantities are presented, where the results of Wilk's test are $A = .105$, $F(2.69) = 294.83$, $\rho = .000$. and partial $\eta^2 = .895$. The data shows *sig* .000 <.050. The results of this test statistically prove that there is a significant difference between the average value of $M = 106.28$ (see Table 2) obtained by students in following the discovery method of teaching compared to the average value of $M = 76.50$ (see Table 2) obtained by students in following CTM. Thus, based on the results of the research, Ha stated in hypothesis 3 is acceptable. The results of this research indicate that there are differences simultaneously (jointly) SPS variable and OLBEC of students who take TDLM and students who take CTM in BEC learning can be accepted.

Based on the research it is found that the experimental group that uses TDLM has a positive effect on SPS and OLBEC. The TDLM approach can shape students' attitudes and interests towards the science subject (Scardamalia & Bereiter, 2002). Students who are positive and interested in the subject, means that the learning process is interesting for them, so the subject provided will be considered according to the stages designed by the teacher, so that students will pay attention with pleasure and carry out the assignment seriously. This statement is supported by reference (Koksal & Berberoglu, 2014), namely TDLM can improve students' attitudes towards science. There is some evidence that schools in the reputation of implementing TDLM are attractive to students.

This research is the same as found in the reference Druckman, D., & Ebner, (2017), that TDLM has an effect on the learning process, because students actively participate by observing patterns and cause and effect of the phenomena and can apply the concept learned (Alfieri et al., 2011). In TDLM, students can understand formulas for calculating and measuring physical quantities in a series circuit, parallel, parallel-series combination, energy, and electrical power. These quantities include current, potential difference, and resistance.

This finding is relevant to the results of the research presented in the literature, namely the TDLM approach can encourage students to actively engage in learning activities (Tam & Ewe, 2018) (Saridewi, Suryadi, & Hikmah, 2017). Through TDLM, students can explore the concept so that students can answer questions when taking the BEC subject exam, namely the score obtained is above average. Students who master this subject can adapt to technological development in the field of electrical engineering in the 21st century era.

Reference Osman, K., & Vebrianto, (2013) and Derilo, (2019) says SPS can influence the students' learning outcomes. Some research results show that students who have SPS can successfully learn the science material (Aktamis, Faculty, & Eyl, 2008) (Delen, I., & Kesercioglu, T., 2012) (Farsakoğlu, Ö., Şahin, Ç., & Karsli, 2012) (B. Feyzioğlu, 2009) (Gürses, Çetinkaya, Do, & Elif, 2015) (Oloyede & Adeoye, 2012). The research findings are relevant to the findings in this research, namely by using TDLM, the SPS potential of students can develop optimally so that it has a positive influence on OLBEC.

Based on the testing of hypothesis 3 which is analysed using the MANOVA statistical technique, it is found that students who take TDLM receive SPS and OLBEC higher than students who take CTM. This finding is supported by some of the literature in the research reports (Ramdhani, M. R., Usodo, B., & Subandi, 2017) (Syarafina & Mahmudi, 2019) (Khasanah et al., 2018) (Panisoara, Duta, & Panisoara, 2015). Based on observation results, students who take TDLM are very active accompanied by frequently asking questions and are able to understand the concept of the BEC subject. The use of TDLM in students motivates them to follow BEC learning. The motivation is an internal condition found in students to move and act in an activity (Pintrich, 2003) (Stipek, Feiler, Daniels, & Milburn, 1995) (Schraw, Crippen, & Hartley, 2006) (Tohidi & Jabbari, 2012). While students who take CTM, tend to be passive and only write the lesson presented by the teacher by reading the textbook, memorising formulas and often making mistakes in calculating electrical quantities and having misconceptions.

Conclusions

Based on the results of the research, it was found that the BEC learning needs to use the teaching approach of the discovery learning method. The teaching is by using this model, can touch students' feelings and emotion so that a positive attitude is formed and stimulating interest will then motivate students to actively participate in BEC learning activities. Students who are positive and have an interest will be motivated in learning activities and can form students of SPS and have a significant effect on OLBEC. The finding of this research is relevant to the research conducted on other science material.

In this research, it is concluded that:

1. Students of SPS who take TDLM is higher than students who take CTM in learning the BEC subject;
2. Students of OLBEC who take TDLM is higher than students who take CTM in learning the BEC subject; and
3. Simultaneously students SPS and OLBEC who take TDLM are higher than students who take CTM in learning the BEC subject.

Reference Osman, K., & Vebrianto, (2013) and Derilo, (2019), says SPS can influence the students' learning outcomes. Some research results show that students who have SPS can successfully learn the science material (Aktamis et al., 2008) (Delen, I., & Kesercioglu, T., 2012) (Farsakoğlu, Ö., Şahin, Ç., & Karsli, 2012) (B. Feyzioğlu, 2009) (Gürses et al., 2015) (Oloyede & Adeoye, 2012). The research findings are relevant to the findings in this research, namely by using TDLM, the SPS potential of students can develop optimally so that it has a positive influence on OLBEC.

The finding of this research can be used as a reference for teachers who teach a subject about electricity, especially BEC. This is important for students of VET for their future.

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