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THE VALIDITY AND EFFECTIVENESS OF PHYSICS INDEPENDENT LEARNING MODEL TO IMPROVE PHYSICS PROBLEM SOLVING AND SELF-DIRECTED LEARNING SKILLS OF STUDENTS IN OPEN AND DISTANCE EDUCATION SYSTEMS

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Abstract. *The Physics Independent Learning (PIL) model is an authentic problem-based model designed teaching guide for improving self-directed learning and problem-solving skills in open and distance education. This research is aimed to analyze the validity and effectiveness of PIL model. This research was conducted using focus group discussions of experts that consisted of three science education experts and applies quasi-experiment of one group pre-test and post-test design to 144 students in East Java, Indonesia. Before applying the lesson using the PIL model, the students are given pre-test and after accomplishing the learning, the students are given post-test. The data collected from pre-test and post-test then is further analyzed by means of validity coefficient (ra), Cronbach's alpha (α), pair t-test, n-gain and ANOVA. The result of research shows that ra = .75 and α = .92 is for content validity; ra = .79 and α = .99 is for construct validity, so that PIL model is validity and reliability qualified. In addition, there are increasing scores of physics problem solving skills and self-directed learning skills of α = 5% with moderate category of n-gain consistent in a limited trial test and of high category in a broader trial test for all groups.*

Keywords: *PIL model, model validity, model effectiveness, physics problem-solving skills, self-directed learning skills, electricity, magnetism.*

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Introduction

Open and Distance Education Systems (ODES) in various countries today apply dual pattern learning that is face-to-face tutorial and online tutorial teaching. During online pattern learning, the students can use internet-based information and communication technology, either virtually or via video conference. Meanwhile, during face-to-face tutorial pattern, the students and tutors conduct a meeting in such a limited period. The application of face-to-face tutorial on ODES in Indonesia today generally uses problem-based learning and cooperative learning models (*Tutorial Guidelines for Student*, 2016).

The problem-solving skills and self-directed learning skills using PBL model and *CL* model of ODES achieved from physics learning are still low and under average level. Such a low level of students' achievement theoretically is due to several issues, those are: lack of involvement, lack of convincing and autonomy support (Brophy, 2013); low Achievement motivation, lack of interest and absence of academic motivation (Legault, Green-Demers, & Pelletier, 2006), lack of outcome and ability (Zimmerman & Schunk, 2011), low intentionality and students' poor self-regulatory (Schunk, 2005), lose initiative and lacking the intention (Yew & Schmidt, 2009), learning model affects students' conceptual development positively (Adeyemi & Adeyemi, 2014); the students are less capable of being more participated, lacking self-confidence prior to the course and have such a poor responsibility as well as less-supportive learning environment (Pless, Maak, & Stahl, 2011).

The defects of PBL model and CL model can be fixed by developing an alternative model that may improve physics problem solving skills and self-directed learning skills of students in ODES. The corresponding teach-

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ing model to be developed is Physics Independent Learning (PIL) that conforms to the learning characteristics of adults and it is the innovation of PBL model and CL model with some modifications. Therefore, it is applicable to all students at various academic levels, education and culture levels and ages as assigned to ODES implementation ("Regulation of the Minister of Education and Culture of the Republic of Indonesia," 2012).

PIL model development corresponds to the demand of curriculum and the development of globalization era in 21st century. PIL model is an innovative physics-learning model that may encourage every individual person to solve problem and teach the stages of problem solving. This is to be able to think critically and independently (Silva, 2009) in which during the physics learning, individual. PIL model development applies scientific approach by means of investigation, assignment, collaboration, discussion, and presentation method, so that it can act as bridge for the gap between the required competence of graduates and the real condition as demanded by the 21st century and Indonesian National Qualifications Framework based curriculum (Adams, Vista, Scoular, Awwal, & Griffin, 2015; "Regulation of the Minister of Education and Culture of the Republic of Indonesia," 2013).

The importance of physics problem solving skills and self-directed learning skills of physics learning at university level is based on the characteristics of physics subject. This is because physics is assumed relatively difficult and complex. This indicates that problem solving is a critical element of learning physics although the students have good ability to solve problems there is evidence that quite basic conceptual understanding is still very weak (Prahani, Pandiangan, & Nasir, 2015). Curriculum demand and globalization era development require education institutions to do a useful innovation for 21st century skills based education (Adams, Vista, Scoular, Awwal, & Griffin, 2015). Education and Culture Minister's Regulation No.73 regarding Indonesian National Qualifications Framework (INQF) of higher education requires universities to compose a curriculum that the students have such a superior competence accompanied by various skills those correspond to the demand of 21st century, such as problem solving skills and self-directed learning skills (Griffin & Care, 2015; "Regulation of the Minister of Education and Culture of the Republic of Indonesia," 2013). Learning in the 21st century requires competent human resources, and the students are directed to achieve learning skills and innovation, such as problem solving skills, self-directed learning skills, critical thinking, creative thinking, responsible, and able to learn independently (Tucker, 2014)

During physics teaching, the problem-solving skills of students are generally weak. There are factors those affect such a weak skill of students in physics problem solving, namely: the research of Brad (2011) shows that while students apply basic strategies well, they use a trial approach, they give up when facing difficulties and have a lack of metacognitive ability, which is a signal to be considered, greater attention should be given to the needs of the students, giving more emphasis on reasoning and understanding, so that students can improve their self-directed learning; the result of research done by Jatmiko, Widodo, Budiyanto, Wicaksono, & Pandiangan (2016) indicates that General Physics learning integrates learning and laboratory and emphasizes on reasoning that can improve procedural and non-procedural problems solving skills.

In addition to problem solving, one of very important features of 21st learning is life skills and career. Life skills implementation in 21st century can be summarized in several matters those are simpler, such as: motivation, self-directed learning skills (Ellinger, 2004), critical thinking and problem solving skills (Cash, 2017), communication and collaboration (Zimmerman-Oster & Burkhardt, 2000), leadership and responsibility (Reimers, 2009). The research of Pandiangan, Jatmiko, and Sanjaya (2016) toward 40 students (two classes) at Indonesia Open University's ODE in Bangkalan-Indonesia indicates that PBL and CL models application to improve physics problem solving skills is still low and self-directed learning skills is under average. The impact of PBL and CL models influence to improve the skills to solve physics problems looks significant at moderate level only on the following indicators: self-confident and love to learn, while initiative and persistence, responsibility, discipline and curiosity, time organization and learning pace management indicators all are low.

Based on the aforementioned descriptions, the question then is how are the validity, reliability, and effectiveness of PIL against the achievement of physics problem solving skills and self-directed learning skills research? To answer such question, PIL model has been developed and a research about the effectiveness of PIL model application on electricity and magnetism subjects against the achievement of physics problem solving skills and self-directed learning skills research of Bachelor Program of class 2016 at Indonesia Open University has been done.

PIL model learning refers to problem solving plot of John Dewey and self-directed learning process plot of Knowles those supported by the newest learning theories. Pandiangan, Jatmiko, & Sanjaya (2016) have formulated the syntax of PIL model learning, of which includes: (1) initiation and persistence, (2) responsibility, (3) self and group investigation, (4) analysis, (5) presenting and discussion, and (6) strengthening and evaluation. The main purpose of this developed PIL model is to create a learning model that can serve as the manual for tutors and students to plan and perform learning that they will be able to improve the achievement of physics problem solving skills and self-directed learning skills of students in ODES.

The indicators of physics problem solving in this research are adapted from Bradford (2015), those are: (1) problem formulation, (2) variable identification, (3) form of hypothesis, (4) data analysis, and (5) conclusion drawing. Meanwhile, the indicators of self-directed learning readiness are adapted from Guglielmino and Guglielmino (1991), those are: (1) initiation and persistence, (2) responsibility, (3) discipline and great curiosity, (4) confidence and strong desire to learn, (5) able to organize time and set the pace of learning, and (6) love to learn and meet the planned target and revision. The indicators of physics problem solving skills and self-directed learning skills respectively are being trained in each stage of PIL model syntax phase presumed to be able to improve physics problem solving skills and self-directed learning skills of students in open and distance education.

Problem of Research

The most primary issue of this research is how to analyze the validity and effectiveness of PIL model against electricity and magnetism subjects can improve the achievement of physics problem solving skills and self-directed learning skills of students in ODES. PIL model is effective when its content validity and construct validity are valid and reliable. PIL model is effective when the learning process is able to reach such a significant improvement of physics problem solving skills and self-directed learning skills (statistically). PIL model validity is formulated according to the following validity formula, r_α = [(Average Square people - Average Square residual)/ (Average Square people + (k-1) Average Square residual)] and Cronbach's alpha $\alpha = k\, r_\alpha/[1+(k-1)\, r_\alpha]$ (Malhotra, 2011). The criteria of PIL model validity and reliability are shown in Table 1.

Table 1. Validity and reliability of PIL model criteria

Check	Scale Statistics	Category	
Validity	Single measures interrater correlation coefficient-ICC (ra)	$r_\alpha \leq$ r table	Invalid
		$r_\alpha >$ r table	Valid
Reliability	Cronbach's alpha/average measures interrater correlation coefficient-ICC (a)	$\alpha < .6$	Unreliable
		$.6 \leq \alpha \leq 1.0$	Reliable

PIL model effectiveness to improve physics problem solving skills and self-directed learning skills of students in ODES is decided by the normalized gain score, namely: n-gain = (post-test score – pre-test score)/ (maximum score – pre-test score) (Hake, 1999). According to the following criteria: (1) when n-gain > .70 (high); (2) when .30 < n-gain < .70 (moderate); and (3) when n-gain < .30 (high). This research is aimed to analyze PIL model validity and effectiveness to improve physics problem solving skills and self-directed learning skills of students in ODES.

Research Focus

The focus of this research is to analyze the validity and effectiveness of PIL model against the improvement of physics problem solving skills and self-directed learning skills. The issues are: 1) is PIL model that has been formerly developed validity and reliability qualified? 2) is there any significant improvement (statistically) of physics problem solving skills and self-directed learning skills before and after learning using PIL model? 3) how much is the improvement of physics problem solving skills and self-directed learning skills of students in open and distance education? 4) is there any different improvement of physics problem solving skills and self-directed learning skills after learning using PIL model among all groups?

Methodology of Research

General Background

This study was conducted in the Odd Semester of the Academic Year 2016/2017 within 15 weeks using electricity and magnetism topics. This research is emphasized on the analysis of PIL model validity and effectiveness

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fulfillment by analyzing the teaching impact using PIL model to improve physics problem solving skills and self-directed learning skills of students in ODES before and after learning using PIL model. In this research, PIL model validity is calculated according to the difference between the score of average square people and average square residual, and the reliability of PIL model is calculated according to Cronbach's alpha. Meanwhile, the effectiveness of physics problem solving skills and self-directed learning skills is calculated according to: (a) the significant score difference between pre-test and post-test, (b) the number of n-gain score can be categorized into low, moderate, and high categories for both physics problem solving skills and self-directed learning skills.

Sample

This research is held toward 144 Open University students of Surabaya regional office from a population of 225 students in three different regions in which there are two groups of students respectively. Determination of number of samples is based on Slovin's formula, i.e. Sample = [population / (1 + e^2 x population)] with error tolerance e = 5 % (Sevilla, Ochave, Punsalan, Regala, & Uriarte, 1984). During a limited trial test, it uses one region with two groups, namely group-1 and group-2 of 22 students respectively. They have the same comprehensive level of physics problem solving skills and self-directed learning skills with respect to electricity and magnetism. Whereas, during a broad trial test, it uses two regions with two groups, namely group-3, group-4, group-5, and group-6 of which consist of 25 students respectively with the same comprehensive level of physics problem solving skills and self-directed learning skills with respect to electricity and magnetism.

Instrument and Procedures

This research was conducted using focus group discussions of experts that consisted of three science education experts and applies quasi-experiment of one group pre-test and post-test design. This research is classified as quasi experiment research using one group pre-test – post-test design, namely: O1 X O2 (Fraenkel, Wallen, & Hyun, 2012). Learning that applies PIL model (X) is firstly validated by three experts of physics education (two experts have doctoral and professorial education background of physics education, 1 expert has pure physics doctoral education, and the three of them have the skills of ODES and ICT) before it is certified to be valid and reliable. Furthermore, PIL model that has been valid and reliable according to the expert shall be used in physics learning of electricity and magnetism subjects. The research is held by giving pre-test (O1) before the group of students learns about electricity and magnetism subject and the test is based on physics problem solving skills and self-directed learning skills indicators. The group of students then shall learn using PIL (X) model.

The process of learning is performed by means of PIL model and the PIL model learning wares that shall include syllabus, learning plan, textbooks for students, and worksheets of students. According to the evaluation done by the validating officers, PIL model and PIL model learning wares have been certified to have been validity qualified both of content and construct, and reliable. The process of learning applied in this research, during both limited and broad tests uses PIL model. Finally, after the learning process is accomplished, all groups of students are provided with post-test (O2), which subjects and problems are similar to those of pre-test.

Data Analysis

The experts according to the validity of both content and construct validate PIL model and PIL model wares. The validity of content is the illustration of need and newness, while the validity of construct is the illustration of consistence between PIL model with the theory/empiric and the consistence among model components (Plomp & Nieveen, 2007). In order to analyze the validity and reliability of PIL model, single measures inter-rater coefficient correlation and Cronbach's alpha are used, accordingly. But, to analyze the impact of PIL model teaching toward physics problem solving skills and self-directed learning skills, the collected scores of pre-test and post-test are tested using pair t-test or non-parametric analysis of Wilcoxon's test (Gibbons & Chakraborti, 2011).

The selection of testing method shall depend on the meeting of normality assumption for pre-test and post-test scores. When the normality assumption for the achieved score is met, the pair t-test then will be applied. When it is not met, the non-parametric analysis shall be used. In addition, the calculation of n-gain adapted from Hake

(1998) is made to decide the level of improvement. IBM SPSS Statistics 22 software is used to test the impact of PIL model teaching toward the improvement of problem solving skills and self-directed learning skills. Furthermore, in order to analyze the consistence of PIL model teaching impact toward physics problem solving skills and self-directed learning skills of the six groups, it uses variant analysis (ANOVA). The testing method shall depend on the compatible result of normality assumption and variant homogeneity tests of n-gain.

Result of Research

PIL model and its wares validation is done through a series of focus group discussion (FGD) activities in which three experts of physics education are invited as the validating officers. Details of validity and reliability scores of each PIL model component item and its ware are shown in Table 2.

Table 2. Validity and Reliability of PIL Model.

Item	Content validity				Construct validity			
	Validity (r_α)		Cronbach's Alpha (α)		Validity (r_α)		Cronbach's Alpha (α)	
1. PIL Model	.75	Valid	.92	Reliable	.79	Valid	.99	Reliable
2. Syllabus	.85	Valid	.99	Reliable	.99	Valid	.99	Reliable
3. Teaching plan	.74	Valid	.96	Reliable	.99	Valid	.99	Reliable
4. Teaching Materials	.79	Valid	.98	Reliable	.73	Valid	.96	Reliable
5. Students worksheet	.70	Valid	.92	Reliable	.98	Valid	.99	Reliable

The scores of pre-test and post-test during the limited trial and broad trial of all groups are shown in Figure 1 and Figure 2. The grey bar indicates the pre-test while the shaded bar indicates the post-test.

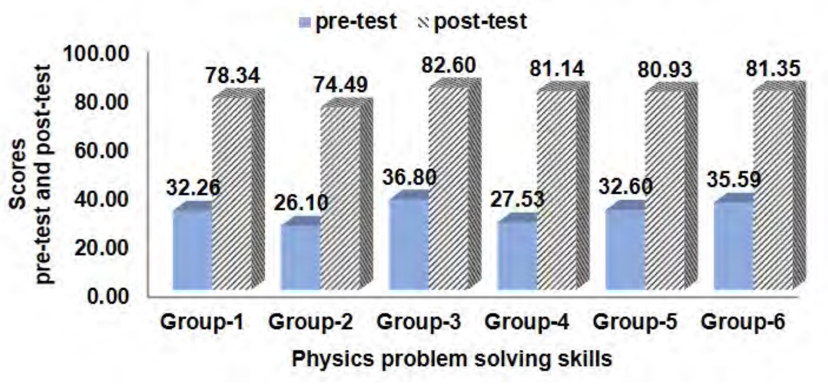

Figure 1: The average scores of the student's pre-test and post-test in terms of physics problem solving skills of all groups.

Figure 1 shows that the average score between pre-test and post-test associated with the physics problem solving skills of electricity and magnetism subjects of all groups is improved. The average score of pre-test, post-test and n-gain with respect to the indicator of physics problem solving skills of all groups is shown in details in Table 3.

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Table 3. The average scores of the pre-test, post-test, and the n-gain of physics problem solving skills of all groups.

Group	Number of the Students	Scores	Problem solving skills indicator				
			Formulating of the Problem	Variable Identification	Form a Hypothesis	Analyze the Data	Draw Conclusions
Group-1	22	Pre-test	28.71	28.18	29.92	42.10	36.93
		Post-test	84.55	78.18	84.62	69.72	76.93
		n-gain	.78	.70	.78	.44	.62
Group-2	22	Pre-test	27.80	26.59	26.97	28.41	26.25
		Post-test	80.23	73.18	82.12	65.51	73.07
		n-gain	.73	.64	.75	.51	.61
Group-3	25	Pre-test	45.23	41.82	46.21	29.83	30.68
		Post-test	88.64	94.32	87.95	68.58	87.73
		n-gain	.79	.86	.78	.56	.81
Group-4	25	Pre-test	28.56	41.82	31.36	24.83	26.48
		Post-test	87.27	94.32	86.97	68.24	82.39
		n-gain	.85	.88	.82	.57	.78
Group-5	25	Pre-test	38.03	39.09	37.95	27.95	32.05
		Post-test	87.35	90.68	87.20	66.76	85.34
		n-gain	.78	.83	.78	.53	.75
Group-6	25	Pre-test	38.71	40.68	41.59	28.52	33.52
		Post-test	87.20	90.45	87.95	68.30	84.20
		n-gain	.80	.84	.79	.55	.76

The teaching outcomes achieved by all groups with respect to self-directed learning skills are shown in Figures 2 and Table 4.

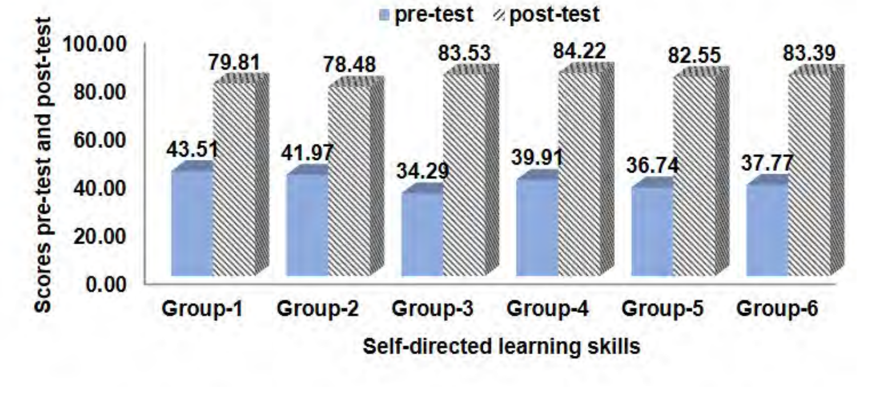

Figure 2: The average scores of the student's pre-test and post-test in terms of the self-directed learning skills of all groups.

Figure 2 shows that the average score between the pre-test and post-test of self-directed learning skills of electricity and magnetism subjects for all groups are also improved. The average score of pre-test, post-test and n-gain with respect to the indicator of self-directed learning skills of all groups is shown in details in Table 4.

Table 4. The average scores of the pre-test, post-test, and the n-gain of self-directed learning skills of all groups.

Group	N	Scores	Self-directed learning skills indicator					
			A	B	C	D	E	F
Group-1	22	Pre-test	48.94	39.22	42.56	45.23	42.21	44.09
		Post-test	79.39	83.38	81.14	74.43	77.92	80.71
		n-gain	.58	.72	.66	.52	.61	.64
Group-2	22	Pre-test	44.85	37.53	42.05	46.25	43.38	39.74
		Post-test	76.82	83.90	79.15	75.11	74.81	79.48
		n-gain	.54	.74	.63	.52	.55	.65
Group-3	25	Pre-test	33.33	34.03	34.43	35.68	32.99	34.55
		Post-test	83.33	86.75	88.64	78.86	79.48	80.84
		n-gain	.73	.77	.80	.65	.67	.68
Group-4	25	Pre-test	40.00	35.19	37.05	41.93	43.25	42.66
		Post-test	85.30	87.01	88.41	79.09	81.30	81.95
		n-gain	.76	.80	.82	.66	.68	.69
Group-5	25	Pre-test	37.58	35.97	36.82	39.55	37.40	34.74
		Post-test	84.55	85.84	88.18	78.52	77.53	78.44
		n-gain	.75	.78	.81	.66	.63	.65
Group-6	25	Pre-test	37.88	35.45	37.27	39.09	38.31	38.44
		Post-test	85.00	87.40	88.52	78.64	80.26	79.09
		n-gain	.75	.80	.82	.65	.67	.64

N= Number of students; A= Initiation and persistence; B= Responsibility; C= Discipline and great curiosity; D= Confidence and strong desire to learn; E= Able to organize time and set the pace of learning; F= Love to learn and meet the planned target and revision

The average n-gain scores of physics problem solving skills and self-directed learning skills of all groups are shown in Figure 3.

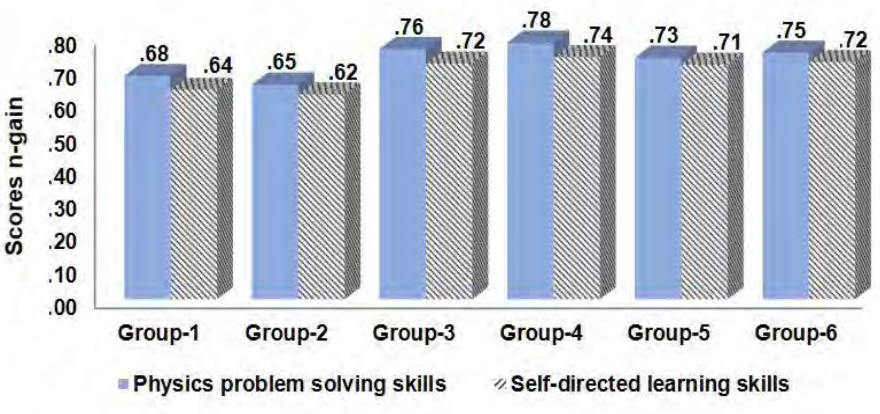

Figure 3: The average scores of the n-gain for both the problem solving skills and self-directed learning skills of all groups.

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Figure 3 shows that the average scores of the n-gain for physics problem solving skills of all groups, from 1 to 6, respectively are: .68; .65; .76; .78; .73; and .75. The average n-gain scores of both groups in the limited test respectively are categorized as moderate, while the average n-gain scores of the next four groups in the wider test respectively are categorized as high. On the other side, the average n-gain scores for self-directed learning skills of all groups respectively are .64; .62; .72; .74; .71; and .72. The average n-gain scores of both groups in the limited test respectively are categorized as moderate, while the average n-gain scores of the next four groups in the wider test respectively are categorized as high.

Pre-test and post-test normality test for all groups are held by means of one-sample Kolmogorov-Smirnov Z test of IBM SPSS Statistics 22 software as shown in Table 5.

Table 5. The normalized post-test and pre-test of physics problem solving skills and self-directed learning skills for all groups.

Group	Test	N	Physics problem solving skills				Self-directed learning skills			
			Mean	Std. Deviation	Asymp. Sig. (2-tailed)	Normal Distribution	Mean	Std. Deviation	Asymp. Sig. (2-tailed)	Normal Distribution
1	posttest	22	78.34	4.88	.01	no	79.81	7.84	.92	yes
	pretest	22	32.26	6.44	.58	yes	43.51	5.13	.96	yes
2	posttest	22	74.49	6.63	.28	yes	78.48	7.40	.82	yes
	pretest	22	26.10	5.21	.90	yes	41.98	4.80	.83	yes
3	posttest	25	82.25	8.75	.77	yes	82.50	8.57	.33	yes
	pretest	25	36.26	7.83	.94	yes	34.80	5.54	.25	yes
4	posttest	25	92.02	9.56	.33	yes	84.66	5.10	.99	yes
	pretest	25	38.82	6.18	.25	yes	39.23	4.90	.89	yes
5	posttest	25	82.50	8.57	.33	yes	82.55	6.06	.71	yes
	pretest	25	80.38	4.02	.90	yes	36.87	4.39	.95	yes
6	posttest	25	33.54	6.61	.67	yes	83.09	6.17	.91	yes
	pretest	25	81.35	4.87	.92	yes	37.68	3.61	.65	yes

N= Number of students

Table 5 shows that post-test and pre-test of physics problem skills and self-directed learning skills are normally distributed to all groups, unless for group-1 that is not normally distributed in the post-test. Therefore, in order to analyze the impact of PIL model teaching further, Wilcoxon test is applied to group-1 that is not normally distributed, while pair t-test is applied for other groups those are normally distributed. Table 6 and Table 7 shows the results obtained in Wilcoxon test and pair t-test after meeting the normality assumption of pre-test and post-test.

Table 6. The Wilcoxon test result of the physics problem solving skills of group-1.

	N	Z	p
Post-test and Pre-test	22	- 4.108	< .0001

**p < .05 (2-tailed)*

Table 7. The pair t-test result of the physics problem solving skills and self-directed learning skills of group-1 up to group-6.

Pair	N	Physics problem solving skills					Self-directed learning skills				
		Mean	Std. Error Mean	t	df	p	Mean	Std. Error Mean	t	df	p
Pair 1	22	Wilcoxon test					36.30	2.22	16.32	21	< .0001
Pair 2	22	48.39	1.87	25.95	21	< .0001	36.50	2.21	16.52	21	< .0001
Pair 3	25	45.99	1.77	25.92	24	< .0001	47.70	2.41	19.80	24	< .0001
Pair 4	25	53.20	2.69	19.79	24	< .0001	45.43	1.34	33.91	24	< .0001
Pair 5	25	46.85	1.52	30.86	24	< .0001	45.68	1.57	29.15	24	< .0001
Pair 6	25	46.15	1.39	33.18	24	< .0001	45.41	1.49	30.40	24	< .0001

Table 6 shows that the score provided by Z is -4.108 with significance level of $p < .05$. This clearly indicates that PIL model does have an impact on improving the physics problem solving skills of group-1. Table 7 also shows that t scores of physics problem solving is $t = 25.95$ for degrees of freedom, $df = 22$, $t = 25.92$, $t = 19.79$, $t = 30.86$, $t = 33.18$ for degrees of freedom, $df = 25$. t score of self-directed learning skills is 16.32 and $t = 16.52$ for degrees of freedom, $df = 22$, $t = 19.80$, $t = 33.91$, $t = 29.15$, and $t = 30.40$ for degrees of freedom, $df = 25$. Such scores are considered significant since $p < .05$.

The consistence of PIL model impact on the skills of physics problem solving and self-directed learning then is further analyzed by means of ANOVA after meeting the normality assumption and variant homogeneity as shown in Table 8.

Table 8. The results of ANOVA of physics problem solving skills and self-directed learning skills of all groups.

n-gain all groups		Sum of Squares	df	Mean Square	F	p
Physics problem solving skills	Between Groups	.208	5	.042	1.979	.302
	Within Groups	1.446	138	.010		
	Total	1.654	143			
Self-directed learning skills	Between Groups	.274	5	.055	1.608	.704
	Within Groups	2.096	138	.015		
	Total	2.370	143			

Table 8 shows that F count gives $F = 1.98 < F_{table\,(5;\,138)} = 2.28$ with significance level $p = .302 > .05$ for physics problem solving skills. Therefore, there are strong indications that the impact of PIL model on the physics problem solving skills for the group is not different at the 5% level of significance. Table 8 also shows that $F = 1.61 < F_{table\,(5;138)} = 2.28$ with significance level $P = .704 > .05$ for self-directed learning skills. Consequently, there are strong indications that the impact of PIL model on the self-directed learning for the group is not different at the 5% level of significance.

Discussion

The Validity and Reliability of PIL Model

PIL model validation is held through FGD activities by experts those are science education expert, physics education expert, and open and distance education practitioner, so that valid PIL model that meets the aspect of necessity and newness based on strong empirical theory in which there is inter-consistence among its structural components is achieved. This PIL model validation is in line with the result of research done by Murgado-Armenteros, Torres-Ruiz, and Vega-Zamora (2012) in which it states that one product validation can be performed through FGD

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activities by the experts, either face to face or online. By taking the availability of facilities and infrastructures into account, this PIL model validation is taken face to face, in which three ODES experts are involved.

The result of FGD activities as shown in Table 2 indicates that PIL model and its components those model rational, theoretical and empirical support, model syntax, social systems, reaction principle, supporting systems, instructional & accompanying impacts are categorized as valid and reliable. Malhotra (2011) states that a product is considered as valid when it has ICC single measure of $r_\alpha = .754 > r_{table}$. In this research, the result of $r_\alpha = .75 > r_{table}$ for content validation and of $r_\alpha = .79 > r_{table}$ for construct validation are obtained, which means that the developed PIL model has such a high validation of both content and construct. It is so with the Syllabus, teaching plan, teaching materials, and university student's worksheet those are valid and reliable. This also corresponds to the research of Plomp and Nieveen (2007) which state that a product does have a good quality when referring to content validity and construct validity those are valid and able to illustrate necessity, newness, inter-component consistence of the model and both theoretical and empirical support.

PIL model that is valid already of both content and construct must be tested for its consistence in order that the model is stable and can be routinely used. According to Sarstedt and Mooi (2014), reliability of certain product can be stable when it meets the following qualifications: stability of the measurement, internal consistency reliability, and inter-rater reliability. PIL model is considered as reliable when the coefficient of Cronbach's alpha (α) and Cronbach's alpha if item deleted is > .60 (Malhotra, 2011). According to the result of FGD, internal consistence reliability and inter-rater reliability of PIL model are found to be all reliable as shown by Table 2 with Cronbach's alpha is: .996 for content validity; .993 for construct validity. The internal consistence reliability is indicated with the value of Cronbach's alpha if items deleted of component are .972 – .976 respectively for content validity and .925 – 1,000 for construct validity. It means that the developed PIL model has such a high reliability of both content validity and construct validity.

The wares of PIL model that is developed those syllabus, teaching plan, teaching materials, and university student's worksheet are the wares of PIL model that is compatible to be used in complementing PIL model. It is to make it corresponds to the need, has the newness feature and is supported by strong theoretical and empirical ground, to have inter-component consistence (Plomp & Nieveen, 2007), good literacy and appropriate to be a teaching plan of *PIL* model to improve the physics problem solving skills and self-directed learning skills (Dunlap, 2005) of the students in open and distance education (Blaschke, 2012).

PIL model is categorized as valid of both content and construct validity, so that it can be used as the reference to make a plan of physics problem solving skills and self-directed learning skills training. This is in line with the research held by Seechaliao, Natakuatoong, and Wannasuphoprasit (2012) in which it is stated that such valid teaching model can assist the researcher and practitioner to design a teaching according to the teaching principles those have been understood. The valid teaching model can be used as the reference for the academics and practitioner to plan a teaching program (Kimbell & Stables, 2007). The valid PIL model can provide the practitioners with a chance to apply it on physics teaching by involving scientific process and product, so that it can be used to train physics problem solving skills and self-directed learning skills (Pandiangan, Jatmiko, & Sanjaya, 2016).

The Effectiveness of PIL Model and Its Application

A good teaching model must have specific characteristics and purpose and meet validity, practicability, and effectiveness aspects. Honebein and Honebein (2015) state that effective teaching is possible when the teaching process is designed according to the core principles of teaching plan theory. Such an effective teaching can be achieved when a lecturer has an appropriate strategy to deliver his/her knowledge to the students structurally and be able to integrate theory and practice into the process of learning (Hughes, 2005). A teaching is categorized as effective when the tutor has a good level of knowledge and comprehension of teaching (Roscoe & Chi, 2007), the students actively participate in the learning (Eom, Wen, & Ashill, 2006), available infrastructures of laboratory equipment's/ computer simulation (Beatty, 2013), and the learning achievement of students is improved as they have a good respond to the learning (Zimmerman & Schunk, 2012). Based on activity theory, increased student engagement can improve learning outcome, with respect to effectiveness, such learning can be measured according to the improved achievement of the students and their respond to the learning (Jatmiko, Widodo, Budiyanto, Wicaksono, & Pandiangan, 2016; Liaw, 2008).

The improvement of student's problem-solving skills can be seen from the n-gain of physics problem solving skills with respect to electricity and magnetism obtained from the calculation of scores achieved in pre-test and pro-test given to the students before and after teaching in which PIL model is applied. According to Figure 1, before learning about electricity and magnetism using PIL model, the students have not had any competence of problem-solving skills yet. Their average scores are still under the standard score that is of 32.26 within the score range from 0 to 100 for group-1; of 26.10 for group-2; of 36.80 for group-3; of 27.53 for group-4; of 32.60 for group-5; and of 35.59 for group-6. This is because the students have not been familiar yet to do the thinking activities as demanded by PIL model in physics problem solving skills, as follows, problem formulation, variable identification, hypothesis forming, data analysis, and conclusion drawing.

This research result is supported by the research done by Mestre (2001) in which it is stated that problem solving skills in physics learning at higher education level is based on the characteristics of physics subject that is assumed to be relatively difficult and complex. Problem solving skills in physics that is abstract is categorized as low and difficult to understand (Snyder, 2000). The preliminary research result to 83 students of Open University Stratum-1 program with respect to physics problem solving skills is still low (Pandiangan, Jatmiko, & Sanjaya, 2015). This is due to the lack of understanding of students about the model and theory of physics (Clement, 1993) and poor competence of understanding science literacy (Yore & Treagust, 2006).

After learning about electricity and magnetism using PIL model, the students achieve good physics problem solving skills competence, which average scores are 78.34 for group-1; 74.49 for group-2; 82.60 for group-3; 81.14 for group-4; 80.99 for group-5; and 81.35 for group-6. It means that the average scores have been improved before and after the application of PIL model as much as 142.20%, as follows: 184.93% for group-1, 72.63% for group-2, 185.71% for group-3, 105.26% for group-4, 152.22% for group-5, and 108.91% for group-6. These improved scores of physics problem solving skills of all groups are significant and consistent at the real level of 5% with respective n-gain of groups are .68 for group-1, .65 for group-2, .76 for group-3, .78 for group-4, .73 for group-5 and .75 for group-6. Such results indicate that teaching using PIL model does have an impact on the skills of problem solving that is really improved. The level of such PIL model teaching impact on the physics problem solving skills of all groups is consistent significantly at the real level of 5%. Group-1 and Group-2 are in the moderate category of limited test, while group-3, group-4, group-5, and group-6 are in the high category of wider test.

Such improvement of competence according to the indicator of physics problem solving skills using PIL model is due to several causes. Those causes among others are: the students have been trained and directed to reach the indicator of physics problem solving skills (Bradford, 2015); course syllabus (Jenkins, Bugeja, & Barber, 2014), teaching materials (Crouch & Mazur, 2001), good worksheet (Bakırcı, Bilgin, & Simsek, 2011), good teaching environment and tool/simulation technique (Sedrakyan & Snoeck, 2012) those provide the students with positive effects while making hypothesis and creating good analyzing skills. Further, the learning initiated with having a problem (Engeström, 2001), trying a simulation before predicting what may happen (Tao & Gunstone, 1999), deciding the purpose of experiment, formulating the problem, identifying variables, and making hypothesis (Bradford, 2015) can grow motivation, initiative and persistence of the students to solve the problem. An explanation about natural symptoms according to the data obtained during the process of investigation is a highly decisive factor to ensure a successful teaching of physics practicum (Champagne, Klopfer, & Anderson, 1980).

Referring to the achieved results as aforesaid, teaching syntax that has been formulated according to physics problem solving skills is supported by the newest empirical data and teaching theory. Such an improved physics problem solving skills using PIL model is also supported by several results of research, as follows: (1) learning effectiveness may be due to the quality of teaching (Palardy & Rumberger, 2008), facilities and infrastructures availability (Piccoli, Ahmad, & Ives, 2001), active participation of students and students' response (Liaw, 2008; Tschannen-Moran & Hoy, 2001); (2) an effective lecturer knows how to assist his/her students in doing their investigation using knowledge, curriculum, and staged teaching to deal with complexity that they may encounter during the class (Rubin, Chamot, Harris, & Anderson, 2007); (3) while solving a problem, it is important to build such knowledge in social aspects according to what is needed by the students and how they should learn (Asheim, Coenen, & Vang, 2007; Hmelo-Silver, 2004), social interaction with others in which they may generate new ideas to improve their intellectual development based on former experience (Csikszentmihalyi, 2014; Ostrom, 2014), the students then become more active in class discussions and are able to maintain a good learning habit (Baxter Magolda, 2003; Kong, 2014).

This result of research is also supported by several theories of teaching with respect to physics problem solving skills of PIL model. Those theories are as follows: motivation theory, which states that a person will be motivated when what he or she does can attract the attention of students (Arends, 2012); top-down process, which states that we'd better be off choosing complex problems to solve and then finding basic skills as required (Moreno, 2010);

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zone of proximal development, which states that students will learn the best concept when such concept is in the closest development zone (Moreno, 2010; Slavin, 2006); and scaffolding, which states that the students should be given complex, difficult, and realistic assignments and provided with gradual assistance to solve the problems (Slavin, 2006). Theoretical analysis states that one of creative problem-solving methods those are often suggested is to analyze and register the main characteristics of problem elements (Moreno, 2010).

As the case with physics problem solving skills, the improvement of university student's self-directed learning skills can be indicated from the n-gain. The n-gain is calculated from those scores achieved in pre-test and post-test given to the student. According to Figure 2, before learning about electricity and magnetism by means of PIL model, the students have such a low skill of self-directed learning, namely as much as 43.51 in group-1, 41.97 in group-2, 34.29 in group-3, 39.91 in group-4, 36.74 in group-5, and 37.77 in group-6 within the score range from 0 to 100. This is since the students have not yet been used to do active thinking as thinking activities of self-directed learning required by PIL model, namely initiation and persistence, responsibility, discipline and great curiosity, confidence and strong desire to learn. They should also be able to organize time and set the pace of learning, and love to learn and meet the planned target and revision. The result of this research is supported by Benegas and Flores (2014), who states that undergraduate introductory physics course, especially electric circuit, has a complex concept to be verbally explained only. Therefore, it will be less effective and practical to improve self-directed learning. The result of preliminary study to 83 students of Open University Stratum-1 bachelor program with respect to self-directed learning skills is still underrated (Pandiangan, Jatmiko, & Sanjaya, 2005).

After learning about electricity and magnetism using PIL model, the students have had a good competence of self-directed learning skills with average scores of 79.81 for group-1; 78.48 for group-2; 83.53 for group-3; 84.22 for group-4; 82.55 for group-5; and 83.39 for group-6 respectively. It means that the average scores are improved before and after PIL model application by 96.73%, which is 104.35% for group-1; 82.26% for group-2; 105.26% for group-3; 103.3% for group-4; 83.74% for group-5; and 93.18% for group-6. These improved scores of self-directed learning skills of all groups are significant and consistent at real level of 5% with respective n-gain of groups are .64 for group-1; .62 for group-2; .72 for group-3; .74 for grou-4; .71 for group-5; and .72 for group-6. Such results indicate that teaching using PIL model does have a real impact on the improved skills of self-directed learning. The level of such PIL model teaching impact on the self-directed learning skills of all groups is consistent significantly at real level of 5%. Group-1 and group-2 are in moderate category of limited test, while group-3, group-4, group-5, and group-6 are in high category of wider test.

Such improvement of competence according to the indicator of self-directed learning skills using PIL model is due to several causes. Those causes among others are: (1) the students have been trained and directed to reach the indicator of self-directed learning skills (Stewart, 2007); (2) both formal and informal trainings may change someone's habit to leave his/her old habit and adapt with new technology to create better products and these technology, together with the quality of the training process, should be a major challenge for the coming time (Daniel, Cano, & Cervera, 2015; Walkington & Sherman, 2013); (3) problem presentation that will effectively encourage the students to be more independent, initiated and persisted to learn (Biggs, 2011); (4) the students have the competence of understanding formulations, graphs, illustrations, review and extend existing frameworks on modeling to develop a new framework that describes model-based reasoning in introductory and upper-division physics laboratories, table reading and relating variables that may help the students to simplify problems, so that the students can learn more independently (Zwickl & Hu, 2015); (5) the students can individually build their own knowledge and develop meanings according to former experiences, either personally or in social context (Greenspan, 2015).

The result of this research is also supported by several teaching theories with respect to self-directed learning skills of PIL. Those theories among others are: advanced organizer theory, which states that the preliminary statement about a subject to be learnt will provide new information structures and relate them to the information that the students have had previously (Moreno, 2010; Slavin, 2006); modeling theory, which states that the students can learn through explanation and observation of others (Arends, 2012; Moreno, 2010); cognitive apprenticeship, which states that a student's process of learning can be taken gradually until he/she reaches the level of expertise while interacting with an expert whose knowledge is higher, either older or at the colleagues (Arends, 2012; Slavin, 2006).

Conclusions

By virtue of the aforementioned research and discussion, learning that applies PIL model and its wares on electricity and magnetism subjects is validly, reliably, and effectively qualified to improve the physics problem solving skills and self-directed learning skills of students at open and distance education systems. The validity, reliability and effectiveness of teaching that applies PIL model and its wares to improve physics problem solving skills and self-directed skills are based on: (1) the validity of the developed PIL model is valid based on single measure inter-rater correlation coefficient $r_{\alpha} > r_{table}$ and Cronbach's alpha $.6 < \alpha < 1.0$; (2) there is such a significant improvement (statistically) of physics problem solving skills and self-directed learning skills before and after applying PIL model; (3) n-gain scores of physics problem solving skills and self-directed learning skills are categorized as moderate in the limited test and high in the wider test; (4) there is not any difference level of improvement between physics problem solving skills and self-directed learning skills (there is no difference of n-gain) for both tests in all groups. It means that PIL model and its wares are consistent to improve physics problem solving skills and self-directed learning skills of the students at open and distance education systems.

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