PAPER • **OPEN ACCESS**

SSP Development with a Scaffolding Approach Assisted by PhET Simulation on Light Refraction to Improve Students' Critical Thinking Skills and Achievement of Science Process Skills

SSP Development with a Scaffolding Approach Assisted by PhET Simulation on Light Refraction to Improve Students' Critical Thinking Skills and Achievement of Science Process Skills

Beatrix Elvi Dasilva*, Heru Kuswanto, Insih Wilujeng and Jumadi
Yogyakarta State University, Indonesia

*E-mail: beatrix.elvi@gmail.com

Abstract. This study aims to determine a) the feasibility of subject specific pedagogy (SSP) with a scaffolding approach assisted by a PhET simulation in physics learning, b) the effectiveness of SSP with a scaffolding approach assisted by PhET simulation developed in improving critical thinking skills and c) achievement of process skills high school students after using SSP with a scaffolding approach assisted by a PhET simulation. The development model used is the 4D model which is define, design, develop and disseminate. In this study, the stage of development only reaches the develop stage. The SSP was validated by two physics experts and through focus group discussion. The field test stage was conducted in MAN 1 Yogyakarta with 32 subjects of students in class XI MIPA 3. Subjects were chosen by purposive sampling technique. Data collection was done by observation, questionnaire, and tests. The results showed that a) the developed SSP was feasible to be used in learning in schools, (b) the SSP with the PhET assisted scaffolding approach could improve students' critical thinking skills, and c) the SSP with the PhET assisted scaffolding approach had a good effect on science process skills namely achieving very high category.

Keywords: SSP; Scaffolding; PhET; Critical thinking skills; Science process skills

1. Introduction

The aim of science learning is to explain to students about the nature of science and how to produce science products [1], [2]. Science products are produced from scientific investigations based on scientific attitudes [3]. Physics is a branch of science. Physics learning directs students to develop process skills and hone thinking skills [3], [4]. The most effective way of learning science is by building process skills and scientific attitudes [5]. Thus, students are accustomed to finding science products by applying scientific work. In accordance with the nature of science, physics learning must facilitate students to achieve science process skills [6]. However, in reality the teacher did not apply learning that honed the science process skills of students. Most teachers tend to emphasize mathematical equality in solving physical problems [7], [8]. This has an impact on students' process skills. The measurement results conducted by Khasanah and Prasetyo show that the science process skills of MAN 3 Yogyakarta students as a whole are dominant in the very high category of 31.25%. However, the achievement for aspects of making the model is mostly included in the low and very low category, which is 40.62% [9].

The learning paradigm in 21st century requires some abilities that must be achieved by students. One of them is critical thinking skills [10]. However, the learning process is still teacher centered [11], [12]. Learning models like this will be difficult to hone students' critical thinking skills. This is evidenced by the low critical thinking skills with a percentage of 45% [13]. The result of the measurement of critical thinking skills in MAN 3 Yogyakarta shows that most students are in the low category. The results of the analysis show that in the basic clarification aspect there were 37.50% of students included in the low category, most of the aspects of building basic skills were included in the very low category at 46.88%, the achievement for advanced clarification aspects were mostly in the very low that is equal to 56.25%, and the achievement for aspects of managing strategy and tactics is mostly included in the low category of 34.38% [9].

The concept of refraction of light is one of the basic concepts in physics. Students need to learn the concept of refraction in the right way to understand advanced physics concepts such as light interference and light spectrum. However, students often experience misconceptions about the concept of refraction [14]. For example, students can not distinguish refraction and reflection, do not understand the direction of light propagation, and how refraction occurs on the surface of a medium [15]. In addition, students also assume that the speed of light is not related to the medium [16]. The possibility of misconceptions about refraction of light must be eliminated. Computer simulation provides students with the opportunity to visualize the refraction of light when passing two different mediums. One of simulation that can be utilized is PhET simulation. The simulation can be accessed for free on the website http://phet.colorado.edu. PhET simulations are generally usable, attractive, and effective learning tools for high school students [17]. PhET simulations on refraction material can develop students' conceptual understanding in science [18]. The use of PhET simulations with guided inquiry approaches can improve critical thinking skills by 76% in high school students [19].

Computer simulation it self is not enough to improve critical thinking skills and science process skills. Therefore, in this study PhET simulations were integrated with the scaffolding approach. Wood, Bruner, and Ross stated that scaffolding allows a child to solve a problem, carry out a task or achieve a specified goal [20]. Scaffolding consisted of three levels. First level, environmental provision. The assistance given by the teacher in the first stage is in the form of learning environment conditioning for students. The teacher provides learning resources, media, provides motivation and encouragement. Second level, explaining, reviewing, restructuring. In the second level, the teacher interacts directly with students. Reviewing is about how the teacher provides assistance in the form of providing opportunities for students to see, touch, explain concepts in their own language. Students actively explain, justify, and criticize a concept or problem. In the restructuring interaction, teacher's task is to interpret the actions and talks of students, then express the thoughts of students in better language without reducing their meaning. At this stage, the teacher helps students solve problems by providing examples that are similar to the problems given. Third level, developing conceptual thinking. At level 3, students develop conceptual thinking. The teacher's task is to provide students with more abstract assignments resulting in conceptual discourse. Students can also develop representational tools that are in accordance with the concepts learned [21]. Several studies and literature reviews show that physics learning with a scaffolding approach can improve students' cognitive and affective abilities. The scaffolding approach is effective to improve the habit of critical thinking and encourage students to think independently [22]. In addition, scaffolding can improve students' problem-solving abilities and mastery of concept [23], [24]. Scaffolding can help to clarify meaning and monitor the learning process of students [25]. Other research results show that the scaffolding approach can also increase students' learning motivation [26]. These findings indicate that scaffolding aided by PhET simulation can improve students' skills.

The implementation of learning requires a special component, namely Subject Specific Pedagogy (SSP). The SSP is a teacher's idea contained in the learning component [27]. The SSP component consists of a lesson plan (called RPP), student worksheet (called LKPD), and assessment instruments. However, there is no specifically SSP for light refraction materials. Based on the above problems, this study aims to develop Subject Specific Pedagogy (SSP) of physics learning which can be used to improve critical thinking skills and hone science process skills in light refraction material.

The rest of this paper is organized as follow: Section 2 describes the proposed research method. Section 3 presents the obtained results and following by discussion. Finally Section 4 concludes this work.

2. Research Method

This paper is the result of research and development research. The products developed are Subject Specific Pedagogy (SSP) which consists of lesson plan (RPP), student worksheet (LKPD), and instruments for assessing critical thinking skills and science process skills. Product development uses the 4D model developed by Thiagarajan [30]. The 4D development model consists of four stages, namely (1) define, (2) design, (3) develop, and 4) disseminate. However, in this study, the stage of development only reaches the develop stage. Figure 1 shows the steps of the modified 4D study from the model developed by Thiagarajan.

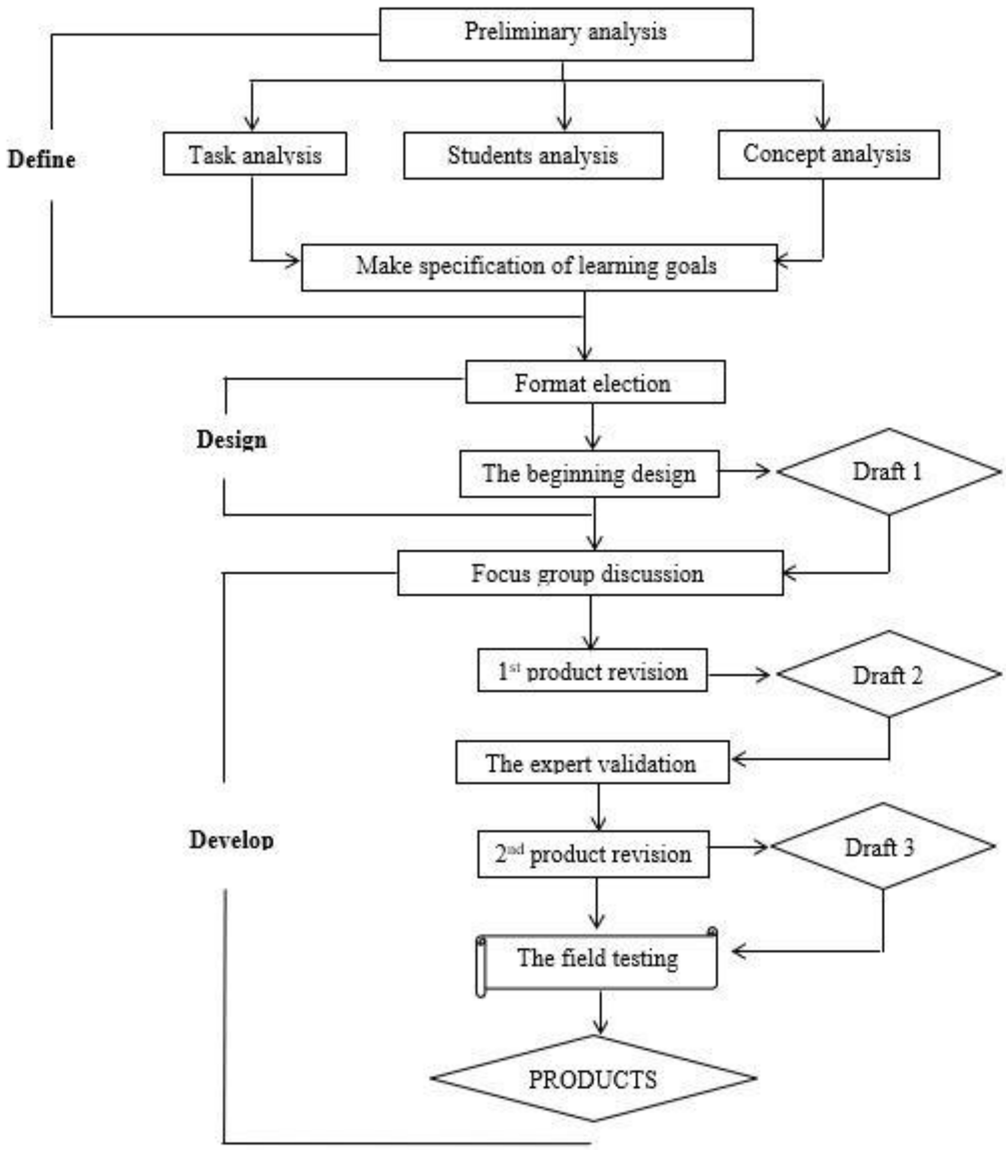


Figure 1. Steps to study model 4D

Field test subjects were students of class XI MAN 1 Yogyakarta. The field test subjects were 32 students from class XI MIPA 3, MAN 1 Yogyakarta. Subjects were chosen by purposive sampling technique. The research is conducted in even semester, 2017/2018 school year. Field tests were conducted during two meetings during the learning process of light refraction material.

The design of field tests for critical thinking skills is one group pre-test post-test design. This design is described in Table 1 as follows:

Table 1. Research design[a].

O_1[b]	X[c]	O_2[d]

[a] pre-test post-test design
[b] pre-test score
[c] learning using SSP with scaffolding approach assisted by PhET simulation
d post-test score

The design for science process skills is a one-shot case study as described in Table 2.

Table 2. Research design[a].

X[b]	O[c]

[a] one-shot case study design
[b] learning using SSP with scaffolding approach assisted by PhET simulation
[c] observation of science process skills

Data collection techniques were tests and non-tests. Data collection instruments consisted of expediency assessment sheets by expert, observation sheets for learning implementation, critical thinking skills questions, and observation sheets of science process skills. Assessment of the expediency of learning devices and assessment instruments is done by physics expert and through Focus Group Discussion (FGD). As for the learning tool and assessment instruments which is considered it's eligibility is RPP, LKPD, critical thinking skills instruments, and science process skills observation sheet. Each learning tool and assessment instruments has several aspects and indicators to be assessed. The assessment sheet of RPP consist of several aspects, i.e., the identity aspect, the aspect of formulation of competence achievement indicators and learning objectives, organizing material aspect, method aspect, media and learning resources, aspects of learning steps and the language aspect. The LKPD expediency assessment sheet consists of several aspects the eligibility assessment of the content's aspect, presentation aspect, performance aspect, language aspect. The LKPD expediency assessment sheet using the Guttman scale with two alternative answers are Yes and No. Answer Yes is 1, declare the mark to agree with the statement. While the answer Not is 0, declare the mark to disagree with the question [31]. The expediency assessment sheet consists of construction aspect, contents aspect and language aspects. The assessment sheet uses the Guttman scale with two answers are Yes and No. Decision of the ratter for each question the uses of four-scale, that is (4) if the item is accepted without revision, (3) if the item is accepted with a little revision, (2) if the statement is about a lot of revision, and (1) if the item is not acceptable or revised total.

Data results of the learning devices ratings and expediency assessment of assessment instruments were analysed using descriptive analysis. The average scores on each the expediency assessment aspects of the learning device are converted to the scale of 4 according to Mardapi [32]. The average score of each aspect the expediency assessment is converted to the value with the criteria as shown in Table 3.

Table 3. Assessment criteria of the four scale.

Respondent Score	Categorization
$X \geq X_i + 1.0\ SB_i$	Very High
$X_i + 1.0\ SB_i > X \geq X_i$	High
$X_i > X \geq X_i - 1.0\ SB_i$	Low
$X < X_i - 1.0\ SB_i$	Very Low

Where

X_i = $^1/_2$ ($maximum\ ideal\ score$ + $minimum\ ideals\ core$) and

SB_i = $^1/_6$ ($maximum\ ideal\ score$ − $minimum\ ideal\ score$)

The improvement of critical thinking skills can be known by calculating Gain Score (GS). Gain score is determined by calculating the difference between pre-test and post-test as shown in equation (1).

$$GS = T_2 - T_1 \quad (1)$$

Where GS = gain score, T_2 = post-test score and T_1 = pre-test score

Implementation of learning is analysed descriptively by calculating the percentage of implementation the RPP based on observations.

3. Results and Disscusion

3.1. Development Results

The product that produced in the study is SSP consisting of RPP, LKPD, and instruments to measure critical thinking skills and science process skills. The SSP is developed has a disabled i.e., using a scaffolding approach integrated with PhET simulation. The PhET simulation is put into steps of scaffolding approach. It's poured into RPP. Learning activities with a scaffolding approach assisted of the PhET simulation directed to improve critical thinking skills and science process skills. Table 4 shows matrix relationship between learning activities with scaffolding approach assisted by PhET to critical thinking skills and science process skills.

Table 4. Matrix relationship between learning activities with scaffolding approach assisted by PhET to critical thinking skills and science process skills

Level of scaffolding approach	Learning activities and teacher's help	Aspects of students' critical thinking skills which are honed	Aspects of students' science process skills which are honed
Level 1 Environment provision	**Meeting I:** 1. Teacher shows how to operate the PhET simulation program to the students 2. Teacher gives motivation in the form of showing the refraction phenomenon "the straw looks broken when put into a glass of water" 3. Students are answering the question from teacher "why does a straw in the water look like it's broken?"	Basic suport	
	4. Students are compiling the questions based on simulations of refraction phenomenon on PhET 5. Students makes a hypothesis from the PhET simulation demonstrated.	Elementary clarification	Observating and formulating the hypohesis
	Meeting II: 1. Teacher ia setting up the practice tools 2. Teacher is sharing the students into the group 3. Sharing the LKPD	Basic support	
	4. Students makes questions based on the image of the refraction phenomenon on the LKPD 5. Students creates a hypothesis based on the image of a refraction phenomenon on the LKPD	Elementary clarification	Observation and formulating the hypohesis
Level 2 Explaining	**Meeting II** Teacher shows how to assemble an improvised instrument.	Setting strategies and tactics	

Level 2 Reviewing	**Meeting I** 1. Students manipulated the angle of incidence on the PhET simulation to see how it's effect to angle of refraction 2. Students manipulated the mediums on the PhET simulation to know how it's effect to speed of the light on difference medium 3. Teacher gives a simple example. 4. Teacher provides refraction problems to students, starting with a simpler problem 5. Teacher gives instructions or direction to the students to solutions using the technique of asking a pushing and investigating.	Setting strategies and tactics	
	Meeting II: 1. Students design the practice of determining the plan parallel glass refractive index 2. Students experimented to determine the plan parallel refractive index and formulate the Snell's Law with their own language	Setting strategies and tactics	Doing experiment
	3. Students performed data analysis through group disscussion		Interpreting and analyzing data
	4. Students are presenting the work in front of the class 5. Teacher provides opportunities for other students to criticize or justify another group work	Making further explanation	Communicating
Level 2 Restructuring	**Meeting I:** The teacher provides contextual situations for abstract situations, for example using an analogy to describe the speed of light in a denser medium and a less dense medium. The analogy used: "the speed of vehicles on a jammed road is smaller than the speed of a vehicle when the road is deserted" **Meting II:** 1. Teacher is clarifying the meaning of student presentation results 2. Teacher is interpreting the actions and talks of students by giving a comment of appreciation to the student's experiment	Elementary clarification	
Level 3 Developing conceptual thinking	**Meeting I:** Teacher with students are makes the conclusions about refraction principles and application of their daily activities. **Meeting II:** Students are concluding the experiment results includes, plan parallel glass refractive index and Snell's Law based on data	Making inference/ conclusion	Making conclusion

Table 4 shows that the critical thinking skills and science process skills of students can be trained through the scaffolding approach aided by PhET simulation. Learning activities train students to be independent, so they can solve the physics issues without the help of teachers. Students actively participate through PhET simulation and experiment activities in the laboratory. Such learning activities, can hone the critical thinking skills and science process skills on students. The PhET simulation role in a learning is help tool to visualize the event of light refinement. The following Figure 2 is a snapshot of refraction simulation when light enters to the medium II (glass) of medium I (air) [33].

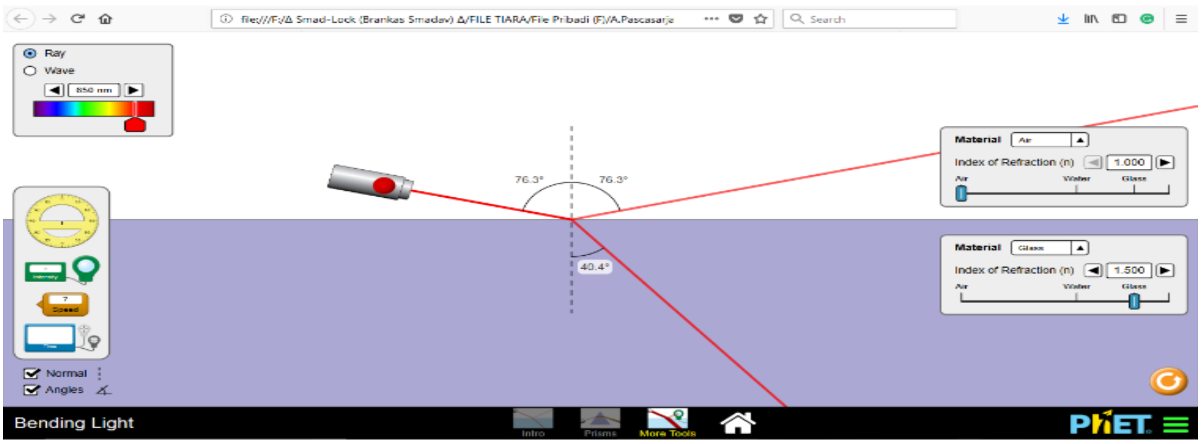
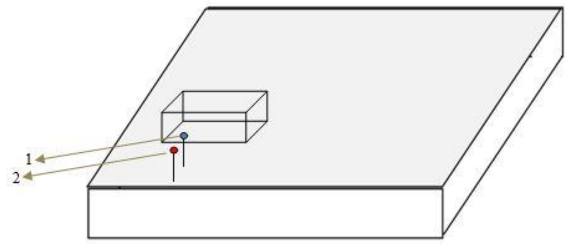


Figure 2. Snapshot of refraction phenomenon simulation of air into the glass

The simulation shown by the Figure 2 helps students to imagine how the occurrence of revenue events. This is in accordance with the basis of PhET development to analyse the less familiar phenomenon with the students [29].

Table 4 indicates that learning with the scaffolding approach can hone students' science process skills through parallel plan glass experiments. It is also shown in activities is undertaken students on LKPD. Table 5 presents activities of students at LKPD.

Table 5. Students' Activities on LKPD.

Science process skills aspects	Students' activities on LKPD
Observating	Observe the image of the refinement phenomenon on the plan parallel glass. *"Sebelum melakukan percobaan, perhatikan ilustrasi berikut!"* 
Formulating of the hypothesis	Students formulating the hypothesis after observing the picture of the refinement phenomenon on the plan parallel glass. *"Jika terdapat jarum pentul yang terletak pada salah satu sisi kaca plan paralel (balok kaca bening), apa yang terjadi jika anda mengamati dari sisi kaca plan paralel yang lainnya? Bagaimana letak bayangan yang anda amati dibandingkan posisi jarum pentul di sisi lainnya? Tulislah hipotesis (dugaan sementara) anda pada kolom jawaban pertanyaan diskusi nomor 1!"*
Doing experiment	Students experimented to determine the plan parallel refractive index and reform the Snell's Law. Students perform three data capture with different angle of rays.
Interpreting and analyzing data	Students performed data analysis *"Buatlah tabel yang sistematis pada kolom berikut untuk menuliskan hasil pengamatan dan pengukuran! Lengkapi data yang kalian peroleh dengan simbol besaran dan satuan yang sesuai!* *Hitung pula besar indeks bias kaca plan paralel dari masing-masing pengukuran yang dilakukan! Tuliskan cara menghitung indeks biasnya!"*
Making a conclusion	Conclude the experiment results.
Communicating	Communicate writes the experiment and discussion results on LKPD and present the discussion results in front of the class.

3.2. Validation Results

The stage of development is done begins with the validation of FGD. FGD activities is followed by 18 students and 2 lecturers from Education Physics graduates of Yogyakarta State University. The revision results based on FGD is a draft 2 products. The draft 2 is then given to the physics expert to be assessed its expediency.

Table 6. The results of RPP expediency assessment by physics expert.

No	Aspect	Score	Categories
1	Identity Completeness	16	Very high
2	IPK formulation and learning objectives	26	Very high
3	Organizing teaching material	16	Very high
4	Methods, Media, and Learning Resources	18	Very high
5	Learning Step	28	Very high
6	Linguistic	6	Very high

Table 6 shows that every aspect of the RPP has a "very high" category. This result indicates that the RPP is prepared already "worthy" to be used in learning. In addition to RPP, the LKPD is also assessed its expediency. Table 7 presents the results of the assessment of the expediency of the LKPD.

Table 7. The results of the LKPD expediency assessment by physics experts.

Aspect	Score	Categories
Contents	26	Very high
Presentation	6	Very high
Performance	28	Very high
Linguistic	14	Very high

Table 7 shows that the student worksheet is "worthy" and can be used without revision. Every aspect assessed on LKPD has a "very high" category, which means LKPD is good.

In addition to learning devices, assessment instruments are also validated by physics experts. Validated instruments are about critical thinking skills and observation sheets of the science process skills. Figure 3 presents the validation result of the critical thinking skills instrument.

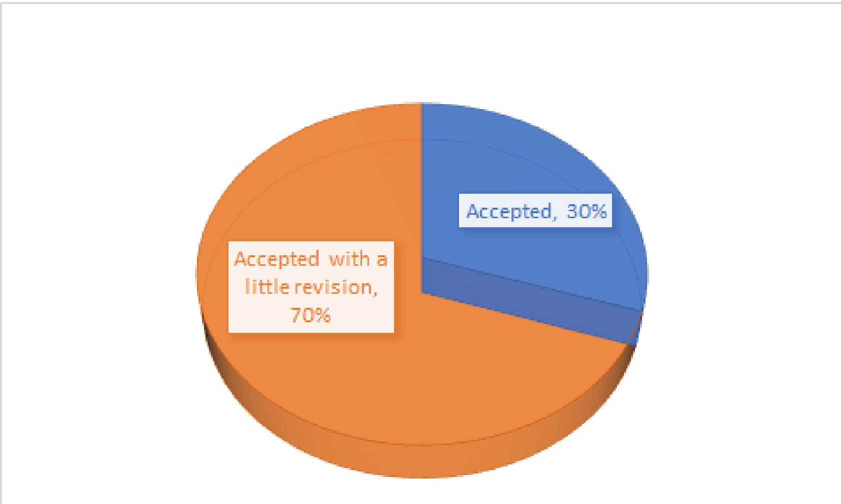


Figure 3. Validation result of the critical thinking skills instrument.

The critical thinking skills instrument consists of ten points. Figure 3 shows that seven questions should be fixed. Improvement on question item are repair of writing, description of the picture and the information on the table. So, it's concluded that the instrument of critical thinking skills assessed is accepted with revision. Science process skills are measured by observation. Observation sheets are prepared based on science process skills indicators. The observation sheet of science process skills is validated by two physics experts. The following table is the validation result of process science skills instrument.

Table 8. Result validation of science process skills instrument by physics experts.

Aspect	Score	Categories
Conformity with indicators	24	Very high
Construction	14	Very high
Practicality and affordability	10	Very high
Linguistic	6	Very high

Table 8 shows that, observation sheets for science process skills is "worthy" to measure skill process of learning bearing. Each aspect assessed on the instrument has a "very high" category. So, the observation sheet of science process skills worthy is used without revision.

Assessment of learning phase execution in RPP is done by an observer. The each phase criteria on syntax is meant are implemented and not implemented. Based on the analysis result of the learning execution, indicating that the treatment was given in the class is well done. It is seen that the results of the observation of learning execution the first meeting of 95% and the second meeting of 83%. In general, the three class of learning is well done.

3.3. Field Test Results

After the SSP is validated and rated its expediency, the next stage is field test results. The field test results aim to see the effectiveness of the SSP is developed against critical thinking skills and science process skills on students. The results of field test are done for two meetings. The first meeting was done in the classroom. Students take part in learning activities with a scaffolding approach assisted of the PhET simulation. The second meeting is the learning in the laboratory. This second learning aims to prove the truth of Snell's Law through experiment of the parallel plan glass. Improvement of critical thinking skills are obtained by seeing the increased ability of students before and after learning using the tools that was developed. Figure 4 presents the critical thinking skills of students before and after learning by using the developed SSP.

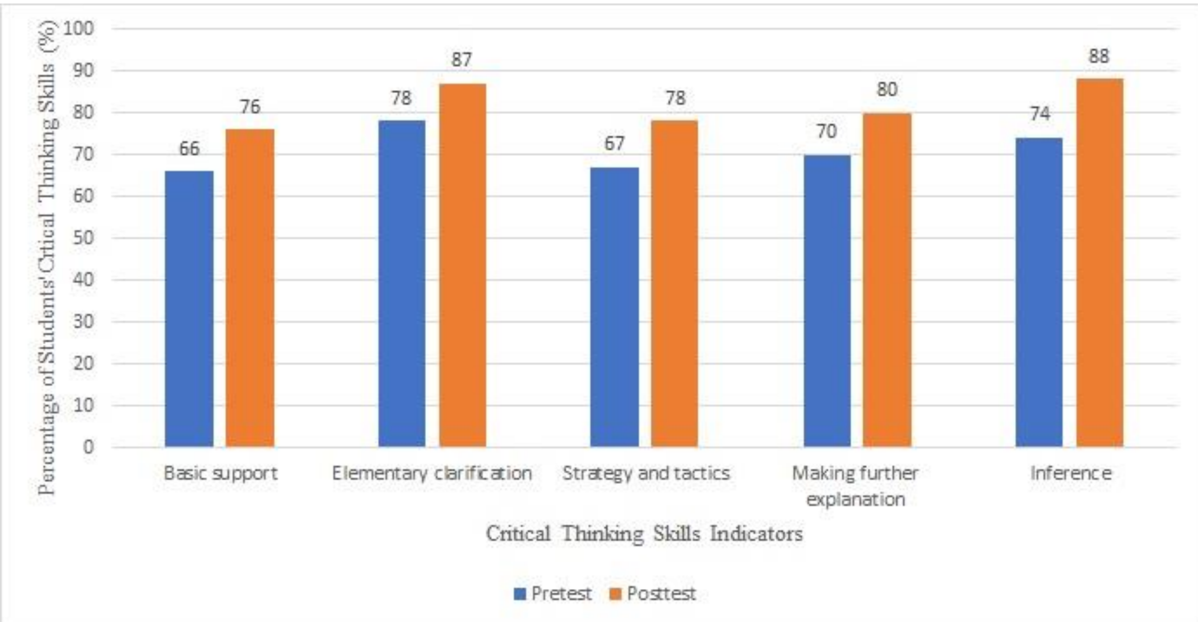


Figure 4. Percentage of Students Critical Thinking Skills Before and After Learning by Using the Developed SSP.

In terms of aspects being observed, science process skills increased of 14,89%. Figure 4 shows that each indicator of critical thinking skills indicates an increase. The “inference” indicator of reached of gain score the highest score. The result is in line with the research conducted by Dwijananti and Yulianti about the development of critical thinking skills through the problem-based instruction. The results showed that, indicators make an inferencing/conclusion experiencing an increase of 31% [34]. This happens because the active participants build their knowledge through systematic activities. The research indicators are obtained by the lowest gain score. Instead, the “elementary clarification” indicator gives the lowest gain score. The research is conducted by Rahmawati, *et al.* shows that the ability of high school students in providing an elementary clarification on the style concept and its application is in the category of the less good [13]. This happens because students were not accustomed to formulate the problem and answer questions that require explanation. However, overall critical thinking skills of students increased.

In addition to the effectiveness of SSP on critical thinking skills, the step of field test also aims to see the effectiveness of SSP on science process skills. Science process skills consists of six aspects described again into some indicators. Table 9 presents the percentage of the science process skills on students.

Table 9. Percentage of the science process skills

Aspect	Percentage (%)	Categories
Observation	87.14	Very good
Formulating the hypothesis	89.29	Very good
Doing experiment	91.48	Very good
Interpret	93.53	Very good
Making a Conclusion	86.61	Very good
Communicate	85.00	Good
Average	**88.84**	**Very good**

Table 9 shows that the “communicate” indicator only reaches 85% and includes good categories. Not all students present the experiment results in front of the class. It happens because the students were not used to expressing the observed oral understanding. In contrast to the research conducted by Anggraini, where the ability of the communications learned to reach 100% with the category is very high scale [35]. Students can communicate the experiment result in front of the class. However, students’ science processes skills generally are categorized “very good”. In line with the results, inquiry learning device with PhET simulation is developed by Saputro, *et al.* proven valid, practical, and effective to train a science process skill of the students [36].

Data analysis of field test results, indicating that the physical learning of using the SSP with the scaffolding approach assisted the PhET simulation can improve the critical thinking skills of the students. The same is disclosed by Nafrianti, *et al.* that the inquiry learning device is fully supported assisted the PhET to increase the critical thinking skills on students [37]. In addition, students also achieve science process skills with the “very good” categories. The results are in line with research conducted by Handayanto, *et al.* that scaffolding combined with simulations can improve the conceptual understanding of students [38]. In addition, students can also solve uncomfortable physics issues. It is in line with the purpose of PhET development to help students build a strong concept of understanding [28]. The assistance is described the explicitly abstract physics phenomena through the animation [17]. Similar research is scaffolding approach combined with PhET done by Kukkonen, *et al.* [39]. The research results showed that scaffolding simulation-based inquiry learnings could enrich the concept of students and have a better understanding of a physics phenomenon [39]. So, can be concluded that SSP with a scaffolding approach assisted of the PhET simulation effectively to improve the critical thinking skills and has a positive effect on science process skills of students.

The SSP is developed in this study facilitates students to build their own knowledge. In this case, the role of teachers only as facilitator. This is in line with the view of the Vygotsky constructivism theory that a child builds its own knowledge as a result of its interaction with others people [40]. In addition, in building his knowledge, student couldn't exceed from the influence of cultural tools where, in this study are the PhET simulation and laboratory tools.

4. Conclusions

This paper has presented the SSP development with a scaffolding approach assisted by PhET simulation on light refraction to improve students' critical thinking skills and achievement of science process skills. The results are showed that: (1) RPP, LKPD, and assessment instruments are eligible to be used on learning without revision, while the critical thinking skills instrument is are eligible to be used with revision; (2) Subject specific pedagogy with scaffolding approach assisted by PhET simulation can improve the critical thinking skills of students and positively influence the skills of students science process; (3) For next research, the scaffolding approach should be developed with the help of the other online media such as using smartphone or computer (web learning).

References

[1] Zeidan H A and Jayosi R M 2015. Science Process Skills and Attitudes Towards Science Among Palestinian Secondary School Students *World Journal of Education* ***5*** (1) 13-24.
[2] Collete A T and Chiappetta E L 1994 *Science instruction in the middle and secondary schools (New York:* Macmillan Publshing Company) p 30.
[3] Gedgrave I. 2009 *Modern teaching of physics* (New Delhi: Global Media) pp 2-5.
[4] Erina R and Kuswanto H 2015 Pengaruh model pembelajaran InSTAD terhadap keterampilan proses sains *Jurnal Inovasi Pendidikan IPA* ***1*** (2) 202-211.
[5] Puti S and Jumadi 2015 Pengembangan modul IPA SMP berbasis guided inquiry untuk meningkatkan keterampilan proses dan sikap ilmiah *Jurnal Pendidikan Matematika dan Sains* ***3*** (1) 79-88.
[6] Kementerian Pendidikan dan Kebudayaan 2016. *Peraturan Menteri Pendidikan Nasional No 21 Tahun 2016* tentang Standar Isi Pendidikan Dasar dan Menengah (Jakarta: Kemendikbud).
[7] Suryani W, Harahap M B, and Sinulingga K 2017 Efek model pembelajaran scientific inquiry menggunakan mind mapping dan keterampilan berpikir kritis terhadap keterampilan proses sains siswa sekolah menengah atas *Jurnal Pendidikan Fisika* **6** (2), 86-90.
[8] Subekti Y and Ariswan A 2016 Pembelajaran fisika dengan metode eksperimen untuk meningkatkan hasil belajar kognitif dan keterampilan proses sains *Jurnal Inovasi Pendidikan IPA* **2** (2), 252-261.
[9] Khasanah A and Prasetyo Z K 2018 Pengembangan instrumen penilaian otentik pembelajaran fisika untuk mengukur keterampilan proses sains dan berpikir kritis *Jurnal Pendidikan Fisika* **7** (5), 438-450.
[10] Saputri A A and Wilujeng I 2017 Developing physics e-scaffolding teaching media to increase the eleventh-grade students' problem solving ability and scientific attitude *International Journal of Environmental & Science Education* **12** (4), 729-745.
[11] Marlina L, Liliasari, Tjasyono B and Hendayana 2018 Improving the critical thinking skills of junior high school students on earth and space science (ess) materials *Journal of Physics: Conf. Series*, 1013.
[12] Rusnayati H, Prima EC 2011. Penerapan model pembelajaran problem based learning dengan pendekatan inkuiri untuk meningkatkan keterampilan proses sains dan penguasaan konsep elastisitas pada siswa SMA *Pros. Seminar Nasional Penelitian, Pendidikan Dan Penerapan MIPA* (Yogyakarta: Universitas Negeri Yogyakarta) p 331-338.
[13] Rahmawati I, Hidayat A and Rahayu S 2016 Analisis keterampilan berpikir kritis siswa SMP pada materi gaya dan penerapannya *Pros. Seminar Nasional Pendidikan IPA Pascasarjana UM* (Malang: Universitas Negeri Malang) p 1112-1119.
[14] Kroothkaew S and Srisawasdi N 2014 Supporting students' conceptual development of light refraction by simulation-based open inquiry with dual-situated learning model. *Journal Computer Education* **1** (1), 49-79.
[15] Kaekwong K, Alex M, Emarat N and Arayathanitkul K 2010 Thai high-school students' misconceptions about and models of light refraction through a planar surface *Physics Education* **45** (5), 97-107.
[16] Djanettea B and Fouad C 2014 Determination of university students' misconception about light using concept maps in Social and Behavioran *Proc. Int. Conf. on Science* 152, 582-589.
[17] Perkins K, Moore E, Podolefsky N, Lancaster K and Denison 2012 C Towards research-based strategies for using PhET simulations in middle school physical science classes *In AIP Conf. Proc*. vol 1413 (AIP Publishing) pp. 295-298.

[18] Kroothkaew S and Srisawasdi N 2013 Teaching how light can be refracted using simulation-based inquiry with a dual-situated learning model *Procedia Social and Behavioral Science* ***93***, 2023-2017.
[19] Fitriani L S, Halim A and Khaldun I 2016 Penggunaan media simulasi phet dengan pendekatan inkuiri terbimbing untuk meningkatkan keterampilan berpikir kritis siswa pada pokok bahasan kalor di SMA Negeri 12 Banda Aceh *Jurnal Pendidikan Sains Indonesia 4* (2), 45-52.
[20] Wood D, Bruner J S and Ross G 1976 The role of tutoring in problem solving *Journal of Child Psychology and Psychiatry* **17**, 89-100.
[21] Anghileri J 2006 Scaffolding practices that enhance mathematics learning *Journal of Mathematics Teacher Education* **9**, 33-52.
[22] Thomas T 2011 Developing first year students' critical thinking skills *Asian Social Science* **7** (15), 26-35.
[23] Amanah P D, Harjono A and Gunada I W 2017 Kemampuan pemecahan masalah dalam fisika dengan pembelajaran generatif berbantuan scaffolding dan advance organizer *Jurnal Pendidikan Fisika dan Teknologi 3*(2), 84-91.
[24] Chen C H 2014 An adaptive scaffolding e-learning system for middle school students' physics learning. *Australasian Journal of Education Technology* **30** (3) 342-355.
[25] Kim M.C. and Hannafin M J 2011 Scaffolding 6th graders' problem solving in technology-enhanced science classrooms: a qualitative case study *Instructional Science* **39** (3) 255-282.
[26] Sari N M R, Sunyono and Rosilawati I 2017 Pengaruh scaffolding dalam pembelajaran simayang untuk meningkatkan motivasi belajar dan penguasaan konsep," *Jurnal Pendidikan dan Pendidikan Kimia* **7** (2), 26-37.
[27] Wilujeng I, Prasetyo Z K and Djukri. 2016 Development the Subject Specific Pedagogy (SSP) of natural science to optimize mastery knowledge, attitude, and skills junior high school students in Yogyakarta *Proc. Int. Conf. on Research, Implementation and Education of Mathematics and Science* (Yogyakarta: Universitas Negeri Yogyakarta) pp. 53-60.
[28] Perkins K, Adams W, Dubson M, Finkelstein N, Reid S, Wieman C and LeMaster R, 2006 PhET: interactive simulations for teaching and learning physics *The Physics Teacher* **44** (1), 18-23.
[29] Research [document on the internet]. Colorado: University of Colorado Boulder, 2015 [cited 2018 August 25]. Available from https://phet.colorado.edu/en/research
[30] Thiagarajan S, Semmel, D S and Semmel M I 1974 *Instructional development for training teachers of expectional children* Minneapolis, Minnesota: leadership training institute/special education, University of Minnesota.
[31] Sugiyono 2013 *Metode penelitian pendidikan pendekatan kuantitatif, kualitatif, dan R & D* (Bandung:Alfabeta) p 139.
[32] Mardapi D 2012 *Pengukuran penilaian & Evaluasi Pendidikan* (Yogyakarta: Nuha Litera) p 162.
[33] Bending Light [document on the internet]. Colorado: University of Colorado Boulder, 2015 [cited 2018 July 23]. Available from https://phet.colorado.edu/en/simulation/bending-light.
[34] Dwijananti P and Yulianti D 2010 Pengembangan keterampilan berpikir kritis mahasiswa melalui pembelajaran problem based instruction pada mata kuliah fisika lingkungan *Jurnal Pendidikan Fisika Indonesia* **6** (2), 108-114.
[35] Anggraini A 2014 LKPD berbasis proses sains untuk melatihkan keterampilan proses sains *Jurnal Pendidikan Sains* **6** (2), 1-5.
[36] Saputro T B R E, Nur M and Purnomo T 2016 Desain riset perangkat pembelajaran menggunakan media kit listrik yang dilengkapi PhET berbasis inkuiri untuk melatihkan keterampilan proses sains *Unnes Science Education Journal,* **5** (3), 1331-1342.
[37] Nafrianti N, Supardi Z A I and Erman 2016 Pengembangan perangkat pembelajaran inkuiri terbimbing berbantuan phet pada materi listrik dinamis untuk meningkatkan keterampilan berpikir kritis siswa *Pendidikan Sains Pascasarjana Universitas Negeri Surabaya* **6** (1), 1100-1106.
[38] Koes-H S, Muhardjito, Wijaya C P 2018 Scaffolding for solving problem in static fluid: A case study. *In AIP Conf. Proc*. vol 1923 (AIP Publishing) p. 030028.
[39] Kukkonen J E, Kärkkäinen S, Dillon P and Keinonen T 2014 The effects of scaffolded simulation-based inquiry learning on fifth-graders' representations of the greenhouse effect *International Journal of Science Education.* **36** (3), 406-424.
[40] Slavin R E 2017 *Psikologi pendidikan: teori dan praktik*, (Jakarta: PT. Indeks).