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Subject Specific Pedagogy Development with Scaffolding Approach Assisted by PhET Simulation on Momentum Conservation Law to Improve Students' Conceptual Understanding and Learning Independence

Tri Utami, Jumadi*, and Insih Wilujeng and Heru Kuswanto
Yogyakarta State University, Indonesia

*Email: utamitri26@gmail.com

Abstract. SSP of physics has been produced with scaffolding approach assisted by PhET simulations on law of momentum conservation to improve the conceptual understanding and the learning independence of high school students. This research uses 4-D development model. the subject in this research is the students of MAN 1 Yogyakarta class X MIPA 3. Instrument data collection in the form of expert validation sheets, learning independence observation sheets, and conceptual understanding test questions. Research data was collected through observation sheets, and written tests consisting of 10 pretest questions and 10 posttest questions. The data obtained is then analyzed descriptively. The results showed that (1) the development of SSP of physics was carried out in accordance with product development procedures. (2) the results of expert validation indicate that the SSP of physics has very good category. (3) There is no significant difference between students' conceptual understanding before and after learning using SSP of physics with scaffolding approach assisted by PhET simulation. (4) Learning independence of students is in the category of good enough and good after learning to use SSP of physics with scaffolding approach assisted by PhET simulation. These results indicate that the SSP of physics is suitable for use as teaching material.

Keywords: Subject-specific pedagogy (SSP); Scaffolding; PhET; Conceptual understanding; Learning independence.

1. Introduction

Physics learning activities should be oriented towards students. Students must learn to get their own physics [1] with independent learning experience or practicum activities that involve students directly, then students will understand the concept of physics by themselves according to the learning experience they do. So, students must be involved in learning activities. Therefore, practicum activities and visualization of physics concept in real terms using instructional media in conveying the concept of physics must be in accordance with characteristics of physics and in accordance with the 2013 curriculum. In line with that, various 21st century skills must be explicitly taught. In short, 21st century learning has a basic principle that learning must be student-centered, collaborative, contextual, and integrated with society [2]. To ensure the learning process takes place conducive and in accordance with the learning needs of the 21st century, a little change in teaching pedagogy needs to

be done. Teachers need to try to take advantage of the times of ICT-based technology as a supporting medium in the learning process [3], so that the scope of learning faced by students will not feel boring and abstract physics concepts can be visualized properly using ICT-based technology, so that it is expected to improve conceptual understanding of students.

The 2013 curriculum refers to the goals of national education based on the evaluation of the previous curriculum and answers to the challenges faced by the nation in the future. The basic competencies of the 2013 curriculum that needs to be possessed by high school students is: (1) analyzing concepts, principles, and laws of physics, (2) using metacognition to explain natural phenomena and solve life problems, (3) modifying or designing simple projects with apply the concept of physics. In addition, there are basic competencies in the realm of attitude. In general, students must have a positive attitude in learning activities [4]. Thus, the learning outcomes of students are not only shown from the improvement of cognitive abilities, but also affective abilities.

2013 curriculum needs are met if the teacher has the ability to teach (pedagogy) as well as the ability to master good subject matter (content), thus students can understand learning material optimally. The ability of teachers to design and carry out learning is closely related to the ability of pedagogical content knowledge (PCK) owned by the teacher. Special domains of teacher teaching knowledge are found in the teacher's ability in pedagogical content knowledge [5]. PCK bridges the mastery of the material with the ability to teach, with this interest the teacher needs to use teaching materials in the form of SSP to develop the PCK owned.

Based on the basic competencies of the 2013 curriculum that have been explained previously, using an innovative learning approach is a solution to improve the literacy and ability of students from cognitive, affective and psychomotor aspects. One innovative approach that can be used is the scaffolding approach. The scaffolding approach can help students have problem-solving abilities in groups, and the understanding of students increases so that individual learning outcomes become better [6,7]. Students will be able to learn the concepts of teaching material well if they are in the zone of proximal development abbreviated as ZPD (the closest development zone). ZPD is the difference between potential ability and actual ability [8]. By using the scaffolding approach, the development zone is expected to increase by providing assistance to students, both given by the teacher, and by peers who have a higher zone of proximal development.

In the process of physics learning, students not only memorize theories and formulas, but emphasize the formation of knowledge processes and conceptual understanding [9]. The learning process is a communication process; the problem is how to make the communication process run effectively so that the message to be conveyed is fully accepted [10]. the use of interactive media can improve students' cognitive abilities [11]. Interactive learning media, namely multimedia which is equipped with a controller so that it can be used by users to choose what they want [12], one of the interactive media that can be used is PhET. The use of PhET as an aid in the delivery of material is useful to connect or visualize concept of physics in real terms and can be used directly by students in an effort to conceptual understanding [13]. The use of interactive simulations such as PhET can provide an environment that supports learning, and can direct students to productive exploration or investigations and minimize the need for explicit guidance [14]. Therefore, in this study the use of PhET is felt appropriate to optimize the delivery of material so that students can understand the learning material well, and the goals and targets of learning outcomes can be achieved.

A good understanding will improve learning achievement. Learning achievement of students is influenced by the attitude of learning independence they have [15]. Students are considered to have an attitude of learning independence if the students know how to set learning goals that they will achieve, what is needed to achieve these goals, and how to achieve these goals [16]. Learning independence can trigger students' positive attitudes, such as high initiative, responsibility, confidence, and curiosity. With the help of the right media, the positive attitude can be optimally improved [17]. This is supported by the results of research conducted by Wahyuni and Djukri [18] namely, computer-based learning media is effectively used to improve the learning independence of students. In this study, the learning independence of students was developed through a scaffolding approach in the form of

providing assistance, such as an explanation or direction to the correct answer. Then, the assistance is gradually reduced until students are able to solve a problem independently without the need for assistance.

Hence, this paper presents the development of SSP of physics with scaffolding approach assisted by PhET simulation. It is considered as a medium and learning tools that can help teachers to improve conceptual understanding and learning independence of high school students. Furthermore, 2013 curriculum competencies and 21st century learning demands can be fulfilled optimally.

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 research adapted the 4-D development model developed by Thiagarajan et al (1974) [19]. Held on April 4 2018 to April 25 2018. Objects research are 27 students of MIPA 3 in MAN 1 Yogyakarta. Subjects were determined by purposive sampling technique [20]. The 4-D model development procedure used includes 3 of the 4 stages developed by Thiagarajan, this is due to the time constraints faced by researchers. These procedures include, define, design, and develop. The research steps in the 4-D model used can be seen in Figure 1.
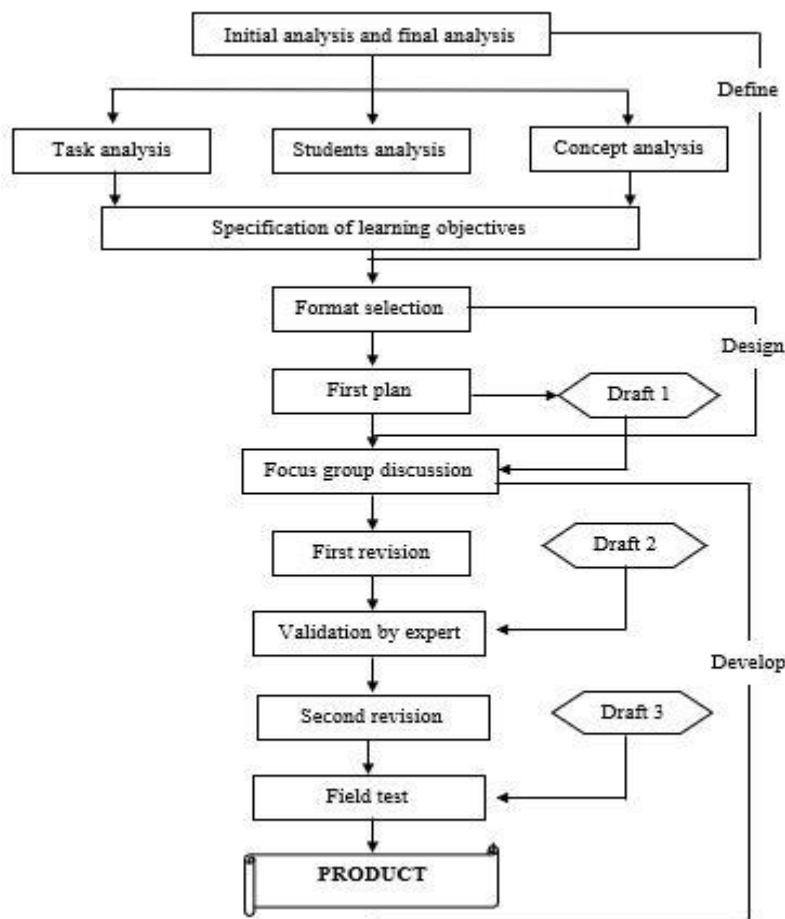

Figure 1. Step of 4-D development model

☐ : development step;   ◇ : results obtained;   ☐ : data retrieval process.

Field test were conducted during two meetings while the learning process of law of momentum conservation materials. The design of field test for conceptual understanding is one group pretest-posttest design. This design is describe as shown in Table 1:

Table 1. research design

O_1	X	O_2

O_1 = pretest score; O_2 = posttest score; X = learning with scaffolding approach assisted by PhET simulation; effectiveness of treatment = $O_2 - O_1$

The research design for learning independence attitude is one shot case study. It shown in Table 2.

Table 2. research design

X	O

X = learning with scaffolding approach assisted by PhET simulation, O = observation of learning independence

Data collection is done using test and non-test techniques. The initial test (pretest) is given at the beginning of learning to students to find out the initial understanding that students have about the material to be delivered, the test in the form of multiple choice questions. Then the value is obtained as an analysis of the level of understanding the concept of the students. After being given the initial test, students are given treatment in the form of learning process using SSP of physics with a scaffolding approach assisted by PhET simulation. During the learning process takes place, observations are made about students learning independence. Observation of learning independence was carried out by 3 observers who had previously been briefed first.

Student learning independence observation sheets in the form of statements regarding the learning independence attitude developed based on related indicators, then the scores obtained were analyzed to get the final score of each student. At the end of the learning, a final test (posttest) is conducted. The conceptual understanding of students when posttest is measured using an instrument sheet which is equivalent to the instrument sheet at the pretest.

Instrument of data collection in the form of expert validation sheets, test questions consisting of pretest and posttest to measure the level of understanding the concept, and the learning independence observation sheet. Data of SSP validation results that have been developed are then analyzed using descriptive analysis using equation 1.

$$\text{Median/Average} = \frac{\text{number of X values from i to n}}{\text{number of individuals}} \quad (1)$$

Furthermore, the results of these analysis are converted into values with criteria based on Table 3.

Table 3. Criteria assessment of four scale

Respondents score	Categorization
$X \geq \bar{X}_l + 1.0\,SBi$	Very High
$\bar{X}_l + 1.0\,SBi > X \geq \bar{X}_l$	High
$\bar{X}_l > X \geq \bar{X}_l - 1.0SBi$	Low
$X < \bar{X}_l - 1.0\,SBi$	Very Low

Adapted from Mardapi in [21]

The results of the assessment of students conceptual understanding that is done by giving the initial test and final test are then analysis using descriptive analysis by looking for the average value of the two tests, then compared to know the increase after being treated in the learning process.

Concept comprehension data were analysis using descriptive statistics which resulted in the average pre-test and post-test scores of students. Then compare the two scores to see an increase in students' conceptual understanding. The scaffolding approach is said to be effective if there is a significant increase in scores. While the data of learning independence observations were analysis by processing the scores obtained by each student then obtained the percentage of the average value of all students using equation 2.

$$\text{Value obtained} = \frac{\text{number of scores obtained}}{\text{maximum score amount}} \times 100 \qquad (2)$$

Furthermore, the percentage of the average value of all the participants is converted into the assessment criteria as shown in Table 4.

Table 4. Assessment of learning independent criteria

Value	Criteria
76%-100%	Good
56%-75%	Pretty Good
40%-55%	Less Good
<40%	Not Good

Adapted from Arikunto in [22]

After all data is analyzed then obtained results as a discussion material to achieve the conclusion in accordance with the objectives of this study. The analysis results are presented in such a way that it is easily understood when used as a reference for the future researchers.

3. Results and Discussion

The product is developed in the form of SSP of physics consisting of RPP, Handout, and LKPD with a scaffolding approach assisted by PhET simulation. In addition, it is also developed validation instrument to assess the expediency SSP, expediency instrument gauge conceptual understanding, and learning independence attitude gauge instrument of the students.

The stage of development is beginning to design the learning device in the form of physics SSP, then followed by validation of Focus Group Discussion (FGD). FGD activities are performed with 18 students and 2 lecturers from graduate physics education State University of Yogyakarta. Revision Results from FGD activities are draft 2 products. Draft 2 then submitted to Material as a validator to assess the expediency SSP is developed.

3.1 Development Results

From the analysis results conducted, then found problem in the learning, the SSP has developed up to RPP, Handout, and LKPD developed with the scaffolding approach assisted the PhET simulation. PhET simulation is used loading the experiment about law of momentum conservation [23].

the conceptual understanding ability and attitudes of learning independence are improved using activities in the RPP and activities in LKPD that are developed with the scaffolding approach. RPP is developed based on a scaffolding approach assisted by PhET Collision-Lab simulation. The specifications of RPP that have been developed is the existence of the level of assistance (scaffolding) of adaptation results from Anghileri in [24] integrated into 5M syntax in activities in RPP. The level

consists of: (1) environmental provisions; (2) explaining, reviewing and restructuring; (3) developing conceptual thinking. In each level, there is a type of interaction by teachers to students as a form of assistance.

Level 1, the interaction type is done in the initial learning activities. Activities is undertaken in the form of organizing classes such as forming learning groups, setting seats, and provide structured tasks to motivate and provide apperception for students. Level 2, the interaction type is done in the main activities of learning. The activity includes explaining the basic concepts about material to be learned, reviewing how students' work when discussing or practicum, and rebuilding the understanding of students when misconceptions. Level 3 scaffolding is done in closing learning activities. This type of activity interaction at this level includes, connecting the results of discussions with the basic concept of the material has previously been explained, providing the opportunity to students to conclude the work of using its own language, and last is the teacher invites students to conclude the learning result that have been done by associating it with the basic concept of physics materials.

Here is a matrix development of RPP with a scaffolding approach assisted by PhET to improve the conceptual understanding and learning independence of students presents in Table 5.
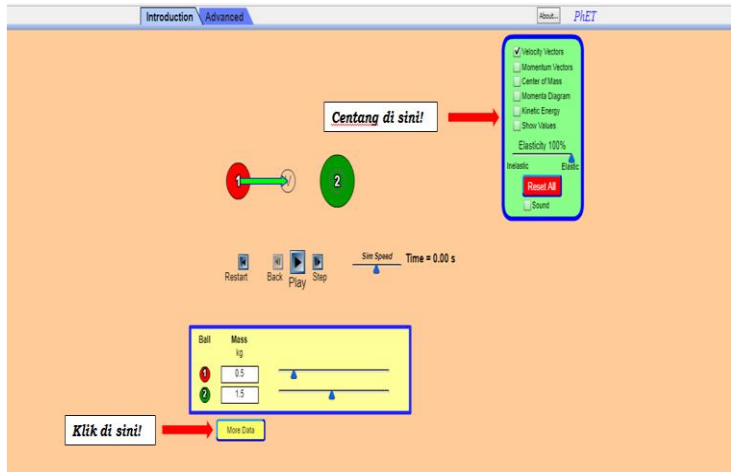
Table 5. Matrix relationship scaffolding approach assisted the PhET to the conceptual understanding and learning independence of the students in learning activities

Activity	Level of scaffolding	Interaction	Improved variables	
			Conceptual thinking	**Learning independence**
Pre-Activity	Environment Provision	Provide apperception and motivation		
		Purchase questions based on the simulation of the law of momentum conservation on PhET	Build a basic understanding	Cause an initiative attitude
		Create a hypothesis on the law of momentum conservation based on the PhET simulation	Explain verbally	
Main activity	Explaining, reviewing, and restructuring	Arranging magnitude and serve of the PhET simulation as required in LKPD on legal material of the law of momentum conservation		Initiative and discipline
		Discuss the findings based on the experiments that have been done	Connecting findings with material concepts	
		Presents the results of discussions by presenting it before the teacher and other groups	Presents the concept in the form of representation	Responsible for the formulated answer
				Confident when conveying the answer
Closing activity	Developing conceptual thinking	Directing students on the correct concept in case of errors		
		Concluded the discussion results based on the findings of experiment	Connecting findings with material concepts	Responsible for the formulated answer

The specification of LKPD that have been developed among others, contains clear clues about the practice of practicum to be performed, contains steps with help leading to the right answers to the correct answer, the minimum reduced assistance in the next steps, each step of the activity is designed to hone the ability of conceptual understanding and learning independence.

Here is a matrix development of LKPD with a scaffolding approach assisted by PhET to improve the conceptual understanding and learning independence of students presented in Table 6.

Table 6. Matrix relationship scaffolding approach assisted the PhET to the conceptual understanding and learning independence of the students in learning activities

LKPD activities	Improved variables	
	Conceptual learning	Learning independence
Set the PhET simulation according to the work step		Cause an discipline attitude
Record findings in experimental activities	Build a basic understanding	Initiative and discipline
Analyze the findings in the experiment	Connecting findings with material concepts	Confident when conveying the answer
		Cause an discipline attitude
Answer the question "*Bagaimana energi kinetik total bola sebelum dan sesudah tumbukan pada tumbukan tidak lenting*?"		Initiative and responsible
Linking findings in experiments with everyday life "*Apa perbedaan antara tumbukan lenting sempurna dan tumbukan tidak lenting? Berikan contoh dalam kehidupan sehari-hari*"	Explain verbally	Cause an initiative attitude
Make a conclusions and deliver "*Dari hasil percobaan, nyatakan hukum kekekalan momentum*"	Presents the concept in the form of representation	Initiative and responsible for the formulated answer
	Connecting findings with material concepts	Confident when conveying the answer

3.2   Validation result
Tabulation data Based on RPP validation results that have been done by 2 lecturers as validator, then adjusted to the criteria in Table 3. Results of expediency Assessment RPP by material expert is shown in Table 7.

Table 7. Results of expediency assessment RPP by material expert

Aspect	Score	Categories
Identity Completeness	30	very high
IPK formulation and learning objectives	32	very high
organizing material teaching	37	very high
Method, media, and learning resources	36	very high
Learning step	31	very high
Linguistics	38	very high

Table 7 Shows that the RPP is developed worthy to use with very high categories for each assessment aspect. the highest score is in the aspect of linguistics, and the lowest is in the aspect of Identity Completeness. Furthermore, results of the expediency assessment Handout are shown in Table 8.

Table 8. Results of expediency Assessment Handout by material expert

Aspect	Score	Categories
Contents	32	very high
Presentations	10	very high
Performances	24	very high
Linguistics	20	very high

Table 8 shows that the Handout is developed worthy to use with a very high category for each aspect of the assessment. the highest score is in the aspect of contents, and the lowest is in the aspect of presentations. Furthermore, results the LKPD assessment by the material expert is shown in Table 9.

Table 9. Results of expediency Assessment of the LKPD by the material expert

Aspect	Score	Categories
Contents	20	very high
Presentations	15	very high
Performances	18	very high
Linguistics	16	very high

Table 9 shows that the LKPD is developed worthy to use with a very high category for each aspect of assessment. From the results of the expediency assessment can be concluded that the SSP is developed worthy to use with the help of PhET simulation to improve the conceptual understanding and learning independence of the students.

In addition to learning devices, instruments of data collection are also validated by the material expert to assess the expediency. Validated instrument is that about the conceptual understanding test and observation sheet of learning independence. Validation result of conceptual understanding instrument is shown in Table 10.

Table 10. Results of expediency Assessment about conceptual understanding by the material expert

Question list	Median Score from two Rater
1	29
2	28
3	29
4	25
5	32
6	30
7	25
8	26
9	29
10	29
Average	28

Table 10 shows the expediency assessment about understanding concept with the average value of 28. Based on categorization in Table 3, the value interprets that the concept of the conceptual understanding is in very high category and worthy to use. validation result of learning independence observation sheet is shown in Table 11.

Table 11. Results of expediency Assessment observation sheet of learning independence on students by the material expert

Aspect	Score	Categories
Conformity with indicators	18	High
Construction	14	High
Linguistics	15	High

Table 11 shows the expediency assessment of the observation sheet of learning independence on students in high categories for each aspect. The value interpreted that the observation sheet of learning independence on students worthy to use.

3.3 Field Test Results

The measurement result of the conceptual understanding of students in the form of the value is obtained at the pre-test and post-test which then obtained the average value for each test as a descriptive analysis material. The results of the analysis are shown in Table 12.

Table 12. Descriptivemeasurement understanding the concept of students

Students Amount	Median/ Average

pretest		28,85
	27	
posttest		32,69

Table 12 shows the change average of the understanding concept of students from the original 28.85 on the pretest to 32.69 on the posttest, the change is very small that it can be said that there is not significant difference between the conceptual understanding before and after learning with the innovation given. These results are less in accordance with the preliminary study is done by researchers based on the previous research that using a scaffolding approach in the learning process can improve the conceptual understanding of students. This happens because in learning with carried out the scaffolding approach assisted by PhET, teachers focus on students and assistance from teachers to complete the task given. Students have been able to complete the task given with the help of teachers. However, the completion of the task does not necessarily result in the exposure the conceptual understanding of students.

The measurement result of the learning independence of students in the form the average score percentage the score calculation result is obtained by the observation activities is undertaken by 3 observer, then converted into criteria the assessment of learning independence shown in table 2. The analysis results of the learning independence of students is shown in Table 13.

Table 13. Descriptive statistics learning independence of the students

Students amount	Categories
9	Good enough
18	Good

From table 13 can be known that, 18 people from the total amount of students as many as 27 people in the MIPA 3 class MAN 1 in Yogyakarta has a good learning independence, this is be designated with achieving indicators of learning independence when observation is done. While 9 other students participants has a good enough learning indepndence attitude, this is because there are some indicators of learning independence of not achieved, for example such as some students look doubt when wanting to ask teachers about the material that is not understood when learning activities take place, then when teachers give a questions to students not directly replied but wait until the teacher appointed them.

4. Conclusion
Based on the results of research that has been done, it is concluded that: (1) the development of SSP of physics was carried out in accordance with product development procedures. (2) the results of expert validation indicate that the SSP of physics has very good category. It can be seen from the results of validation that shows that RPP, Handout, LKPD, and assessment instruments of understanding concept and learning independence of students be in the very good category. (3) There is no significant difference between students' conceptual understanding before and after learning using SSP of physics with scaffolding approach assisted by PhET simulation. This is shown by the difference from average value of the pretest and posttest value is very low. (4) Learning independence of students is in the category of good enough and good after learning to use SSP of physics with scaffolding approach assisted by PhET.

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