Development of teaching materials for momentum assisted by scratch: building the pre-service teacher’s skills for 21st century and industry revolution

A Rusilowati*, B Subali, M P Aji and R A Negoro

Physics Education, Post Graduate, Universitas Negeri Semarang, Indonesia.

*Corresponding author: rusilowati@mail.unnes.ac.id

Abstract. Learning physics problems still appear in many parts of the world. Along with this, the development of civilization demands the development of education to produce the skills that are the ultimate in every human being. 21st Century skills are skills that are relevant to the demands of the development of civilization. Pre-service Teacher needs to be prepared to overcome the problems of learning Physics by following with the times. This study aims to develop a skill-oriented Momentum teaching material of the 21st Century and the industrial revolution. This research is development research with stages: 1) Analysis of potential and problems, 2) Product design, 3) Design validation and design revision, 4) Product testing, 5) Analysis of trial results, and 6) final product assembly. The research instruments were in the form of observation sheets, tests, and questionnaires. The data analysis technique uses descriptive percentages. The results of the study in the form of scratch-assisted teaching materials that have characteristics provide opportunities for students to make momentum simulations independently. The percentage of the material validity score was 92.23% and the media validity was 88.64%. The results of the trial show that the acquisition of each skill score is more than 71, so it can be concluded that the materials teaching developed are practically used and effective to build 21st-century skills and industrial revolution 4.0.

1. Introduction

In the international scope, there are many problems related to the teaching and learning of material physics Momentum. The momentum learning problems that are commonly found include low mathematical skills, low interest in learning because of many mathematical formulations, and misconceptions where the most common misconceptions that arise and are the most crucial [1], [2]. Based on these problems, the teacher must focus on the learning objectives in the form of material content so that it can be achieved effectively by students in each process and can overcome existing problems [1]. Steps that can be taken is to consider the design of learning that is made in such a way by the teacher. Preparation of the ability to design and overcome problems in physics learning relevantly is very important for the pre-service teacher [3][4].

At present success at work generally requires 21st-century skills, namely skills for learning, creative and critical thinking, collaboration, and the ability to utilize ICT (Information Communication and Technology) in various fields [5]. In higher education, pre-service teachers must seek experience to hone their abilities, including collaborating with colleagues to conduct investigations, critical
thinking, and innovate in solving existing problems. Therefore, they must be able to learn without stopping adjusting to the times [3].

Many students have views about the ideal learning model. This model usually follows the characteristics of civilization at that time [3][6][7]. Based on this, the reliability of tradition and culture influences the presumption of the ideal learning model. In the present time, there are many needs for teaching instruments that are complementary to the development of new learning methods [3][8][9]. The pre-service teacher education program is a way for long-term change in the field. Changes in schools can be started from pre-service teachers, how to adapt to the new learning culture and implement it.

Based on this, 21st-century skills are relevant for pre-service teachers, especially physics teachers, to be able to overcome student learning problems with alternative solutions that are in harmony with the development of civilization. 21st Century skills are segmented into 4 important parts, namely creativity, critical thinking skills, collaboration and communication that are integrated with access to information and technology as the demands of the industrial revolution 4.0 [3][5]. Creativity is the ability of students to find and use new ideas that remain logical and rational and relevant to the learning context [10]. One of the objectives of creative teaching is to create a student-centered learning environment with multimedia assistance that can encourage students to think creatively in imagination freely and understand the relationship of concepts to real-life [11]. This creativity is the basic ingredient for pre-service teachers so that they can create a variety of momentum learning designs that are innovative and appropriate to the needs of students.

Critical thinking skills also support problem-solving in learning momentum material Physics. Pre-service Teacher is expected to be able to dig deep into the factors that cause problems such as misconception of momentum material. Important aspects of critical thinking skills are Hypothesis testing, Argument Analysis, Reasoning, Likelihood and uncertainty analysis, and Problem-solving and decision-making [12].

Besides, in order to succeed in solving problems of learning, especially learning physics, material momentum, it is necessary to combine the expertise and ideas of several parties in various collaborative situations. This collaboration requires social skills and commitment to coordinate with peer learning. Three segments are a collaborative learning approach: (1) collaborating for learning (learning that is packaged in a productive collaborative learning environment); (2) learning to collaborate (learning so that they have collaborative skills); and (3) learning by applying a collaborative learning approach. The application of collaborative learning in the context of pre-service teacher education serves to develop new pedagogical competencies in teaching to renew ideas about learning [3][13]. Recent research shows that in Finland, high school students have 21st-century skills that are the most superior in collaboration skills [14]. This reinforces that collaborative learning is recommended as a thing to do in pre-service teacher education. The straightforward portion of collaborative learning can foster productive interactions in learning activities, such as asking questions, explaining and clarifying opinions, arguments, and elaboration [15][16]. But if collaboration is not well supported there will be no productive learning and worse students may get a negative learning experience [3][17]. In short, the pre-service teacher needs to consider various aspects of collaboration for the design of learning so that it effectively presents the concept intact. Another competency of 21st Century Skills that are inseparable especially with collaboration skills is Communication. Communication skills include skills in the delivery of thoughts or ideas clearly and persuasively in oral and written. This skill is very much needed by Pre-Service Teacher as a medium for students to analyze and overcome problems that students have. The European Union has identified that communication is a competency for lifelong learning [18].

Another thing to consider for alternative solutions is the use of advanced technology relevant to physics learning. This utilization requires skills or mastery of technology for access to information and communication. Three important components, namely content, pedagogy and technology, and their interrelationship are the heart of learning [19]. Studies show that Pre-service teachers a design technology-based learning in the form of spreadsheets that benefit learning design that can
accommodate the provision of the material well [20]. So, the use of technology is important to facilitate material accommodation.

Furthermore, the use of technology in the form of computer programming can provide a broad tool for developing skills. Computer programming can facilitate the development of high-level thinking skills such as systematic thinking, logical thinking, creative thinking, and problem-solving through computational thinking [21] [22]. Mastery of technology to develop various skills, access various information, and providers of communication is a skill called ICT literacy.

Although computer programs are run by computers, programming tends to build thinking skills rather than computer skills [22][23][24]. Through computer programming concepts, the development of student skills to form a good conception of momentum material is very relevant to computer programming applications comprehensively involving 21st Century skills. This is because programming requires students to investigate (inquiry) natural phenomena to know their principles in using critical thinking skills [25].

One of the computer programmings that is Scratch can support the development of 21st-century skills through computer [26]. First, through Scratch programming, students get experience in the form of media such as simulation or animation. They will also learn how to identify, manipulate, and integrate various media to be used effectively during learning. Second, Scratch engages students in systematic thinking through critical thinking and solving problems with their ideas. Third, Scratch encourages students to work collaboratively by trading simulation scripts that their friends have made. When students share their projects, they receive feedback from others and learn how to elaborate on new ideas. Through scratch, the Preservice teacher has the opportunity to develop a simulation or animation to learn momentum with his ideas or even design a learning design that involves the use of Scratch by students. [22].

Based on the description above, a container is needed to provide various content to support the development of 21st century skills so that the learning of momentum material physics is effective. The researcher considered one of the containers in the form of teaching material. Teaching materials are a set of material or substance lessons that are arranged systematically, displaying a complete figure of competencies that will be mastered by children in learning activities [27]. Besides, the design of teaching materials usually adapts to the child's condition [28]. Teaching materials for pre-service teachers are made in such a way as to facilitate them to have 21st century skills comprehensively. The instructional material designed involves an active media Scratch. The learning context in this teaching material is made based on the principle of independent learning so that later the pre-service checker can use and develop relevant learning by itself [29][30].

2. Methods

This development or R & D research develops teaching materials for education. R & D is a process for developing and validating a product [31][32]. The teaching material developed is material Momentum, its development is assisted by Scratch and its orientation to 21st Century Skills.

The research and development of momentum teaching materials assisted by Scratch consist of 6 stages adapted from 10 stages from Borg and Gall [32]. The development research phase includes: 1) Analysis of potential and problems, 2) Product design, 3) Design validation and design revision, 4) Product testing, 5) Analysis of trial results, and 6) final product assembly.

2.1 Potential Analysis and Problems

At the beginning of the activity, Analysis of the potential and problems in learning Physics Experiments was carried out and continued with data collection by conducting a literature study on 21st Century Skills-based learning. The data obtained were analyzed and used as a reference to design teaching materials.
2.2 Design of teaching materials
The products produced in this study are teaching materials for students that will be used in learning to improve critical thinking skills. The initial design of teaching materials follows the structure of Momentum teaching material content presented in Figure 1.

![Figure 1. Momentum teaching material content structure](image)

2.3 Validation of teaching materials
Before being used, teaching materials are tested validity by material experts and media experts (expert judgment). Content validity in terms of material aspects, construction, and language/culture, as well as media conformity with the material. The results of the material and media expert tests were analyzed using a formula [33].

\[
P = \frac{f}{N} \times 100\%
\]

Where :
- \( P \) = percentage of value
- \( f \) = score obtained
- \( N \) = overall score

The validity criteria for teaching materials are shown in Table 1.

| Percentage of Value | Criteria   |
|---------------------|------------|
| 85% < value ≤ 100%  | very valid |
| 70% < value ≤ 85%   | valid      |
| 50% < value ≤ 70%   | quite valid|
| 0% < value ≤ 50%    | invalid    |
2.4 Product Trial
The trial was conducted twice, small scale trials, to determine the readability of teaching materials and ease of use of teaching materials. The test subjects were ten students. The second trial is a large-scale trial, carried out in classroom learning. Large-scale trial subjects were students of Semarang State University physics education in semester VI, as many as 28 people. The trial uses post test only design, to see the effectiveness of teaching materials in developing 21st century skills, including creative thinking skills, critical thinking, collaborative, and communication as well as the skills of the industrial revolution era 4.0, ICT literacy.

2.5 Test Result Analysis
Analysis of the results of 21st century skills and ICT literacy using the percentage formula. Teaching materials are said to be effective if the value of each skill is at least 71 (equivalent to the conversion of the value of B in Higher Education).

2.6 Research Instrument
The research instrument consisted of observation sheets to assess creative thinking skills, communication, and ICT literacy. Tests for measuring critical thinking skills, ICT literacy, and questionnaires to find out collaboration skills.

3. Result and Analysis
The results of the development of this study are momentum-assisted teaching materials Scratch oriented to skills education in the 21st Century. These teaching materials have 2 strategic functions namely overcoming student misconceptions on momentum material and building 21st century skills. straight, regular movements, the collision of various types.

3.1 The Existing Potentials and Problems Found
Potentials based on the needs analysis and observations indicate that in the classroom there are facilities such as LCDs and laptops that Pre-service Teachers can already use to sustain learning using Scratch assisted teaching materials. The existing problem is the low utilization of technology by the Pre-service teacher, this is indicated by the ignorance of the preservice teacher about programming Scratch which can create various simulations related to physical phenomena, especially momentum. Based on the potential and problems found in the field in the needs analysis, researchers felt the need to develop momentum-assisted teaching materials Scratch that facilitated the use and creation of interactive momentum material simulations.

Information obtained from the literature is read directly from books, journals, articles, and accessed through the Internet. In addition, information was extracted through interviews with lecturers. Based on the results of information gathering, the components that need to be developed momentum teaching materials assisted by Scratch that are oriented to skills education in the 21st Century that raise the concept of momentum material in depth through the use of technology so that pre-service teachers have alternative design learning that is in line with the times. The description of teaching materials can be seen in the segmentation including product design, product validation, and testing.

3.2 Product Design
Scratch-assisted momentum teaching materials that are education-oriented skills of the 21st Century were developed using Adobe PhotoShop, Microsoft Word, and Scratch programs. The design of the development of momentum teaching materials assisted by Scratch in this study are as follows; (1) Cover containing material title, mechanical illustration, developer name, author's name, and target user; (2) Introduction to momentum teaching materials assisted by Scratch in the form of illustrations using the Scratch program; (3) Basic competencies; (4) Learning Objectives; (6) Moment material (7) Project critical thinking; (8) Enrichment projects for creative thinking and collaboration skills; (9) Bibliography.
This teaching material carries the concept of learning through computer programming or computing. Programming is closer to thinking skills than computer skills. But this learning still requires computer skills as a whole so that the learning process about conceptual material can work effectively. Therefore, teaching materials are equipped with an introduction to the use of the Scratch program. Teaching materials compiled assisting the Scratch program to facilitate the development of high-level thinking skills such as logical thinking, creative thinking, problem solving, and systematic thinking through computational thinking. At the same time, creativity is built through the provision of projects to create momentum simulations, previously Pre-service Teacher built critical thinking skills through principle analysis on the phenomenon of momentum. Collaboration is built when exchanging ideas in the project maker group. An example of the results of developing the initial design of teaching materials can be seen in Figure 2.

Figure 2. Design of Momentum Learning Materials Assisted by Scratch (a) cover (b) content of the simulation

3.3 Product Validation
After the initial product is finished, the next step is to test the validity of the expert consisting of material experts and media experts. Material experts examine whether the content component of the momentum teaching material is aided by Scratch by the quality values set by the Center for Curriculum and Books. While media experts assess conformity indicators such as the component design on the cover, suitability of the design components of the book content and the overall packaging design of the book. Based on the material feasibility test questionnaire obtained a total percentage of 92.23% with very valid criteria. Based on the media feasibility questionnaire obtained a percentage of 88.64% with very valid criteria.

3.4 Test Results
Teaching materials were tested on 28 students. Learning was done by following the contents of the teaching materials coherently assisted by Scratch. Students in the learning process create simulations of straight motion and various kinds of collisions which are enrichment projects. The process of
making a project requires students to analyze the relationships between variables that are then included in the script. From the results of the trial results obtained in the form of 21st Century Skills description.

3.4.1 Creativity

Based on the analysis of student projects, it can be concluded that various aspects of creative thinking are achieved after using teaching materials. The creative thinking aspect that is the reference is the aspect proposed by Bosch [34]. These aspects include Fluency, Flexibility, Originality, Elaboration. The project undertaken by students is a group project, so that the analysis of aspects in the form of a mean percentage of aspects achieved by each group. The results of the analysis of creative thinking skills can be seen in Figure 3. One of the results of the Pre-Service Teacher creativity project can be seen in Figure 4, which is the simulation of various types of collisions.

![Figure 3. Achievement of Creative Thinking Skills](image)

Based on Figure 3 it can be seen that the highest aspect is fluency. This aspect has an indicator that the pre-service teacher designs the program syntax that is following with the program/simulation that has existed until it runs correctly. This is influenced by the small expertise factor in using scratch where pre-service teachers tend to still adopt existing simulations. On the other hand, Elaboration which has an indicator Designing advanced program syntax from a pure idea of the pre-service teacher is hampered by the skill of using Scratch. Because of the limited learning time to explore content from the scratch program. But in general, the creativity that is built is categorized as high with an average percentage of 83.33%.

3.4.2 Critical Thinking Skills

Critical thinking skills are built through the analysis of momentum phenomena to be built into a simulation. This requires actively various aspects of critical thinking skills. These aspects include Hypothesis testing, Argument Analysis, Reasoning, Likelihood and uncertainty analysis, and Problem-solving and decision-making [12].

Teaching materials have content to build critical thinking skills through programming. Aspects of the hypothesis testing, argument analysis, likelihood and uncertainty analysis are built through a
process of variable analysis that influences a momentum phenomenon for the basic material to form a script for making simulations. Then after the simulation is successfully made, aspects of Hypothesis testing, Reasoning, and Problem-solving and decision-making are explored by giving a problem related to the simulation that has been made. After students complete momentum learning using teaching materials, a critical thinking description test is given to see each aspect of student critical thinking.

Table 2. Achievement of Critical Thinking Skills

| Domain                           | Percentage (%) |
|----------------------------------|----------------|
| 1 Hypothesis testing             | 79.59          |
| 2 Argument Analysis              | 68.93          |
| 3 Reasoning                      | 87.50          |
| 4 Likelihood and uncertainty analysis | 71.83         |
| 5 Problem-solving and decision-making | 72.14         |
| **Average**                      | **76.00**      |

Based on the results in Table 2, some aspects that have the lowest achievement compared to the others, namely the aspect of argument analysis. This is most likely due to a lack of learning using instructional materials namely, first, Pre-service teachers still need a longer adjustment to learning using scratch. Second, Pre-service teachers are still unable to explore various forms of cases related to one's interpretation of a momentum phenomenon that is packaged in arguments because of the limited ability to access and manage Scratch programs. In general, based on the test results reinforce the view that Scratch integrated into Teaching Materials is actively able to build critical thinking skills just like previous studies [22][35].

3.4.3 Communication
The results of communication are obtained through observation of group work from the time of discussion to presentation in front of the class. measured aspects are the general communication skills of the group. This indicator of communication skills adapts 21st century skills [36]. The four main indicators are (1) discuss learning content; (2) express thoughts or ideas in groups; (3) demonstrate the simulation in the discussion room; (4) narrating the making of simulations and various content inside. The results of observations from each aspect that were averaged from all groups were 87.5% fulfilling all aspects.

3.4.4 Collaboration
Collaboration can be measured by the ability to collaborate in groups, conduct discussions before completing assignments, there is a clear division of tasks when completing the task of designing simulations with Scratch, and helping each other in groups and responsibilities in completing tasks. The results of giving questionnaires to students obtained results as in Table 3.

Table 3. Results of Collaboration Skills Pre-Service Teacher

| No | Domain                          | Skor   |
|----|---------------------------------|--------|
| 1  | Cooperate in groups             | 86.71  |
| 2  | Discuss before completing the assignment | 86.71 |
| 3  | Share clear tasks               | 82.14  |
| 4  | Help each other in groups       | 89.28  |
| 5  | Responsible for completing tasks| 89.28  |
|    | **Average**                     | **86.82** |
The average collaborative ability score is 86.82. The achievement of each indicator is relatively large, which is greater than the minimum criteria required. Thus, scratch-assisted teaching material is effective for building student collaboration skills.

3.4.5 **ICT Literacy**
21st Century Skills that are measured later are ICT literacy. These skills are described from observations and tests. In the learning process, direct observation is carried out by each to see how mastery and use of technology to access information. The results of observations and tests related to ICT literacy can be seen in Table 4 and Table 5.

**Table 4. Achieving ICT Literacy through observation**

| Aspek  | Value |
|--------|-------|
| Access | 94.29 |
| Manage | 70.24 |
| Integrate | 84.52 |
| Evaluate | 78.93 |
| Create  | 70.24 |
| **Average** | **79.64** |

**Tabel 5. ICT Literacy test results**

| Skills      | Average |
|-------------|---------|
| ICT Literacy| 80.18   |

Based on the results of the achievement of ICT Literacy, it can be seen that after the pre-service teachers used the momentum teaching materials for learning on an average they had high literacy ICT ICT. During the observation, it is known that the aspects of managing and creating are still classified as the lowest aspects of other aspects. This aspect requires deepening mastery of the scratch application in the script processing section. The same factor as the cause of other skills is less than optimal is the problem of relatively short learning time. The ideal time needed to study all momentum material with teaching materials is approximately 4x2 hours.

**4. Conclusion**
Based on the results of research and discussion, it can be concluded that momentum-assisted teaching materials Scratch have the characteristics of loading animation programs that can be created independently by students. Teaching materials developed are valid, easy to use as instructional materials in learning, and effective for building the skills of the 21st Century and industrial revolution 4.0, which adapts the principle of computational learning. The results of the assessment of 21st century skills include the ability to think creatively, think critically, communicate and collaborate as well as the skills of industrial revolution 4.0, ICT literacy, all over 71, so it can be concluded that the scratch-assisted momentum teaching material was effective in building Pre-Service Teacher’s 21st century skills in

**Acknowledgment**
Thank you to Universitas Negeri Semarang for providing funding to conduct PUPT Skema Inovasi, with a number contract research letter 208.13.5/UN 37/PPK.3.1/2019 On 13th May 2019.
References

[1] Kumar R, Zhi-gang Z and Livadiotis G 2016 J. Phys. Conf. Ser 739.
[2] Bryce T G K and Macmillan K 2009 J.Research in Sci.Teaching 46 739
[3] Häkkinen P Järvelä S Mäkitalo-siegli K Ahonen A Näyikki P and Valtonen T 2016 Teachers And Teaching Theory And Practice 060 1
[4] Rusilowati A Yulianto A Astuti A and Nurulhuda A R 2019 . J. Phys. Conf. Ser 1321 022027
[5] Binkley M 2012 Defining Twenty-First Century Skills England: Springer Science+Business Media
[6] Ma, K Kohnle C and Fischer F 2011 Learning and Instruction 21 257.
[7] Schratzenstaller A 2010 The classroom of the past. Chapter 2 Rotterdam: Sense Publish
[8] Väliljärvi J 2011 Teacher’s 교원교육 27 289.
[9] Krofkors L Kynäslihti H and Stenberg K 2011 Teaching Education 21 37
[10] Gunawan G Suranti N M Y Nisrina N Herayanti L and Rahmatiah R 2018 J. Phys. Conf. Ser 1108 12043
[11] Horng J Hong J Chanlin L Chang S and Chu H 2005 International Journal of Consumer Studies 29 352
[12] Tiruneh D T Weldeslassie A G Kassa A Tefera Z Cock M and Elen J 2016 Educ. Technol. Res. Dev. 64 481
[13] Bakkenes I Vermunt J D and Wubbels T 2010 Learn Instrument 20 533
[14] Ahonen A K and Kinnunen P 2014 Scandinavian Journal of Educational 37
[15] Häkkinen P Arvaja M Hämäläinen R and Pöysä J 2010 IGI Global 180
[16] Mäkitalo-Siegli K Stegmann K Frete A and Streng S 2012 Comput. Education 75
[17] Farrell B J 2008 S Journal of University teaching & learning practice 5 2
[18] Gordon J 2009 Key competences in Europe: Opening doors for lifelong learners across the school curriculum and teacher education CASE Netw. Reports no. 87
[19] Mishra P and Koehler M J 2006 Teach. Coll. Rec 108 1017
[20] Agyei D D and Voogt J 2012 Australas Journal Education Technology 28 4
[21] Pesakis G and Serafatie K 2009 ACM SIGCSE Bulletin 41 258
[22] Choi H 2012 Computers in education 7 15
[23] Barr V and Stephenson C 2011 Inroads 2 48
[24] Tasneem S 2012 J. Comput. Sci. Coll. 27 81
[25] Tiruneh D T and De Cock M 2018 Int. J. of Sci. and Math. Educ. 16 1065
[26] Rush N Resnick M and Maloney J 2012 Retrieved July 2 201
[27] Depdiknas 2006 Pedoman memilih dan menyusun bahan ajar Jakarta: Depdiknas
[28] Widodo C S and Jasmadi S T P 2008 Panduan menyusun bahan ajar berbasis kompetensi Jakarta: Elex Media Komputindo
[29] Tibebu D Gu X De Cock M. and Elen J 2018 Int. J. Educ. Res 87 1
[30] Blessinger P and Carfora J M 2014 Innovations in Higher EducationTeaching and Learning 1 223
[31] Sugiyono 2013 Metode penelitian pendidikan Bandung: Alfabeta
[32] Borg W R and Gall M D 2007 Educational research: An introduction London: Longman
[33] Anas S 2008 Pengantar statistik pendidikan Jakarta: Raja Graf. Persada
[34] Corgnet B Esp’in A M and Hernán-González R 2016 Front. Psychol 7 1626
[35] Pinto A and Escudeiro P 2014 ICT 9th Iberian Conference on Information Systems and Technologies (CISTI) 1
[36] Trilling B and Fadel C 2009 21st century learning skills San Fransisco: CA John