Worksheets_Development_for_Computational_Thinking_Practices.pdf

by Lusia Rakhmawati

Virtual Laboratory-Based Student Worksheets Development for Computational Thinking Practices

1st Lusia Rakhmawati
Department of Electrical Engineering
Universitas Negeri Surabaya
Surabaya, Indonesia
lusiarakhmawati@unesa.ac.id

2nd Achmad Imam Agung
Department of Electrical Engineering
Universitas Negeri Surabaya
Surabaya, Indonesia
imamagung@unesa.ac.id

3rd Miftahur Rohman
Department of Electrical Engineering
Universitas Negeri Surabaya
Surabaya, Indonesia
miftahurrohman@unesa.ac.id

2022 Fifth International Conference on Vocational Education and Electrical Engineering (ICVEE) | 978-1-6654-7581-5/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICVEE57061.2022.9930462

***Abstract*— This research intends to create a virtual laboratory-based student worksheets model on Electrostatic Forces, Fields, and Equipotential Lines to educate students computational thinking. This study was divided into four stages: needs analysis, practicum learning design, student worksheets development, and evaluation. The literature research and field investigations employed in the needs analysis stage are related to the need for virtual laboratories, whereas the practicum learning design stage begins by determining competency criteria and milestones in computational thinking. The decomposition process, pattern recognition, abstraction, and algorithms are all highlighted in the student worksheets development stage. Expert validation and limited trials are used in the evaluation step. Student responses and learning outcomes are classified as good and practicable to be used as a source of learning in learning activities based on the results of the validation.**

Keywords—Virtual laboratory, student worksheets, computational thinking, Physics Education Technology (PhET).

I. Introduction

Digital learning has made it into homes to maintain social distance during the pandemic. While many organizations allow employees to work from home, researchers and academics are turning to virtual laboratories as one of the first stages in addressing the "new normal"[1].

One of the technological advances among modern teaching approaches is the virtual laboratory. Computers are utilized in virtual laboratories to create a 3D virtual environment. This enables students to interact directly by playing variables, as well as the availability of visuals that might help knowledge [2,3]. Students can finish their experiments in real time if they have access to the internet and computers [4]. Furthermore, they have access to knowledge in a variety of materials and disciplines, which helps them enhance their abilities and keep up with day-to-day advancements in the industry.

There are numerous benefits to learning in virtual laboratories [6,7], including: 1) Allowing students to do numerous experiments that would be impossible to conduct in a real laboratory due to safety concerns. 2) Helping teachers and students in saving time and effort by not requiring them to enter the lab or transfer from one location to another at a specific time. 3) Allow for experimentation freedom. The same experiment can be repeated multiple times. 4) Keeping teachers and children safe from dangerous or radioactive materials, as well as handling explosive or electrical devices. 5) Makes it simple to modify the experiment's inputs and variables. 6) Enables students to stay connected to the Internet, allowing them to search for and gather information.

Physics Education Technology, abbreviated as PhET [8], is one example of a virtual laboratory. The University of Colorado created PhET, which is freely available on their website (www.phet.colorado.edu). This website has over 50 simulations of physical subjects that are accessible both offline and online. This simulation is intended to be a highly dynamic, engaging, and open learning environment that offers the user with animated feedback.

The physical simulation model shows dynamic accuracy, is very visual, and is a representation of the principles of physics [8]. The PhET simulation is equipped with student activities, teacher guidance, and worksheets. Many researchers in science have determined that implementing virtual laboratories in the instruction process significantly improves student achievement [9; 10] and a positive effect on student attitudes [11]. In the process of improving student achievement and having a positive attitude in learning, students experience an environment that can support them to gain knowledge and have a positive impact. Luketic & Dolan [12] stated that students' perceptions of their learning environment influence how and to what extent they learn and retain knowledge. Therefore, the researcher decided to analyze the students' cognitive and their perception of their science laboratory environment in studying waves and sound using Physics Education Technology (PhET) as a virtual laboratory. Prima, Putri, & Rustaman [13] have implemented PhET Simulation to improve students' understanding and motivation in studying the solar system. Prima, Oktaviani, & Sholihin [14] conducted a lesson about electricity using Arduino-PhET to train STEM literacy. This research was conducted to analyze the implementation of waves in string student activity by Esler[15] a planning plan, analyzing cognitive profiles and the environment of a science laboratory in learning and sound waves using PhET as a Virtual Laboratory. The results of this study are expected to be used by teachers as information to guide students in increasing understanding related to learning materials.

Computational thinking is a way of thinking to solve a problem [16]. The trick is to break down each problem into several parts or stages that are effective and efficient. It can also be interpreted as a method for solving a problem that is designed to be solved by humans or systems or both [18]. Based on the concept, computational thinking has four main stages [17,18], including: 1) Decomposition, which is breaking a complex problem into small and simple parts. So, we can find the problems that occur by solving them one by one. 2) Pattern recognition, pattern recognition will help you in solving problems. At this stage, we look for a certain pattern or equation in a problem. 3) Abstraction, several things were done at the abstraction stage, among others, looking at the problem, generalizing, and identifying information. In this way, we can see important information and ignore less relevant information. 4) Algorithm, this is the stage when we develop the system, create a list of instructions and troubleshooting steps effectively and efficiently.

Computational thinking can be applied in various fields to solve problems. Some of the steps that must be taken include [17]: 1) Detailing the problem, the first step when facing a problem is to analyze the problem. Then, do the description of the problem correctly and precisely. Finally, set the criteria for the solution of the problem. 2) Analysis and elaboration can be done by dividing complex problems into small problems to make them easier to manage and analyze. After that make several hypotheses regarding the elaboration of possible solutions to the problem. 3) Thinking of a systematic algorithm. After the first step is completed, the next step is to find the right algorithm. Algorithm here can be interpreted as appropriate steps to solve problems based on data. 4) Implementation, solution, and evaluation, by making actual solutions and evaluating them systematically to test the truth of your hypothesis. Then, evaluate and modify the hypothesis, until it no longer requires modification. In this step, we can see if our solution can be generalized to the automation process.

This research develops an worksheets based on virtual laboratory, PhET, with focus on computational thinking. Section 2 describes the method. The results and discussion described in Section 3. Section 4 gives a brief summary and describes possible future works.

II. Method

This research consists of 4 stages: needs analysis, practicum learning design, worksheets development, and evaluation.

A. Needs Analysis

This stage is carried out by applying a qualitative descriptive approach that begins with a literature study related to the advantages and disadvantages of virtual laboratory-based learning, then field studies related to the situation in the previous class and the developed student worksheets products.

B. Practicum Learning Design

In this stage, in general, identify the expected basic competencies, and choose the appropriate material to be included in the virtual laboratory-based by paying attention to the steps in the computational thinking approach. The practical topics chosen are Electrostatic Forces, Equipotential Fields and Lines. By participating in this practicum, students will be able to: 1) Understand electrostatic forces, equilibrium fields, and lines. 2) Electrostatic force theory, equipotential fields, and lines simulation on the PHET website. 3) Compare the practical results to the existing theory. 4) Draw conclusions from your practical experience.

C. Worksheets Development

This stage is the worksheets production with a computational thinking approach. This series of processes aims to develop a product by refining existing products before testing the feasibility of the new product. The indicators used in the worksheets follow the computational thinking ability which can be seen in table 1.

TABLE I. The Indicator of the Computational Thinking Ability Used in Worksheets Development

Ability indicator	Competency indicators
Decomposition	Student can identify problems in a simpler way so easy to understand.
Pattern Recognition	Student can look for patterns, usually in a problem that has a certain pattern to solve it, we find out for ourselves how the pattern is.
Abstraction	Student can generalize and identify the general principles that generate these patterns, trends, and regularities. Usually by looking at the general characteristics and making a model of a solution.
Algorithm	Student can develop instructions for solving the same problem step-by-step, so that others can use the steps/information to solve the same problem.

TABLE II. Validation Content Outline

No.	Assessment criteria	Indicator
1.	Physical Worksheets	The worksheets cover can protect the worksheets from being damaged by dirt.
		The front of the worksheets cover is interesting.
		The cover face of the worksheets contains the worksheets title, the author's name, and the name or logo of the university.
2.	Worksheets Material	The worksheets text can be read.
		The worksheets material is summarized in the curriculum.
		The worksheets material is in accordance with the learning objectives.
		The worksheets material is in accordance with the recommended subjects.
		The level of truth of the material concept on the worksheets.
		Text and images are interrelated.
		The object of the image corresponds to the material.
		The object of the image is clear and not blurry.
		Questions or assignments encourage student activity.
		Information on the worksheets is sufficient.
3.	Worksheets language	Language that is simple to understand
		Language conforms to Spelling Enhanced.
		Font size and type according to the rules.

D. Evaluation

The worksheets are validated at this point. Product validation is a procedure for determining whether a product design is viable. Validation is a judgement based on rational thought, not facts on the ground, at this level. Validation of a product can be accomplished by presenting a group of experts known as validators. If there are multiple flaws and weaknesses in real-world use, product revisions are carried out. The outline of expert validation sheets can be seen at Table II.

Product trials are intended to collect data that can be used as a basis for determining the level of effectiveness, efficiency, and attractiveness of the resulting product. In the limited test items of the product, the following items are explained: trial design, test subjects, types of data, data collection instruments, and data analysis techniques.

Worksheets product and questionnaires were utilized as data collection instruments, which can be done by the student response questionnaire items as describe at Table III. The trial data was analyzed using qualitative analysis methodologies and procedures, which included data in the form of diagrams and tables. This stage is completed when the product has been successfully tested, and the product is subsequently used in real-world settings for a broader scope. The experimental method is utilized at this level. There are still some product enhancements to be made after testing. Then it's a ready model or a completed model. However, it was only evaluated on a restricted scale in this study.

III. Result And Discussion

Students are required to examine the coulomb force between electric charges, electric potential map, and electric field lines using PhET

A sample experiment can be seen at Fig. 1 and Fig. 2. The results of the worksheets design based on computational thinking skills can be described in the following section.

A. Decomposition

In this indicator, students are asked to be able to identify problems becomes simpler, thus it's easy understood. Students are expected to understand the desired learning results in the experiment by providing the objectives of the experiment, including:

- The electric field generated by electric charges is explored using a variety of electrode shapes.
- Electric potential measurements are used to create electric field maps.
- The magnitudes of electric fields between electrodes are computed.
- The magnitude of an electric charge is computed for locations such as electrodes.

B. Pattern recognition

In this indicator, students are asked to find or recognize the similarity of patterns within and between problems to be solved. To investigate Coulomb's force, students' complete analysis of electrostatic forces in relation to charges at shown in the example in the table IV and analysis of charges and electrostatic forces at shown in the table V.

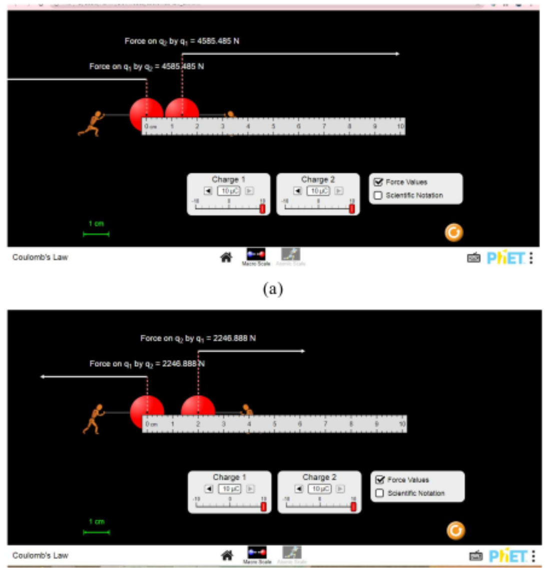

Fig. 1. Experiment with both charges under the electrostatic force (a) the same charge at distance 0 cm; (b) the same charge at distance 2 cm.

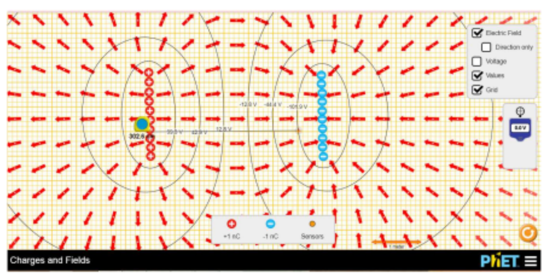

Fig. 2. Equipotential maps for two plates

TABLE III. Student Response Questionnaire Items

No.	A list of questions	Answer: Yes	Answer: No
1.	Do the worksheets look attractive to you?		
2.	Is the language used in the worksheetss easy to understand?		
3.	Is the material in the worksheets easy to understand?		
4.	Is the material in the worksheets in accordance with the material in your textbook?		
5.	Is the material in the worksheets in accordance with the material presented by the teacher?		
6.	Can the activities in the worksheets be carried out properly?		
7.	Can the worksheets make it easier for you to understand the material of bipolar transistors as power amplifiers?		

TABLE IV. Electrostatic Force Analysis As A Function Of Charges

Charge-1 Q1 (μC)	Charge-2 Q2 (μC)	Q1.Q2 (pC²)	Distance R (cm)	Force Simulated F_Sim (N)	Force Calculated F_Cal (N)	Percenntage Difference (%)
10	1	10	0.014	458.55	458.16	0.08415
10	2	20	0.014	917.09	916.33	0.08404
10	3	30	0.014	1375.65	1374.48	0.08408
10	4	40	0.014	1834.19	1832.65	0.08404
10	5	50	0.014	2292.74	2290.82	0.08406
10	6	60	0.014	2751.29	2748.98	0.08404
10	7	70	0.014	3209.84	3207.14	0.08406
10	8	80	0.014	3668.38	3665.31	0.08404
10	9	90	0.014	4126.93	4123.46	0.08405
10	10	100	0.014	4585.45	4581.63	0.08404

TABLE V. ELECTROSTATIC FORCE ANALYSIS AS A FUNCTION OF DISTANCE

Charge-1 Q1 (µC)	Charge-2 Q2 (µC)	Distance R (cm)	R^2 (cm^2)	Force Simulated F_Sim (N)	Forse Calculated F_Cal (N)	Percenntage Difference (%)
10	10	0.014	0.00019	4585.4	4581.63	0.0210117
10	10	0.02	0.0004	2246.8	2245	0.0210156
10	10	0.03	0.0009	998.61	997.77	0.0210184
10	10	0.04	0.0016	561.72	561.25	0.0210156
10	10	0.05	0.0025	359.50	359.2	0.0210100
10	10	0.06	0.0036	249.65	249.44	0.0209934
10	10	0.07	0.0049	183.14	183.26	0.0158708
10	10	0.08	0.0064	140.43	140.31	0.0209266
10	10	0.09	0.0081	110.95	110.86	0.0209183
10	10	0.1	0.01	89.876	89.8	0.0211491

C. Abstraction

In this indicator, students are taught to look at the problem from the ground up so that they can observe a broader range of the more significant ones while ignoring the minor elements that are truly less important. This can be accomplished by posing pre-lab questions:

- Could you describe the electric field lines?
- At what point does the electric field line begin and end?
- How would you describe the equipotential lines?
- At what point does the equipotential line begin and end?
- Describe the work required to transfer a charge particle between close equipotential lines.
- Describe the work required to drive a charge particle along an equipotential line.

D. Algorithm

To make the same pattern more effective and efficient, students are expected to create a system, sequence, or set of solution procedures that may be thoroughly applied to the pattern. Students are expected to solve problems rapidly if clear and precise experimental procedures are provided. Examples of procedures that students do are as follows.

- Set the charge of the object-1 to +10.0 C and position it at 0.0cm.
- Charge object-2 to +10.0 C and place it as near to object-1 as possible.
- Determine the electrostatic force exerted on charged items.
- Using Coulomb's law, calculate the electrostatic force on items.
- Calculate a percentage to compare the observed and calculated coulomb force between charged items difference.
- Then, repeat the preceding procedure by altering the value of charged object-2 in 1.0 C increments time.
- Maintain a charge of 10.0 micro-Coulombs on each item.
- Then, move the object-2 away from the object-1 by 1.0cm at a time, calculating the coulomb force for each example.
- Using Coulomb's law, calculate the electrostatic force on items.
- Calculate the percent difference between the observed and calculated coulomb force between charged items.
- Create a force-charge graph and explain the behavior in terms of Coulomb force.
- Create a force-versus-distance graph and explain the behavior in terms of Coulomb force.

The overall results of the worksheets validation seen from the 3 criteria namely the appearance, language, and content showed that the worksheets were categorized as good with a score percentage of 82%. From these categories, it can be concluded that the worksheets were appropriate to be used as a learning resource in learning activities.

Student response data was obtained through response questionnaire sheets given to students after students worked on problems in the worksheets. The response questionnaire sheet was filled out by 17 students as respondents. The results of the student response questionnaire were used to determine student responses to the worksheets which had been used as a learning resource in classroom learning activities. The results will be presented as a percentage. In the first question up to the seventh question, 100% of the 17 students answered that the worksheets display was interesting, and the results of the rest of the questions are 70.6%, 64.7%, 64.7%, 76.5%, 100%, 94.1% respectively. From the results of these calculations, it can be concluded that the results of student responses to the worksheets are categorized as good with an average positive response percentage of 81.5%. From these categories, it can be concluded that the worksheets are appropriate to be used as a learning resource in learning activities.

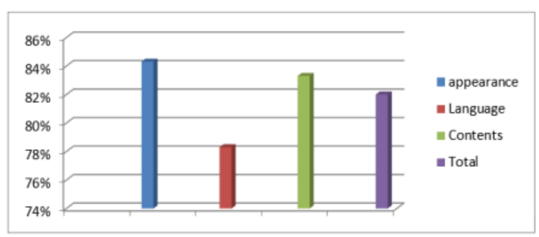

Fig. 3. Student Worksheets Rating Results

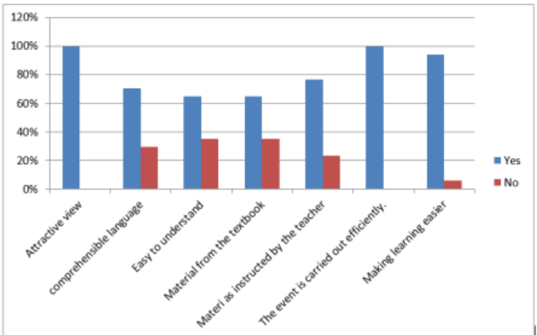

Fig. 4. Graph of Student Response

TABLE VI. STUDENT LEARNING OUTCOMES

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	70.00	3	17.6	17.6	17.6
	80.00	6	35.3	35.3	52.9
	90.00	8	47.1	47.1	100.0
	Total	17	100.0	100.0	

Data on student learning outcomes is data from the results of trials obtained from the results of working on student worksheets. The results of this study were obtained from three aspects of assessment in the work of worksheets, namely cognitive, psychomotor, and affective aspects. The following is presented data on student learning outcomes in Table VI. Based on the frequency distribution table, of the 17 students who worked on the worksheets, there were 3 students who scored 70; 6 students who scored 80; and 8 students scored 90, which means that 17.65% of the 17 students scored 70; 35.29% of the 17 students scored 80; and 47.06% of the 17 students scored 90. The total score was 1390, with an average score of 81.76.

IV. Conclusion

Student worksheets to train students' computational thinking were successfully developed with a percentage of the rating results by validators on worksheets from the overall criteria of 82%. While the percentage of positive responses from the results of student responses to the worksheets from the overall criteria is 81.5%. From the results of the trial run on student worksheets, the learning outcomes obtained with an average value of 81.76. From the acquisition of the three percentages, it can be concluded that the worksheets is categorized as good and feasible. to be used as a learning resource in learning activities.

Acknowledgment

This research was supported by PNBP 2022 Faculty of Technology Universitas Negeri Surabaya.

References

[1] G. Demircioğlu and M. Yadigaroğlu, "The effect of laboratory method on high school students' understanding of the reaction rate," Western Anatolia Journal of Educational Sciences, Special Issue: Selected papers presented at WCNTSE, pp.509-516, 2011.

[2] N.R Herga, B. Čagran, and D. Dinevski, "Virtual laboratory in the role of dynamic visualisation for better understanding of chemistry in primary school," Eurasia Journal of Mathematics, Science & Technology Education, vol 12, pp.593-608, 2016.

[3] R. Md Zahidur, "Teaching electrical circuits using a virtual lab," In Transit: The LaGuardia Journal on Teaching and Learning, vol 6, pp.85-92, 2014.

[4] Pyatt, K., & Sims, R. "Virtual and physical experimentation in inquiry-based science labs: Attitudes, performance and access". Journal of Science Education and Technology, 21(1), 133-147, 2012.

[5] Myneni LS, Narayanan NH, Rebello S. "An interactive and intelligent learning system for physics education," IEEE Transactions on Learning Technologies 2013; 6(3): 228-239

[6] Tatli, Z & Ayas, A. Virtual Chemistry Laboratory: Effect Of Constructivist Learning Environment. Turkish Online Journal of Distance Education, 13 (1), 183 – 199, 2012.

[7] Herga, N. R, Grmek, M. I., Dinevski, D. "Virtual Laboratory As An Element Of Visualization WhenTeaching Chemical Contents In Science Class". The Turkish Online Journal of Educational Technology,13 (4): 2-3, 2014.

[8] Finkelstein, N. D., Adams, W. K., Keller, C. J., Kohl, P. B., Perkins, K. K., Podolefsky, N. S., ... & LeMaster, R. "When learning about the real world is better done virtually: A study of substituting computer simulations for laboratory equipment". Physical Review Special Topics-Physics Education Research, 1(1), 010103, 2005.

[9] Tüysüz, C. "The Effect of the Virtual Laboratory on Students' Achievement and Attitude in Chemistry". International Online Journal of Educational Sciences, 2(1). 37-53, 2010.

[10] Tatli, Z., & Ayas, A. "Effect of a Virtual Chemistry Laboratory on Students' Achievement". Journal of Educational Technology & Society, 16(1),159-170. 2013.

[11] Pyatt, K., & Sims, R. "Virtual and physical experimentation in inquiry-based science labs: Attitudes, performance and access". Journal of Science Education and Technology, 21(1), 133-147, 2012

[12] Luketic, C. D., & Dolan, E. L. "Factors influencing student perceptions of high-school science laboratory environments. Learning environments research, 16(1), 37-47, 2013.

[13] Prima, E. C., Putri, A. R., & Rustaman, N. "Learning Solar System Using PhET Simulation to Improve Students' Understanding and Motivation". Journal of Science Learning, 1(2), 60-70, 2018

[14] Prima, E. C., Oktaviani, T. D., & Sholihin, H. "STEM learning on electricity using arduino-phet based experiment to improve 8th grade students' STEM literacy". Journal of Physics: Conference Series. 1013(1), 012030, 2018.

[15] Esler, J. "Waves on A String Students Activity". PhET. University of Colorado Boulder. 2022.

[16] Angeli, C., Voogt, J., Fluck, A., Webb, M., Cox, M., Malyn-Smith, J., & Zagami, J. "A K-6 computational thinking curriculum framework: Implications for teacher knowledge". Educational Technology and Society, 19(3), 47–57, 2016.

[17] Kalelioglu, F., Gulbahar, Y., & Kukul, V. "A Framework for Computational Thinking Based on a Systematic Research Review. Baltic Journal of Modern Computing, 4(3), 583, 2016.

[18] Wing, J. M. "Computational thinking's influence on research and education for all ". Italian Journal of Educational Technology, 25(2), 7–14, 2017.

Worksheets_Development_for_Computational_Thinking_Pra...

ORIGINALITY REPORT

10%	8%	6%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to October University for Modern Sciences and Arts (MSA) Student Paper	2%
2	Submitted to Bergen Community College Student Paper	1%
3	icvee.conference.unesa.ac.id Internet Source	1%
4	Hapsari Peni Agustin Tjahyaningtijas, Laras Suciningtyas, Andi Kurniawan Nugroho, Cucun Very Angkoso et al. "Brain Tumor Classification Using Deep Neural Network Based on MRI Images", 2022 Fifth International Conference on Vocational Education and Electrical Engineering (ICVEE), 2022 Publication	1%
5	idr.uin-antasari.ac.id Internet Source	1%
6	repository.iainpalopo.ac.id Internet Source	1%

7	plri.de Internet Source	1 %
8	link.springer.com Internet Source	<1 %
9	Naim Rochmawati, Hanik Badriyah Hidayati, Yuni Yamasari, Wiyli Yustanti et al. "Covid Symptom Severity Using Decision Tree", 2020 Third International Conference on Vocational Education and Electrical Engineering (ICVEE), 2020 Publication	<1 %
10	www.atlantis-press.com Internet Source	<1 %
11	journals.ametsoc.org Internet Source	<1 %
12	repository.uinjambi.ac.id Internet Source	<1 %
13	ekacahyaprima.staf.upi.edu Internet Source	<1 %
14	scholar.lib.ntnu.edu.tw Internet Source	<1 %
15	I.G.P. Asto Buditjahjanto, Luthfiyah Nurlaela, Ekohariadi, Mochamad Riduwan. "Learning Programming Technique through Visual Programming Application as Learning Media	<1 %

with Fuzzy Rating", International Journal of Information and Communication Technology Education, 2017
Publication

16	journal.stkipsingkawang.ac.id Internet Source	<1 %
17	www.amrita.edu Internet Source	<1 %
18	www.constructionism2018.fsf.vu.lt Internet Source	<1 %

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		