Virtual Laboratory for Elementary Students

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Abstract. Experiment-based science learning for elementary school children in Indonesia is constrained by infrastructure. Only a few elementary schools have integrated laboratories, which led to science-based thematic learning mostly limited to conceptual or theoretical. The solution offered by this article is the use of a virtual laboratory (VLab-“little scientist”) designed specifically for elementary school students. The little scientist simulates several types of basic experiments using attractive, colorful, and simple visual displays that are easily understood by the young learner. The Virtual Lab-little scientist was developed using the RnD method and operated using screen-based hardware like PC or Mobilephone. The VLab-little scientist was tested on 4th and 5th graders of Elementary School. The test results that the utilization of virtual labs is able to improve students' science process skills. Students were able to experiment with real equipment, after using the VLab-little scientist. Subsequent development needs to consider the elementary school science curriculum and further test to explore the effectiveness of using virtual lab.

1. Introduction

Science process skills are focus on the learning process to develop the basic concepts of science, skill to discover and developing facts, concepts, and values [1][2]. Scientific processes through scientific experiments are considered as one of the important methods and processes to understand the scientific phenomena and discovering scientific principles. In the contrary, elementary schools in Indonesia generally using conventional learning methods, there is an imbalance in the portion of practical learning and theory [3]. In addition, the application of scientific practices is also constrained by the lack of laboratory facilities owned by the school. This problem has an impact on the next stage of science education, causing Indonesia in the low position in the term of international science ranking (62 out of 70 countries based on PISA). [4].

The findings of the present study imply the effectiveness of experiment-based learning for an elementary student, where student understanding occurs when they carry out simple experiments [5][6][7][8]. Regarding the use of technology (ICT) in learning, several studies state that digital learning media are proven effective to improve students' understanding of science [9][10][11]. Specifically, the application of digital media especially virtual laboratories in science learning has proven to be effective in increasing students' understanding [12][13][14]. However, most of the existing learning media is intended for middle school to high school age. There are significant differences in the teaching techniques of elementary school age children, because of some specific
characteristics of children aged 5-12 years. Teaching science to an elementary student should be fun and rewarding, the teacher should know how to create an active learning environment [15]. This means that learning media must be able to facilitate the nature of students in terms of activity, interactivity, and design.

This paper aims at discussing the use of "Little Scientist" the virtual laboratory that specifically designed for elementary school students. The virtual lab specifically will be explained in terms of subject matter, activity, interactivity, and design. The paper is organized as follows. Section 2 reviews background and basic concepts regarding virtual lab. Section 3 describes the method utilized in this paper. Next, Section 4 presents the design of a virtual lab for elementary school. Section 5 presents observations and results obtained from the implementation of virtual labs. Finally, Section 6 concludes the paper.

2. Basic Concept of Virtual Lab

In the ICT era, teachers have a profound effect on student learning by bringing the real world to students through technology such as visual learning, multimedia, CBT and many more [16][17]. An example form of ICT in education is the virtual lab. A virtual laboratory is a virtual reality environment that simulates the real world for the purpose of discovery learning [18]. Virtual labs were capable to provide the students with tools, materials and lab sets on screen in order to perform experiments subjectively [19]. In virtual labs, students interact with virtual experimental tools through a user interface. The virtual lab provides a simulation of an experiment, whereby a student able to interact with virtual objects generated by the computer program [20].

Furthermore, in the virtual lab, experiments are visualized using real-time animation techniques with 2D or 3D graphics. The student can interact with virtual equipment in a way that is similar to the real lab equipment [21]. The experiments are dynamically controlled with a computer program so the student can learn science more flexible by providing diverse conditions to produce diverse outputs as well. Which in the end students can conclude themselves the results of the experiments conducted.

There are several advantages in using a virtual lab, for example, students acquire basic skills and knowledge for work in a laboratory without the risk of incidents in a real laboratory [22]. Virtual labs provide conventional and entertaining ways to learn science. The virtual lab is able to simulate tools that cannot be owned because of the limitations of a school's infrastructure [23]. Virtual labs can easily be operated through several screen-based media such as computers and mobile phones, this allows the learning process to be done anytime-anywhere.

3. Method

The method used in this study is mixed method. The development of "Little Scientist" is using RnD research. To measure its effectiveness, one group pretest-post-test was used. In this study, we ask students to do a simple experiment regarding the unit of measure of weight, length, and volume. Students are asked to take measurements following the book's instructions. After that, we test the effectiveness of using a virtual lab by asking students to use the "Little scientist" application and repeating measurements to get post-test data.

The population in this study is the four and fifth-grade students of Laboratorium UNNES Elementary School (SD Lab UNNES) in Semarang, which consists of 40 students at the average age 10-11 years old. The data processing in this research began by calculating pre-test and post-test scores. Subsequently, the effect of Virtual lab learning on students' science process was determined by using normalized gain analysis. The development before and after the virtual lab learning was calculated by computing normalized gain equation \(<g>\) as follows. The normalized gain criteria proposed by Hake [24] can be seen in Table 1.
Table 1. Normalized gain criteria.

| $(g)$          | Criteria |
|---------------|----------|
| $(g) \geq 0.7$ | High     |
| $0.3 < (g) < 0.7$ | Medium  |
| $(g) < 0.3$    | Low      |

4. Result and Discussion

In a Virtual Labs "Little Scientist" there are 5 science experiments included in the science curriculum of elementary school. Experiments are including: (1) Measuring objects using basic measuring instruments (2) Looking at objects using a microscope (3) Experiments on power and energy (4) Experiments using magnets (5) Electromagnetic experiments. The experiments are visualized in a two-dimensional simulated laboratory, which is colorful, interactive and obtains the necessary equipment (measurement tools, microscope, magnet, electromagnetic tools, etc.). Students are possible to use the virtual measuring instruments or to change the parameters of the experiments.

Figure 1. The user interfaces of Virtual lab “Little Scientist”
Compared to static conventional textbooks, in this virtual lab students can interact with tools through the screen display. For example in the use of calipers, students can simulate how to use the calipers, shift the scale and determine the size of the objects provided by the system. This interactivity is adapted directly from the actual equipment so that after using this virtual lab, students are expected to be able to practice it using real tools.

![Figure 2](image1.png)

**Figure 2.** Visualization of calipers in books (left) and in the virtual lab (right)

To attract student attention, "Little Scientist " using the pedagogical agent, an animated character called Tom and Rocky, gives some guidelines in the speech (audio) or text-based form. These pedagogical agents enable the virtual lab's interfaces to become more attractive for children [25].

![Figure 3](image2.png)

**Figure 3.** Visualization of pedagogical agent Tom and Rocky.

During the trial process conducted by students at the SD Laboratorium, the use of a virtual lab is able to increase science process skills. Aspects of the science process skills observed include five indicators, namely observing skills, inferring skills, measuring skills, communicating skills, and classifying skills. The results of the normalized gain analysis of experiments using virtual labs are presented in Table 2. It shows that the utilization of virtual lab is able to improve students' science process skills.
Table 2. Normalized gain analysis

| Indicators          | Average score | Criteria |
|---------------------|---------------|----------|
|                     | Pre-test | Post-test | <g>   |
| observing skills    | 0.65     | 1.70     | 0.44  | Medium |
| inferring skills    | 1.25     | 2.00     | 0.42  | Medium |
| measuring skills    | 0.75     | 2.65     | 0.84  | High   |
| communicating skills| 1.05     | 1.95     | 0.46  | Medium |
| classifying skills  | 1.55     | 2.50     | 0.65  | Medium |

5. Conclusion

The utilization of virtual labs for elementary school is proven that the students are able to improve their problem-solving skills in science. "Little Scientist" Virtual laboratory provides learners with the opportunity to learn by doing, exciting, motivating activities to discover and to solve problems systematically. Students are able to experiment as much as possible without limitation on tools, time, and place. Virtual labs for elementary school students designed with simple experimentation, the use of colorful interfaces and the use of pedagogical agents. We believe that this approach can be a solution to the lack of infrastructure for science learning. Further research is suggested to focus on the integration of virtual labs with basic curriculum, different experiments, and new forms of interactivity that are interesting to investigate.

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