Online science learning strategies: challenges and benefits

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Abstract. Covid-19 is one pandemic that influences all sectors in the world, including the educational system for learning science. To overcome this situation, most of the school conduct online learning. This study aims to investigate the challenges and benefits of some online learning, such as virtual laboratories, webcomic, and game-based learning, and to find a more beneficial strategy. The literature review by using secondary data analysis was performed to identify the patterns an existing data and make interpretation from twenty-seven articles both from the Indonesian and International journals. Each article was synthesized and analyzed to result in which strategy is more beneficial. The results show that virtual lab and game-based learning are an attractive strategy to enhance students’ problem-solving skills, while webcomic is more focused on students’ literacy. It also found that game-based learning is more beneficial as the strategy for online science learning. Despite the benefits that gained from those three online learning strategy, they will be more effective if it is done along with the classroom and hands-on activity to cover up the challenges and limitations.

1. Introduction
The whole world was shocked by the Coronavirus outbreak. This virus is transmitted very quickly and has spread to almost all countries and become the Covid-19 pandemic. This virus has influenced all sectors in the world. Globally, activities that are typically carried out in daily life have stopped, including the educational process. Students cannot rely on learning activities only at school because some teaching and learning processes must be delayed or often canceled. The increasing spread of cases of rapid viral infections throughout the world has created feelings of uncertainty and anxiety about what will happen and also can affect students psychologically. They can be frustrated and short-tempered when their daily routine is disrupted[1].

However, students must continue to learn through online learning because it aims to increase awareness and the process of stopping the spread of viruses through direct interaction between humans. Online learning is the use of Internet technology to improve knowledge and performance and also as a learning process created through interactions with network-based content delivered through digital platforms [2]. So, online learning in teaching and learning is one form of implementation of an online-based learning system. The effectiveness of online learning must be achieved with a thorough understanding of the educational needs of students and especially those who wish to utilize the Internet and the number of applications and technological tools that can be used to enhance their learning experience.
This online learning has a huge impact, both positive and negative effects. Online learning can refer to flexibility, accessibility, student focus, interactivity, and student improvement. Learning developed on the web has advantages in providing learning material content because it can be accessed anytime and anywhere. This learning is also faster than other conventional distance education methods. However, there are some limitations to online learning, such as the lack of a robust access signal for rural areas, the lack of public awareness of the needs of the internet network, and the majority of Indonesians are still unfortunate in access to learning media. The adoption of online learning requires large investments. All parties must consider this. Also, students must be able to access and use media in online learning correctly[3].

Each online learning course is unique, with specific objectives to determine its approach. There are several strategies in online learning, such as video storytelling, branching scenarios, reflective learning, infographics, webcomics, virtual science laboratories, game-based learning, and more. Interestingly, we want to analyze three strategies in online learning, namely webcomics, virtual science laboratories, and game-based learning, especially in science learning. The evaluation process examines the strengths and weaknesses of online science learning and how the results are generated. Therefore, this paper aims to investigate the challenges and benefits of virtual science laboratories, webcomics, and game-based learning and also to compare and discover which strategies are more useful for online learning science.

2. Methods
The study conducted a literature review. The literature review by using secondary data analysis was performed to identify the patterns an existing data and make interpretations [4]. On the other hand, literature reviews aim to analyze problems based on depth and critical reviews of relevant references and also to investigate scientific publications carried out on a specific field. There were twenty-seven both from the Indonesian and International journals were reviewed and synthesized. There were several steps in this secondary data analysis: (1) formulating research question; (2) conduct literature review from the local and international journal; (3) establish criteria by sorting the articles; (4) collecting the data; (5) analyzing the data; (6) writing the findings. The conclusions were summarized from each strategy for comparing and finding more beneficial strategies.

3. Result and Discussion

3.1 virtual science laboratory
In teaching science and achieving its objectives, experiments and laboratories are the critical part. Laboratories can be described as controlled conditions in which scientific experiments are carried out [5]. Science laboratory activities are also giving advantages in increasing students’ more in-depth understanding of science concepts and correcting their misconceptions by forming the link between new information and existing information so that they support meaningful learning. In traditional laboratories, students use hands-on to activate experiential ideas and engage with scientific phenomena in real conditions. This type of laboratory benefits students by incorporating concrete objects in science learning and give opportunities to interact directly with the scientific phenomena being studied [6].

As computing technologies are getting more advanced and increasingly affordable, school science experiments are no longer limited by physical equipment and materials. One of the advances in science education technology is the virtual laboratory, which is appeared beside the traditional laboratory. The virtual laboratory provides “learning by doing for everyone.” It allows the users to explore a variety of scenarios by changing the input and observing the effect of the output [5].

A virtual lab provides various benefits in achieving the various learning outcomes. It allows doing more secure experiments since it is done in cyberspace, so it will not harm anyone. It can simulate complicated, expensive, and inaccessible devices [7]. Once it is developed, students might repeat the experiment with no extra cost. The result of the experiments has also come with zero error because the data is all computerized. It means that the learners can be able to focus on the relation between the parameters. The visualization could help students to overcome the gap between micro and macro worlds.
thus leading to a better understanding [8]. The virtual lab also provides additional support to understand abstract concepts and phenomena with flexible time management [9]. It also always provide observable outcomes, no matter how complex the experiment [10]. By using a virtual laboratory, we can do many times of experiments without buying some materials that needed. The time allocation to do a virtual laboratory is more effective than a traditional laboratory. So, the virtual laboratory is suitable for Millenials students that like to experiment.

On the contrary, the virtual lab also gives challenges to both the teacher and the students. Compared with traditional lab, the virtual lab does not explain about the way things work, or theory-in-action, especially in physics [9]. One of the criticisms of virtual laboratories is the fact that they do not teach laboratory techniques and manipulative skills well. Because students do not work with real materials and equipment, they lack their responsibility, and carefulness towards them. Students might feel like they are playing a video game, not in a learning situation [5].

Visualization of experiments through virtual lab had been applied in school science subjects, such as physics and chemistry. The usages of virtual laboratories in chemistry classes provide specific advantages and the ability to present teaching matter at the macroscopic, symbolic, and dynamic submicroscopic levels [8]. Virtual labs provide the ability to transform abstract concepts such as engineering concepts into perceptual representations. But the understanding of the macroscopic level is more difficult compared with traditional laboratory.

Several physics topics that might include virtual lab are frictional force, pulley (simple machine), work, and potential energy [9]. Several articles found that virtual labs can enhance and improve students’ problem solving, critical thinking, creativity, conceptual understanding, and attitudes toward science, motivation and interest, perception, and learning outcomes. Also, it could improve the learning environment to become more constructivist. However, it is suggested because each type of laboratory activity has weaknesses and strengths. For this reason, lessons should combine both virtual laboratory and real laboratory activities to maximize the opportunity to create a constructivist learning environment [11].

3.2 game-based learning
In this era, technology has improved and a lot of learning has been based on online. The latest digital material provides sufficient audiovisual stimulation for students. Digital games provide a variety of animated images, audio effects, and deep stimulation. Game-Based Learning is a learning process that requires questions, observations, data exploration, and data manipulation [12]. Game-Based learning can be used as a classroom teaching tool to facilitate learning. Many teachers have used game-based learning strategies to help students learn.

Some research has defined that games as in-depth, voluntary, and fun activities where challenging goals are pursued according to the rules agreed in the game [13]. These games can be entertaining or educational. Entertaining games are usually designed for fun, entertainment, and recreation, while educational games are games that are designed for educational purposes [14]. Game-based learning must be compatible with the goals of the game, and that includes the teaching objectives and experiences that students will get through the game. Teaching objectives must be considered first when it will be designed. Evaluating and assessing learning achievement can be set in the game [15]. There are many types of genres in game-based learning. Educators must be able to choose the right genre and appropriate to reach their goals. A challenging game world can shape cognitive abilities with expectations regarding student development in improving learning abilities. Some examples of game based learning are classticraft, foldit, eterna, phylo, tyto ecology etc.

Engagement and motivation are attractive benefits of using games but not enough for educational purposes. The game content can produce simplifications of reality. Students can imagine the material quite easily through digital games. Games are often cited as essential tools for teaching 21st-century skills because students accommodate a variety of learning styles and promote various contexts in solving complex problems, a set of skills embedded in a well-designed game is a suitable partner for students.
comics continue to develop various types of comics such as comics, cartoons, doodles, and comic strips, and after technology develops very quickly, they also update the comics to webcomics.

3.3 webcomic

Comics are drawings, and other symbols are contiguous or adjacent in certain utterances which aims to deliver information and achieve aesthetic responses from readers [24]. Comics can also be used effectively to raise interest in reading, develop vocabulary and reading skills, and can be used as an effective medium for learning purposes [25]. Similarly, there was a studied comics program for posters on public streets in India and found the simplicity of comics communication to be effective in spreading awareness and engagement on social issues [26]. Emotional, deep connection, and change can happen from reading educational comics [27]. An excellent comic in motivating and teaching that person is not too familiar with scientific principles [28]. The subsequent studies found that readers who learned from comics learned better, retained information better, and paid more attention to educational content than control groups with traditional lectures or pure text [29].

Comics continue to develop various types of comics such as comics, cartoons, doodles, and comic books, and after technology develops very quickly, they also update the comics to webcomics.
Webcomics start webcomics is an exciting comic evolution. Their digital nature, easy to share and read, shows excellent potential for interacting with readers and deeper levels of understanding [31]. Webcomic becomes the face of visual literacy. Reading comics involves the pictures and their meanings about the language, and the key to understanding comics does not lie in the words or pictures themselves but the interaction between them [30].

Webcomics became a new hope in science education, and they returned by following the development of the internet and technology. They become easier to read, carry, and make. Webcomic also provides micro and macro-scale data that is difficult to see before it becomes fun. Many skills can be further developed by webcomics, such as increasing student literacy, creative thinking, and problem-solving in a scientific way. Combining visual information with verbal explanations can lead to more creative problem solving for some students [32]. The combination between picture and text becomes the main benefit of the webcomic as learning strategy in science teaching learning [28]. The assessment also could help by webcomic. The teacher would easily make the short quiz, which refers to the webcomic itself. The webcomic is really helpful for online teaching-learning or just for homework.

There is also a lack of using webcomics as a learning strategy. One study states that the webcomics project has no effect on education and involvement in social issues or a slight positive effect on engagement - comics can only change the readiness of one reader [29]. Creativity in making science comics is highly demanded because, as we know, it is not easy to explain science in a limited bubble text. The struggle in making a webcomic as a learning strategy is a deep thinking skill. It can be assumed that it is not effective using a webcomic. Students are limited by the information provided in the comics because text and images must be combined well. We cannot use all images or use all text in comics. Also, science skills such as science attitude, lab skills cannot be sharpened and cannot be assessed.

It can be concluded that the webcomic cannot be used as a learning strategy. It can only be used as an adjunct to teaching and learning science, increasing scientific literacy and student creativity. Webcomics can be combined with learning materials such as inquiry-based learning, and problem-based learning that functions as a medium that can involve students' critical thinking.

### 3.4 comparison of the benefits

Because the challenges, benefits, and implications of each strategy have been discussed above, we summarize the three learning strategies based on Literature (table 1).

**Table 1.** Benefit comparison among virtual laboratory, webcomic, and game-based learning for online science learning based on literature

| Benefits to enhance                  | Virtual Laboratory | Webcomic | Game-Based Learning |
|-------------------------------------|--------------------|----------|---------------------|
| Problem Solving                     | V                  | V        | -                   |
| Critical Thinking                   | V                  | V        | V                   |
| Creativity                          | V                  | V        | -                   |
| Conceptual Understanding            | V                  | -        | -                   |
| Attitudes Toward Science            | V                  | V        | V                   |
| Motivation and Interest             | V                  | V        | V                   |
| Learning Outcome                    | V                  | -        | -                   |
| Self-Confidence and Efficacy        | -                  | -        | V                   |
| Communicative Skill                 | -                  | -        | V                   |
| Decision Making                     | -                  | -        | V                   |
| Students’ Performance               | -                  | -        | V                   |
| Students’ Literacy                  | -                  | V        | -                   |
| Total                               | 7                  | 6        | 8                   |

Three learning strategies can enhance most skills, including 21st century skills. Some of them have the same skills that can be improved, and some are different. However, each learning strategy is unique. Virtual laboratory can enhance problem-solving skills, critical thinking skills, creativity, conceptual
understanding, attitudes, motivation, interest, and learning outcome. Another learning strategy, webcomic can enhance problem-solving skills, critical thinking skills, creativity, attitude, motivation, and students’ literacy. And the last game-based learning can enhance critical thinking, attitude, motivation and interest, self-confidence and self-efficacy, communication skill, decision making, and students’ performance. Conceptual understanding should be more focused on whatever the learning strategy. Based on the literature, the only virtual laboratory can enhance conceptual understanding. Still, all learning strategies should increase conceptual understanding because it is the key to master the material and can impact other skills. Another thing that should be concerned is how if we want to use these learning strategies. Some considerations for the teacher are characteristics of materials, learning outcomes, and students’ condition including learning styles of the students.

4. Conclusion
This research seeks to investigate learning strategies that would be more appropriate to be used in this Covid-19 pandemic. The learning process is limited, so the teacher as a facilitator must think creatively to be able to make the process more effective, especially in science subjects, there are many skills that students must agree. The results showed that virtual laboratories and game-based learning were interesting strategies to improve students’ problem-solving skills, while webcomics focused more on student literacy. It was also found that game-based learning was more useful as a strategy for online learning. Apart from the benefits gained from the three online learning strategies, they will be more effective if carried out together with classes and direct activities to cover challenges and limitations.

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