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# Effectiveness of web-based virtual laboratory on grade eight students' self-regulated learning

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**Abstract**
Self-regulated learning (SRL) is an important factor in online learning and is defined as the process of actively managing one's own learning process to achieve a desired outcome. However, many issues remain unsolved about how to improve cognitive strategies and self-regulation in online learning environments where teachers are not physically present. As a result, this study aims to explore the effectiveness of a web-based virtual laboratory on enhanced students' SRL. A quasi-experimental pre-/post-test with a control group design was employed involving 40 female students aged 14-15 years old. While the students in the experimental group carried out the practical activities using a specially developed web-based virtual laboratory, the students in the control group used a physical laboratory. The results obtained indicated that the virtual laboratory significantly enhanced metacognitive self-regulation, effort regulation, peer learning, and overall SRL more than the physical laboratory. These findings could be attributed to how students learn using the virtual laboratory. For instance, students can navigate the virtual lab website at their own pace at anytime and anywhere.

**Keywords:** virtual laboratory, self-regulated learning, practical activities

## INTRODUCTION

Science is an active, hands-on subject that students learn via doing rather than just listening or memorization and might be considered the most fascinating subject at school for both students and teachers (Howe, 2002). Additionally, science education encourages students to assess problems critically and come up with possible solutions as well as develop an understanding of the world around them (O'Connell, 2014). In science, students learn through asking questions, weighing up the evidence, reasoning and doing, as well as carrying out experiments. According to the National Research Council (NRC) (NRC, 2007), learners who are proficient in science have a few characteristics:

1. understand the nature and development of scientific knowledge,
2. be familiar with, apply, and interpret scientific explanations of the natural world,
3. actively participate in scientific practices and discourse, and
4. generate and assess scientific evidence and explanations.

Electricity is one of the fundamental topics in science. Its applications cover many aspects of our daily life. Many important scientific concepts are associated with electricity, including but not limited to electric current, voltage, resistance, etc. Therefore, attention must be given to teaching the concepts with proper methods and approaches (Kapici et al., 2019). Nevertheless, several studies found that many learners are struggling to grasp electricity-related concepts such as electric current, resistance, and voltage (Moodley & Gaigher, 2019; Stavrinides et al., 2015). It is believed that learners generally cannot grasp these complex and abstract concepts without using concrete materials and opportunities for hands-on practice in a laboratory (Ambusaidi et al., 2013, 2018).

Research on students' learning such as 'learning electricity' has revealed that when students do not have


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**Contribution to the literature**

- The findings of this study show that a virtual laboratory can be an effective tool to enhance students' SRL.
- In science laboratories, students collaboratively ask questions, plan, design, and have opportunities to investigate and make decisions. As seen within this study, physical and virtual labs have the capacity to help students improve their SRL. However, virtual laboratories have advantages that make them superior in regulating students' learning. For instance, the virtual laboratory was available online and students could use it whenever and wherever they wanted to at their own pace.
- Teachers should try to establish a classroom environment that facilitates and improves students' SRL in their classes. From a teaching perspective, teachers should provide students with activities that encourage them to investigate, develop, and improve their ideas, methods, and techniques. Instead of dispensing knowledge, a teacher's role should be that of a facilitator. Therefore, the virtual laboratory used in this study can be a tool that can help teachers to provide these learning environments.

direct experiences with the concepts they are learning about, they find it hard to understand the information presented in the curriculum (NRC, 1997). That is why it is believed that if the students discover and learn through experimentation and enquiring, they will develop a deeper understanding of the underlying principles of science.

Physical school laboratories promote the most crucial purpose of using experiments in the educational process, which is to provide realism (Abdulwahed, 2010) and there is growing evidence that action and manipulation are fundamental to cognition and can influence how concepts are processed (Smith, 2015). Physical laboratory environments are unique in that they can incorporate haptic feedback in addition to visual feedback during interaction with physical materials (Smith, 2015). In addition, learners in a physical lab communicate their findings to their peers and teachers as well as engage in evidence-based arguments. Moreover, learners in physical labs conduct authentic activities similar to those conducted by experts in the field (Raish, 2016). However, several studies (Ali et al., 2014; Awan, 2015; Hamidu et al., 2014; Kapting'el & Rutto, 2014; Ndihokubwayo, 2017; Zengele & Alemayehu, 2016) found that there are problems with using laboratories in teaching science, which, in general, prevent students from developing a proper conceptual understanding. For instance, there are numerous obstacles related to the physical conditions of science laboratories including insufficient laboratory resources and limited space in the laboratory, leading to overcrowding. Conversely, studies have shown that students should be encouraged to articulate and share their ideas and findings with their classmates, which is difficult to do in an overcrowded laboratory (Kapting'el & Rutto, 2014; Ndihokubwayo, 2017). Moreover, several studies found that it is common in many schools to have a single science laboratory serving all sciences (biology, chemistry, and physics), which causes clashes in laboratory programs, and hence, there is only a limited period for carrying out laboratory activities (Ali et al., 2014; Hamidu et al., 2014; Gericke et al., 2022; Zengele & Alemayehu, 2016). In addition, during the COVID-19 pandemic, many schools have been forced to urgently consider the switch from in-presence teaching to online teaching, including laboratory teaching. To overcome the difficulties mentioned above, the current study used a virtual laboratory that may serve as an available resource for grade 8 students by virtually providing them with materials, tools, and lab sets on a computer to carry out experiments as well as help science teachers to improve their teaching methods.

Virtual laboratories can be defined as "a virtual learning space that enables students to conduct experiments individually or in groups interactively via the internet" (Aljuhani et al., 2018, p. 6). They combine all the relevant pedagogical, technological, and human resources to carry out practical activities that are adapted to the requirements of the teachers and students in a virtual environment. Virtual laboratories are an open environment through which a real science laboratory is simulated, and the practical part is linked to the theoretical part, allowing students to practice science inquiry skills and make decisions about their learning without worrying about making mistakes (Molohidis et al., 2015). They make it possible for students to explore new domains, make predictions, design experiments, interpret results (Alneyadi, 2019) and permit visualizing objects and processes that are otherwise impossible to show in a real environment (Martín-Gutiérrez et al., 2017).

Furthermore, virtual laboratories enable learners to carry out and repeat scientific experiments anytime and anywhere. In other words, virtual laboratories give students an opportunity to self-evaluate their performance during experiments and the flexibility to use the lab activities at any time and at their own pace, which enables them to self-regulate their learning (Shudayfat, 2014).

Self-regulated learning (SRL) is "an active process by which learners direct and coordinate their efforts, thoughts, and feelings in order to achieve their learning goals" (Zimmerman, 2002, p. 65). It is believed that self-regulated learners are better prepared to tackle educational obstacles and have the ability to address problems independently. They practice self-motivation, self-direction, and self-evaluation to try their hardest to master the learning goals (Delen & Liew, 2016). Self-regulated students are engaged and enthusiastic in their learning; set short and long-term educational goals, track their own progress, and have the ability to control and apply self-imposed constraints. These students also practice self-reflection to track their development and plan their learning activities (Daniel et al., 2016).

Recently, researchers in the field of educational psychology have shown increased interest in how students might enhance their academic performance by controlling their learning processes and techniques. SRL has been shown in certain research to be an important stimulus for academic achievement (Beishuizen & Steffens, 2011; Effeney et al., 2013; Fadlelmula et al., 2015; Farajollahi & Moenikia, 2010; Rakes & Dunn, 2010; Rosário et al., 2013; Zimmerman & Schunk, 2011). In this regard, it could be said that the concept of SRL represents a shift in educational research from treating students' environments and learning capacities as fixed entities to concentrating on students' learning processes and responses, which are dynamic in nature and enhance academic success. But many issues remain unsolved about how to improve cognitive strategies and self-regulation in online learning, particularly at the school level. Also, most previous studies on virtual labs focused on establishing the effectiveness of virtual labs in students' learning and achievement while research on its impact on students' SRL is still limited. Thus, this study intends to explore whether web-based virtual lab can improve students' SRL.

## Self-Regulated Learning

Promoting the development of self-regulation skills and, therefore, creating possibilities for lifelong learning should be the main objectives of any contemporary education, whether for children or adults (Puustinen & Pulkkinen, 2001). Learners use self-regulatory processes to guide their learning and provide information about themselves that can strengthen their personal identity, sense of self, agency, and motivation toward mastery (Schunk & Zimmerman, 2012). This means that the learner can control, monitor and modify his own activity through the self-assessment of his cognitive abilities and behavior in order to manage the learning process, facilitate his own learning, and achieve academic success (Nikolaki et al., 2017).

Zimmerman (2002) suggests that there are several factors that affect SRL, which can be categorized as external and internal factors. External factors include the structure of the learning environment and social experience. Internal factors coming from within the individual include intrinsic values and beliefs about self-ability, while individual knowledge includes the condition of affection, behavioral changes and the academic goals to be achieved. Therefore, it is believed that teachers should train their learners 'how to learn' so that learners can manage, control, monitor, and evaluate their learning processes by themselves using different techniques and strategies (Sardareh et al., 2012). Moreover, Anderman and Sinatra (2009) argued that science teachers could help their students' self-regulation development in a variety of ways. Firstly, it is important to give students some control over how they learn science materials. Secondly, teachers must provide students with the opportunity to assess their work as they progress by allowing them to reflect on whether they are accomplishing their learning objectives.

There are a wide variety of definitions of SRL, but according to Johnson (2012), SRL consists of three main components: cognition, metacognition and motivation. Students use cognitive strategies (rehearsal, elaboration, and organization) to encode, memorize, and recall information. Metacognitive strategies include skills that enable learners to understand, plan and monitor their cognitive processes. Motivation (intrinsic goal orientation, task value, self-efficacy and task anxiety) affects the use and development of cognitive and metacognitive skills. In the present study, SRL is composed of two primary components (Pintrich & DeGroot, 1990), namely: motivational beliefs that consist of self-efficacy for learning and performance; and learning strategies that consist of metacognitive self-regulation, managing time and study environment, effort regulation, and peer learning. **Table 1** presents these components.

According to Pintrich and DeGroot (1990), self-regulated learners can efficiently and effectively plan, monitor, and modify their learning, as well as handle their academic tasks with a consistently high level of task performance and the ability to dismiss any distractions. Zimmerman (2002) believed that "self-regulation is not a mental ability or an academic performance skill; rather, it is the self-directive process by which learners transform their mental abilities into academic skills" (p. 65). Learning is seen as a proactive activity that students engage in for themselves rather than as a covert event that occurs in response to teaching. Moreover, self-regulated students have the ability to face and solve educational problems and challenges by themselves (Asim & Farooq, 2021). In addition, self-regulated learners are active in their metacognitive process and use self-motivation and self-directed actions to maximize the success of their learning process (Zimmerman, 2002).

It can be said that self-regulated learners are those learners who are "metacognitively, motivationally, and behaviorally active in their own learning processes and in achieving their own goals" (Shuy, 2010, p. 1). Also, SRL strategies assist students in developing the essential ability to transfer skills, knowledge, and abilities from one area or context to another, as well as for lifelong learning.

**Table 1.** Self-regulated learning components (Pintrich & DeGroot, 1990)

| Component | Description | Category |
|---|---|---|
| Motivational beliefs | It involves judgments of one's capacity to complete a task & confidence in one's abilities to carry it out. | Self-efficacy for learning & performance |
| Learning strategies | Metacognitive self-regulatory activities include three main processes:<br>1. Planning activities such as task analysis & goal setting help to prime or activate relevant aspects of prior knowledge that make it easier to organize & comprehend material.<br>2. Monitoring activities include tracking one's attention while self-testing, reading, & asking questions: These help students to comprehend material & integrate it with existing knowledge.<br>3. Regulating activities is supposed to enhance performance by helping students monitor & adjust their actions while they work on a task. | Metacognitive self-regulation |
| | Time management includes scheduling, planning, & managing one's study time. Study environment management refers to setting, where student does her work. | Managing time & study environment |
| | It comprises learners' ability to manage their effort & focus on face of distractions & uninteresting tasks. | Effort regulation |
| | Collaborating with one's peers can help a student clarify course material & gain insights that one may not have acquired on their own. | Peer learning |

SRL is seen as a mechanism to help explain achievement gaps between students and enhance students' achievement (Schunk & Zimmerman, 2012). Numerous recent studies have emphasized the importance of learners' SRL skills for successful learning (Akyol et al., 2010; Alpaslan et al., 2016; Bogdanovic et al., 2015; Liu, 2016; Sadi, 2017; Sungur & Gungoren, 2009; Vrieling et al., 2012). Therefore, it is important to train and encourage students to use SRL strategies. For instance, a teacher can share his goals and plans at the beginning of the course and inform students about the way to carry out the course and the requirements of the learning process (Ozturk & Cakiroglu, 2021). Hence, students can set goals and select strategies to achieve these goals. Liu (2016) argued that a teacher could enhance students' SRL by goal setting and expectations, guiding self-beliefs, enhancing introspection dialogues, connecting abstract concepts, offering feedback, and providing new experiences.

According to Alotaibi et al. (2017), planning and goal setting were the most significant predictors of academic success. Moreover, Wang (2011) claimed that the most important aspect of SRL is self-assessment in which students evaluate their own performance and use the results as a guide for self-regulation.

## Social Cognitive Theory of Self-Regulation

In social cognitive theory, human behavior is extensively motivated and regulated by the ongoing exercise of self-influence. For example, it is not possible for people to change or modify their own behavior and motivation unless they are fully aware of how they perform in any given circumstances and of the short- and long-term consequences of their actions (Bandura, 1991).

Many theoretical frameworks of self-regulation have been developed (Puustinen & Pulkkinen,2001) with many similarities and differences occur in all of them, but most provide supportive evidence for the development of learners' achievement and performance (Al-Rawahi, 2015; Puustinen & Pulkkinen, 2001). One of the well accepted frameworks proposed in the context of science education is Zimmerman's (2000) social cognitive model of self-regulation. This model is based on Bandura's (1986) social cognitive theory. Zimmerman (2000) proposed a three cyclical phase model of SRL: forethought, performance, and self-reflection, as shown in **Figure 1**. The cycle is described, as follows.

The first phase, forethought, includes two processes, namely task analysis and self-motivation. These include goal setting, planning, self-efficacy and goal orientation.

In the second phase, performance, there are two major classes: Self-observation and self-control. Self-observation refers to the use of specific strategies, such as self- instruction, imagery, task strategies and attention focusing.

The third phase, self-reflection, includes self-judgment and self-reaction. In this stage, students evaluate their performance against a standard and criteria. The three phases are interrelated and mutually influencing to form a cycle (Zimmerman & Campillo, 2003).

Zimmerman's (2000) model is considered comprehensive as it offers a theoretical framework that determines what aspects are relevant if we want to improve students' self-regulation (Panadero & Alonso Tapia, 2014). In addition, Nikolaki et al. (2017) argued that the application of educational models for supporting SRL in web-based learning highlights the necessity to provide feedback to check the development of the learner's cognitive processes, which should be done on a cyclical basis and repeated often.

Zimmerman's (2000) model was chosen in the present study because in online learning environments where the teacher's presence is low, learners' ability to self-regulate their own learning becomes a crucial factor in their learning success. In this study, the virtual lab

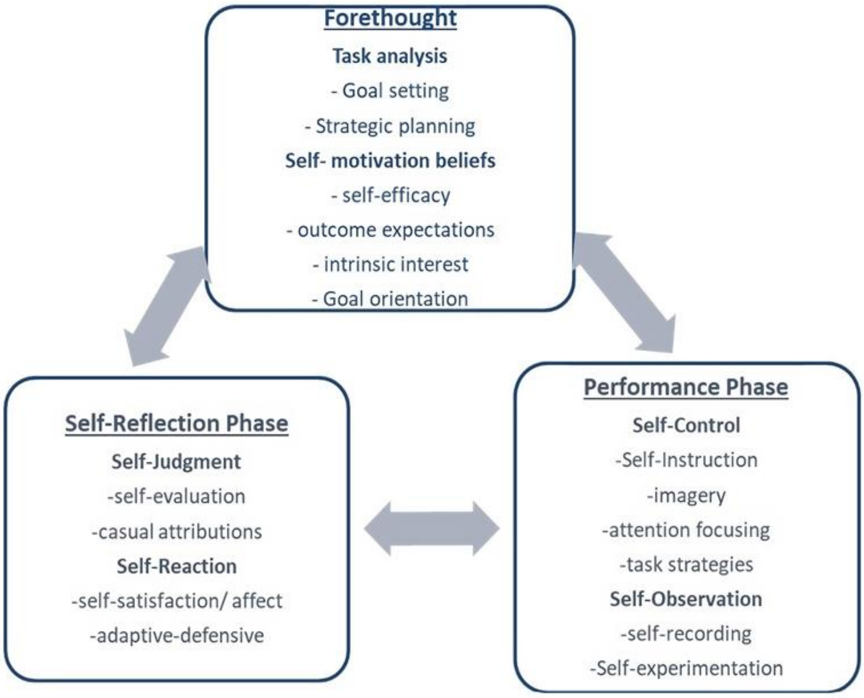


**Figure 1.** A three cyclical phase model of self-regulated learning (Zimmerman, 2000)

features and the instructional procedures can be linked with the three phases (forethought, performance, and self-reflection) to support students in practicing different SRL strategies.

For instance, in the first phase (forethought) students should be aware of the learning goals and try to revise their prior knowledge. Additionally, according to this model, if the students have a clear understanding of the task, they can use specific strategies to perform the task. Thus, the main purpose of the virtual laboratory should be stated clearly on the homepage, and the learning outcomes of each experiment should be defined clearly at the beginning of each activity. In addition, in this phase, the value of the learning topic should be made obvious by relating the topic to the student's daily life. In this regard, Bandura (1991) reported that those who set no goals for themselves achieved no change in effort and were surpassed by those who aimed to match their previous level of effort who, in turn, were outperformed by those who set themselves the more challenging goal of bettering their past endeavor.

During the second phase (performance), it is important that the students maintain their concentration and use appropriate learning strategies (Panadero & Alonso Tapia, 2014). Therefore, the virtual lab should be well-organized and simple to navigate. Subsequently, students will be able to use these tools at their own pace in an iterative manner to allow concepts to be reinforced (Mallory, 2012). Additionally, students can be provided with a guided step-by-step procedure worksheet to carry out the experiments, which enhances inquiry skills and helps them record their ideas. In this phase, students also can take notes while carrying out the experiments and discuss with peers and teachers. These discussions are useful in supporting help-seeking strategies. Moreover, students can have opportunities to repeat the experiments and control variables (inputs) of the experiments.

In addition, students can use self-instruction, which is self-directed orders or descriptions of the task that is being performed (Panadero & Alonso Tapia, 2014). Self-directed learning is a process in which individuals take the initiative to plan, carry out, and evaluate their own learning experiences without the help of others (Zimmerman, 2013). Therefore, the virtual laboratory should be supported with a user manual to guide students how to use the virtual lab successfully. Additionally, students can be provided with a guided step-by-step procedure worksheet to carry out the experiments, which enhances inquiry skills and helps them record their ideas. In this phase, students also can take notes while carrying out the experiments and discuss with peers and teachers. These discussions are useful in supporting help-seeking strategies. Moreover, students can have opportunities to repeat the experiments and control variables (inputs) of the experiments.

During the third phase, self-reflection, students judge their work and formulate reasons for their results (Panadero & Alonso Tapia, 2014). Accordingly, in the virtual lab, students can evaluate their own learning process by doing self-assessment tasks to monitor their thought process and learning outcomes. They can control their learning by themselves through direct feedback from online learning and feedback from the teacher in the synchronous online sessions and the face-to-face classes. Panadero and Alonso Tapia (2014) believed that if the teachers want their students to learn how to self-assess, they should give them the opportunity to reflect on their mistakes.

From the foregoing, in the virtual lab, when students have choices and are allowed to control major aspects of their learning such as what topics to pursue, how and when to study, which emerging learning technologies they want to use, and which outcomes they want to achieve, they are more likely to achieve self-regulation of thinking and learning processes (Zheng, 2016).

### Self-Regulated Learning in Online Environment

Online learning relies extensively on the learner's capacity to control and direct the learning process, both by setting appropriate goals as well as creating and implementing appropriate strategies to achieve them (Nikolaki et al., 2017). Since online learning setting is characterized by learner's autonomy, it should go without saying that SRL must be seen as an important and crucial component for its success.

According to Seyedeh and Masoud (2014), a direct relation exists between information communication technology (ICT) and SRL. Moreover, Onivehu et al. (2018) discovered a significant relationship between ICT utilization and SRL in their study. Besides, they found a significant relationship between ICT utilization, self-regulation (organization, metacognition, elaboration, help-seeking, peer learning, and critical thinking), and academic performance.

Broadbent and Poon (2015) conducted a systematic review to better understand how students could use SRL strategies to succeed academically in the online setting. They examined SRL strategies linked to academic achievements in online contexts from 2004 to December 2014. From the twelve studies, they found out that metacognition, critical thinking, time management, and effort regulation strategies were positively connected with academic performance, whereas organization, elaboration, and rehearsal strategies were shown to be less effective. Similarly, a systematic review carried out by Wong et al. (2019) was aimed to report on approaches to support SRL strategies in online learning environments. The authors discovered ways for SRL to effectively assist online students, considering the fact that each learner benefits differently from each type of support (e.g., feedback, prompts, and an integrated support system). For example, through feedback, students become more aware of their current learning state, thereby taking steps to improve their learning.

Web-based virtual laboratories provide virtual environments in the form of a website via the internet and findings suggest that a web-based learning environment is optimal for supporting SRL. In this study, it is expected that using a web-based virtual laboratory will improve students' SRL. Online students have the self-generated ability to plan, control, and manage their learning actions (Broadbent & Poon, 2015). In their study, Dabbagh and Kitsantas (2005) attempted to highlight previous research findings that different types of web-based pedagogical tools (WBPTs) supported different SRL strategies. They also sought to further explore which WBPTs were most effective in supporting learners' SRL while completing the course assignments. A mixed approaches methodological approach was used, and the sample consisted of 65 students who were enrolled in three distributed courses. Quantitative analyses confirmed that different WBPTs did indeed support different SRL processes. For instance, delivery tools and content creation in WBPT (resources, readings, and assignments/ rubric features) supported SRL processes of help-seeking, task strategies, goal-setting, and self-evaluation. On the other hand, communication and collaborative tools supported help-seeking, time-planning and management, goal setting; administrative tools supported self-evaluation, help-seeking, and self-monitoring, while assessment tools supported self-evaluation, self-monitoring, and task strategies. Moreover, Johnson and Davies (2014) argued that to support and facilitate SRL in an online environment, learners must comprehend the requirements of the task to be finished, the abilities to be demonstrated and the material to be learned. Therefore, teachers can support students' understanding by giving clear instructions and precise directions.

Zheng (2016) conducted meta-analysis research to examine the impacts of SRL scaffolds on academic achievement in computer-based learning settings from 2004 to 2015. With a total sample size of 2,648 students, a total of 29 articles were included in the analysis after meeting the inclusion criteria. The findings of this meta-analysis indicated that SRL scaffolds in computer-based learning environments produced a medium positive effect on academic performance. However, few adaptive scaffolds were used to promote SRL. According to the findings obtained, an online learning environment is best for facilitating SRL. The scaffolds should assist the whole process of SRL, which consists of goal setting, formulating plans, putting strategies into action, and adapting metacognition.

It can be concluded from previous studies that since teachers are not physically present to provide support, online learning requires students to self-regulate their learning. As a result, enhancing SRL strategies and learning outcomes appears to be possible by supporting SRL through the integration of various features into virtual laboratories. For instance, Bhargava et al. (2006) pointed out that virtual laboratories offered learners the chance to work at their own pace. Therefore, virtual laboratories must be easy to use and to navigate (Makransky et al., 2019). Additionally, adding clear instructions is required on how to use the virtual lab, specifically regarding the simulations to manipulate the experiments successfully (Wästberg et al., 2019). Besides, it is crucial for students to be self-aware and mindful of their learning processes, including understanding why they are learning a certain subject and considering the best learning strategies (Delen & Liew, 2016). Moreover, Bahri et al. (2021) and Winters et al. (2008) reported that several different representations of information aid students to gain more information, make them responsible for and control their learning.

Based on the reviewed literature, the following features can be embedded in the web-based virtual laboratories, which can be effective in enhancing SRL strategies:

1. Virtual laboratories must be easy to use and to navigate, so the students can work at their own pace.
2. Clear instructions on how to use the virtual lab should be available.
3. The assessment tools in the virtual lab should provide a clear rubric of how learners will be evaluated, and learners should be able to compare the outcome of their performance with a standard or goal.
4. Instant feedback must be available, so learners become more aware of their current learning state, thereby taking steps to enhance their learning.
5. Additional access to learning resources should be provided.
6. Multiple representations of information that can be controlled by the learner should be available.
7. Students should understand the requirements of the task to be completed. Teachers should support students' understanding by giving them clear instructions and thorough guidelines.
8. Communication and collaboration tools in the virtual lab and the discussion feature allow learners to seek help and self-monitor their learning by reflecting on their progress throughout the discussion period and articulating their understanding at their own pace.

Consequently, based on these features, an attempt has been made in this study to investigate the effect of both the web-based virtual laboratory, which was designed prior to this study, and the physical school laboratory on students' SRL.

### Aim & Research Questions

The aim of this study is to determine the effectiveness of a web-based virtual laboratory in learning electricity on 8th grade students' SRL.

Following research questions further guided study:

1. Is there any significant mean difference in metacognitive self-regulation between 8th graders who learn using web-based virtual lab and those who learn using physical lab to learn electricity?
2. Is there any significant mean difference in self-efficacy for learning and performance between 8th graders who learn using web-based virtual lab and those who learn using physical lab to learn electricity?
3. Is there any significant mean difference in time and study environment between 8th graders who learn using web-based virtual lab and those who learn using physical lab to learn electricity?
4. Is there any significant mean difference in effort regulation between 8th graders who learn using web-based virtual lab and those who learn using physical lab to learn electricity?
5. Is there any significant mean difference in peer learning between 8th graders who learn using web-based virtual lab and those who learn using physical lab to learn electricity?
6. Is there any significant mean difference in SRL overall score between 8th graders who learn using web-based virtual lab and those who learn using physical lab to learn electricity?

## RESEARCH METHODOLOGY

The present study is based on a non-equivalent (pre-/post-test) control-group quasi experimental research design. In this design, the experimental and control groups are selected without random assignment. The random distribution could not be implemented because the research was conducted on existing classes and the investigator had to use naturally formed groups (e.g., a classroom) (Creswell, 2007). The existing classes were those determined by the school administration. That meant that everyone stayed in their original class. To avoid interfering with the natural setting, the researcher did not create a new class with a random distribution concept. Despite the limitations of this design, random selection was used to select the school from the population and existing classes for the control and experimental groups. Furthermore, before the intervention, the homogeneity of the two groups was tested. Both groups underwent pre-test and post-test.

### Participants

The participant of this study comprises of 8th grade students in Al-Batinah South Region schools in Oman. The sample consists of the 8th grade students in one school known as the Basic Education School located in Al-Batinah South Region. Random selection was conducted to select the school from the population and existing classes to choose the control and experimental groups. The sample consists of forty female students aged 14-15 years who participated in the study–20 students in the experimental group and twenty students in the control group.

Schools in the Sultanate of Oman, from grade five and above, are not mixed-gender schools and due to the COVID-19 pandemic, the researcher conducted the study in only one school, which was randomly selected. In addition, gender was not considered as a variable in the research as it was not relevant to the main aim of the current research.

A computer lab with a good internet connection for the study activities is available in the selected school. In addition, all students do not have any pre-experience in the virtual lab. Prior to this study, the researcher obtained informed consent from students and their parents to participate in this study. All the students agreed to participate in this study.

### Instruments to Measure Self-Regulated Learning

To measure students' SRL, this study used the motivated strategies for learning questionnaire (MSLQ), which was developed by Pintrich et al. (1991) and is considered one of the most widely used instruments designed to measure SRL (Jackson, 2018; Zimmerman, 2008).

Pintrich et al. (1991) developed an 81-item self-reporting questionnaire composed of two major sections: Motivation and learning strategies. The motivation section includes three scales: valuing components (task value, extrinsic goal orientation, intrinsic goal orientation), expectancy components (self-efficacy for learning and performance, control beliefs), and affective components (test anxiety). The learning strategies section is further divided into a resource management section, which includes effort regulation, managing time and study environment, help-seeking, and peer learning and a cognitive-metacognitive section, which includes metacognitive self-regulation, critical thinking, elaboration, rehearsal, and organization. Students responded to statements using seven-point ratings that range from 'not at all true of me' to 'very true of me'. Pintrich et al. (1991) reported that "the Cronbach's alphas are robust, ranging from .52 to .93. This indicates that MSLQ shows reasonable factor validity" (p. 809).

Pintrich et al. (1991) reported that depending on the researchers' interest, the scales in MSLQ could be used together or separately. In their study, Triquet et al. (2017) reported that 68 studies exclusively used MSLQ, while 26 studies used parts of MSLQ. According to MSLQ's basic instructions, the students respond based on their beliefs and behavior toward the particular course they enrolled in. Each item was designed to emphasize how specific this course was (for example, "In this course...," "When I study for this course ...") (Vanderstoep et al., 1996).

Therefore, for the purpose of this study, metacognitive self-regulation, effort regulation, managing time and study environment, and peer learning from the learning strategies section as well as self-efficacy for learning and performance from the motivation strategies section were used. The distribution of survey items for each category is shown in **Table 2**.

**Table 2.** Distribution of MSLQ items

| Category | Total items |
|---|---|
| Metacognitive self-regulation | 12 |
| Managing time & study environment | 8 |
| Effort regulation | 4 |
| Peer learning | 3 |
| Self-efficacy for learning & performance | 7 |
| Total | 34 |

The items were scored according to a five-point Likert-like format with one being 'strongly disagree' and five being 'strongly agree'. This research instrument was adopted and translated to Arabic language using back-to-back translations. It was only slightly modified to fit the Omani content and culture. The content validity of the instrument was determined by six experts in educational measurement, psychology, and educational technology. They were asked to review the items and decide on how well they represent the intended content area.

The construct validity of the scale was also verified by applying it to a sample consisting of 66 grade eight students from the Omani public schools and these students were different students than those who were involved in the actual study. The items were calculated for their correlation coefficient of each item with the dimension to which they belong. These values ranged between 0.28-0.76. The correlation coefficient of each dimension with the other dimension and with the total score of the scale was also calculated. These values ranged between 0.36-0.82, and all of them are statistically significant at the significance level 0.05. Additionally, the data obtained were calculated to determine the reliability coefficient of the five constructs of SRL (self-efficacy for learning and performance, metacognitive self-regulation, managing time and study environment, effort regulation, and peer learning). Cronbach's alpha reliability coefficient ranged from 0.61-0.74, which is considered acceptable (Hair et al., 2006). It took participants 20-25 minutes to complete the questionnaire.

### Procedure

Permission to conduct research at the school was obtained, and the duration of the research was nine weeks. During the data collection, Oman observed a strict SOP due to the COVID-19 pandemic. The mode of instruction that the school followed then was blended learning. For instance, a group of classes were taught physically at the school for a week (face-to-face classes). For the following week, the same students were taught remotely (synchronous and asynchronous online classes) using the Google Classroom platform. This situation helped avoid the internal threats related to communication between experimental and control groups to maintain the experiment's integrity. In other words, the virtual lab group and the physical lab group were kept separate from each other since each group attended school physically on different days. Thus, the chances of them meeting were not likely. Moreover, the treatment group was the only one who could access virtual laboratory with their username.

The students and the teacher were given an orientation and training on how to use the virtual lab and lesson plans prepared by the researchers in the first week. At the end of the first week, the pre-test of MSLQ was administered to the experimental group (virtual lab group). The week after, the questionnaire was then administered to the control group (physical lab group).

In the second week, the intervention commenced and lasted for seven weeks (January 10, 2021-February 25, 2021); a total of three hours (180 minutes) per week were spent on class interaction. The researcher observed the intervention for the virtual lab group (VL) and the physical lab group (PL) throughout the period. Both groups were taught by the same science teacher.

The control group (PL) carried out the practical experiments during the week they attended school in the school's laboratory. During the week that they are taught remotely (synchronized online classes), they could not carry out the practical part, and could only do the theoretical part. However, the experimental group was able to carry out the experiments in all the weeks using the virtual laboratory. In all cases, both groups had no learning loss in any unit topics.

The virtual laboratory was linked with the Google Classroom platform to facilitate the process of communicating with experimental group (VL) students during synchronized online classes. After MSLQ was administered as a post-test for both groups.

### Web-Based Virtual Laboratory

The experimental group used the web-based virtual lab. The virtual lab is specially designed and developed to provide an optimal user experience using the local language. For instance, the virtual lab was available to the experimental group students at any time, and they could access the virtual lab's website from home and at school. They can use it either synchronously or asynchronously with their teacher and classmates. The home page includes topics/titles of the practical experiments supported by graphical icons to attract students' attention and facilitate access to the experiment to be carried out (see **Figure 2**).


**Figure 2.** Virtual lab homepage (this picture taken from web-based virtual lab created and own by the first author)

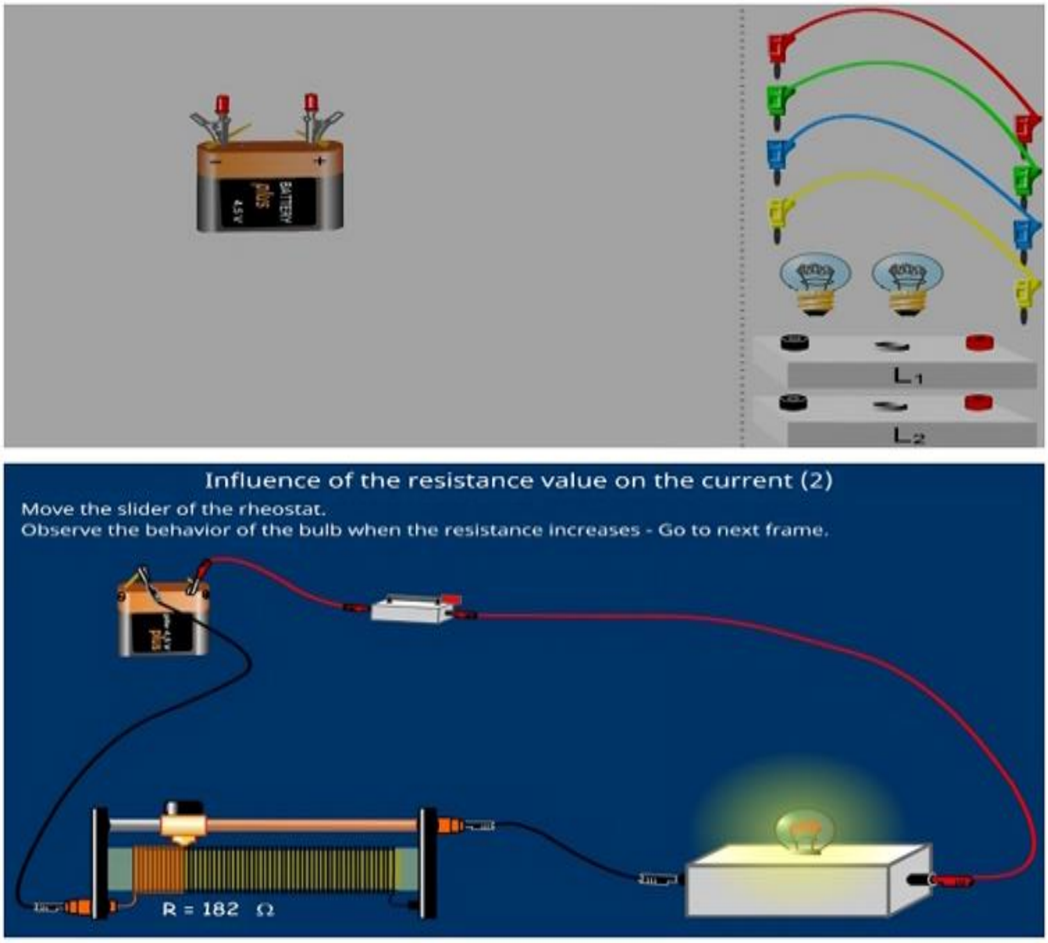


**Figure 3.** Simulations in virtual lab (this picture taken from web-based virtual lab created and own by the first author)

The content of the virtual laboratory was divided into 15 parts according to grade eight science curriculum for the topic "magnetism and electricity unit". Each part contains the following:

- **Simulation:** The learners conduct the experiments by using its components. The simulation's features allowed students to manipulate different variables as well as predict and visualize results. Simulations served as a mini virtual laboratory, particularly when participants predicted the results, manipulated the variables, and collected data in real-time, as shown in **Figure 3**.
- **Learning activities:** A guide to students on how to do the experiment, record the data, and record their findings and explanations. They contained step-by-step procedures to help students perform the experiments and practice different inquiry skills.
- **2D and 3D animation videos:** They illustrate the unit's topics to support the students' understanding.
- **Online self-assessment:** Students can evaluate their understanding a number of times and at any time.
- **Communication tools:** Tools that students can communicate with teacher or classmates via virtual classroom meetings via Google Meet, chat, and email, which are embedded in virtual lab.

To enhance students' learning using the virtual lab, each topic in the virtual lab was presented in a sequence according to the 5Es learning model that guides the teaching and learning processes in science classrooms, leading students through five phases: Engage, explore, explain, elaborate, and evaluate. Students were advised to go through all the phases either individually or within a group with supervision of the teacher. The components of the virtual lab for each topic are shown in **Figure 4**.

Students in the control group, that is the physical laboratory group, went through all these phases, but all the practical activities took place in the school laboratory (physical lab), and the learning activities and the guided instructional materials (worksheets) were printed out for the students. All the experiments were carried out in the usual way hands-on, as shown in **Figure 5**.

### Data Analysis

Data from MSLQ were analyzed using the paired sample t-test. Paired sample t-test was performed to investigate the significant difference between the pre-


**Figure 4.** Virtual lab components (this picture taken from web-based virtual lab created and own by the first author)

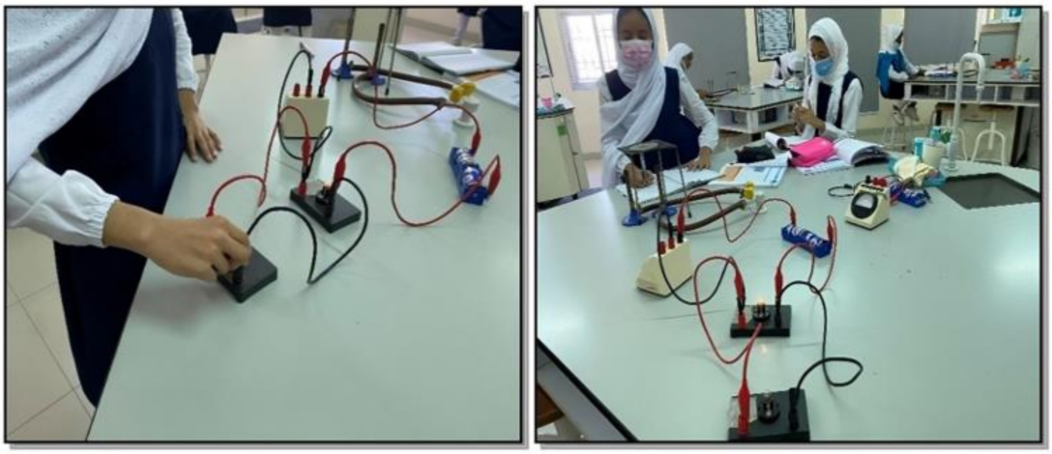

**Figure 5.** Physical laboratory lesson (control group) (this picture is taken and owned by the first author)

and post-test of SRL for both groups. Then, multivariate analysis of variance (MANOVA) was used to determine the significant differences in SRL between the two groups. Alpha level 0.05 was used as the significant level for all the statistical analyses. Finally, assumptions for paired sample t-test and MANOVA were checked. Before the analysis, the normality check was performed on the pre- and post-test data. The Skewness and Kurtosis values ranging from -2 to +2 depict that the data were normally distributed (George & Mallery, 2019).

Cohen's d was used to calculate the effect size to determine the magnitude of the learning gains between groups. The result of the learning gains was interpreted using 0.2 as the small effect size, 0.5 as the medium effect size and 0.8 as the large effect size (Cohen, 1977).

First, descriptive statistics were employed to determine the mean difference between the experimental and control groups in enhancing students' SRL. The data obtained were analyzed to compare the experimental and control groups' mean and standard deviation in the overall score and the five components of SRL (metacognitive self-regulation, self-efficacy for learning and performance, time and study environment, effort regulation and peer learning).

## RESULTS

The result of the descriptive statistics is presented in **Table 3** and **Figure 6** presents the result graphically.

The result shows an improvement in students' SRL from the pre-test in all dimensions of SRL in both groups, except in terms of metacognitive self-regulation dimension in the control group. The mean gain differences in metacognitive self-regulation, self-efficacy for learning and performance, time and study

**Table 3.** Mean (M) & standard deviation (SD) comparison of pre- & post-test result for self-regulated learning (SRL) of experimental & control groups

| SRL components | Group | Pre-test | | Post-test | | Mean gain | Mean difference |
|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | | |
| Metacognitive self-regulation | Control | 3.58 | 0.66 | 3.55 | 0.65 | -0.03 | 0.29 |
| | Experimental | 3.87 | 0.44 | 4.20 | 0.43 | 0.32 | |
| Self-efficacy for learning & performance | Control | 4.11 | 0.83 | 4.22 | 0.79 | 0.11 | 0.23 |
| | Experimental | 4.12 | 0.71 | 4.46 | 0.55 | 0.34 | |
| Time & study environment | Control | 3.86 | 0.87 | 3.91 | 0.81 | 0.05 | 0.17 |
| | Experimental | 3.87 | 0.42 | 4.09 | 0.56 | 0.22 | |
| Effort regulation | Control | 3.83 | 0.91 | 3.86 | 0.91 | 0.03 | 0.39 |
| | Experimental | 3.99 | 0.84 | 4.41 | 0.52 | 0.43 | |
| Peer learning | Control | 3.40 | 0.72 | 3.43 | 0.80 | 0.03 | 0.40 |
| | Experimental | 3.60 | 0.63 | 4.03 | 0.73 | 0.43 | |
| Total | Control | 3.77 | 0.65 | 3.80 | 0.56 | 0.03 | 0.30 |
| | Experimental | 3.91 | 0.44 | 4.24 | 0.40 | 0.33 | |

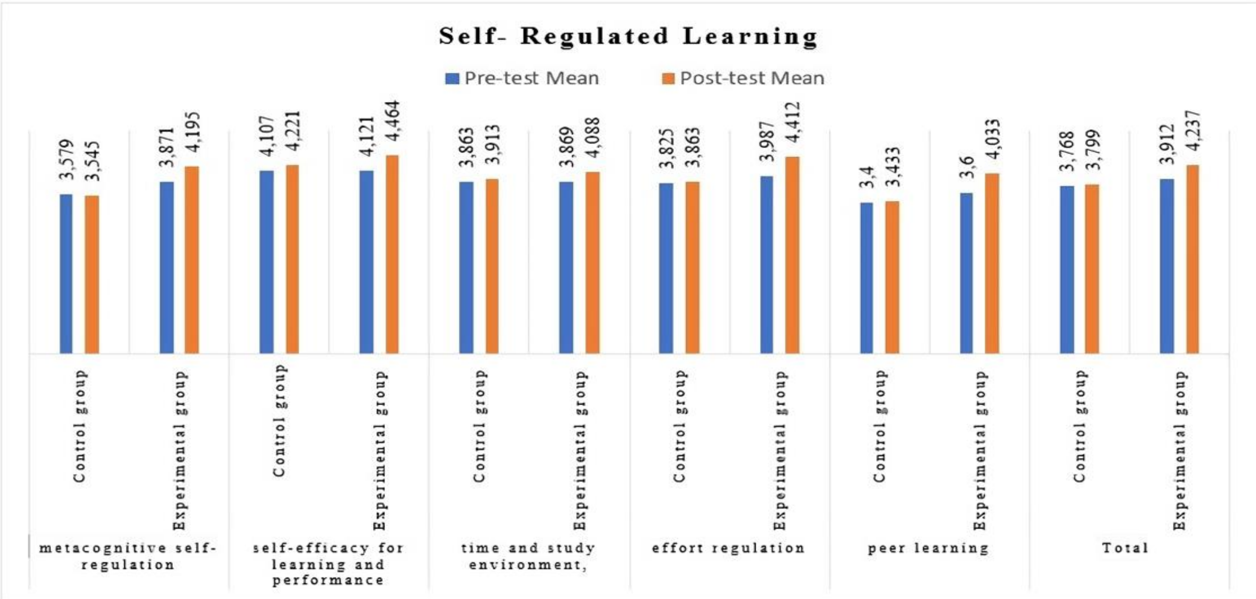


**Figure 6.** Pre- & post-test comparison of experimental & control groups in self-regulated learning (this picture was created and owned by the first author)

**Table 4.** Paired-samples t-test results of experimental & control groups (pre- &d post-test) in MSLQ

| Dependent variable | Group | Pre-test: M (SD) | Post-test: M (SD) | df | t-value | Sig. | d² |
|---|---|---|---|---|---|---|---|
| Metacognitive self-regulation | Control | 3.87 (0.44) | 4.20 (0.43) | 38 | 3.710 | .001 | 1.17 |
| | Experimental | 3.58 (0.66) | 3.55 (0.65) | 38 | 1.640 | .108 | 0.52 |
| Self-efficacy for learning & performance | Control | 4.12 (0.71) | 4.46 (0.55) | 38 | 1.120 | .267 | 0.35 |
| | Experimental | 4.11 (0.83) | 4.22 (0.79) | 38 | .059 | .954 | 0.01 |
| Time & study environment | Control | 3.87 (0.42) | 4.09 (0.56) | 38 | .790 | .432 | 0.24 |
| | Experimental | 3.86 (0. 88) | 3.92 (0.81) | 38 | .029 | .977 | 0.01 |
| Effort regulation | Control | 3.99 (0.84) | 4.41 (0.52) | 38 | 2.350 | .024 | 0.75 |
| | Experimental | 3.83 (0.91) | 3.86 (0.91) | 38 | .589 | .560 | 0.18 |
| Peer learning | Control | 3.60 (0.80) | 4.03 (0.73) | 38 | 2.490 | .017 | 0.79 |
| | Experimental | 3.40 (0.63) | 3.43 (0.80) | 38 | .930 | .356 | 0.28 |
| Total | Control | 3.91 (0.44) | 4.24 (0.40) | 38 | 2.870 | .007 | 0.91 |
| | Experimental | 3.77 (0.65) | 3.80 (0.56) | 38 | .817 | .419 | 0.25 |

Note. *Significance at (α≤0.05)

environment, effort regulation, peer learning, and overall SRL between the experimental and control groups are in favor of the experimental group thus indicated that the virtual laboratory enhanced students' SRL greater than the physical laboratory.

The significant differences between the pre-test and post-test of overall and five components of SRL for both groups were calculated using paired-samples t-test. The findings are shown in **Table 4**.

**Table 5.** Tests of between subjects effects of experimental & control groups in self-regulated learning in post-test

| Dependent variable | Type III sum of squares | df | Mean square | F | p-value | Partial η² |
|---|---|---|---|---|---|---|
| Metacognitive self-regulation | 4.23 | 1 | 4.23 | 13.77 | 0.001 | 0.266 |
| Self-efficacy for learning & performance | 0.59 | 1 | 0.59 | 1.27 | 0.267 | 0.032 |
| Time & study environment | 0.31 | 1 | 0.31 | 0.63 | 0.432 | 0.016 |
| Effort regulation | 3.03 | 1 | 3.03 | 5.55 | .024 | 0.127 |
| Peer learning | 3.60 | 1 | 3.60 | 6.22 | .017 | 0.141 |
| Total | 1.92 | 1 | 1.92 | 8.25 | .007 | 0.178 |

Note. *Significance at (α≤0.05)

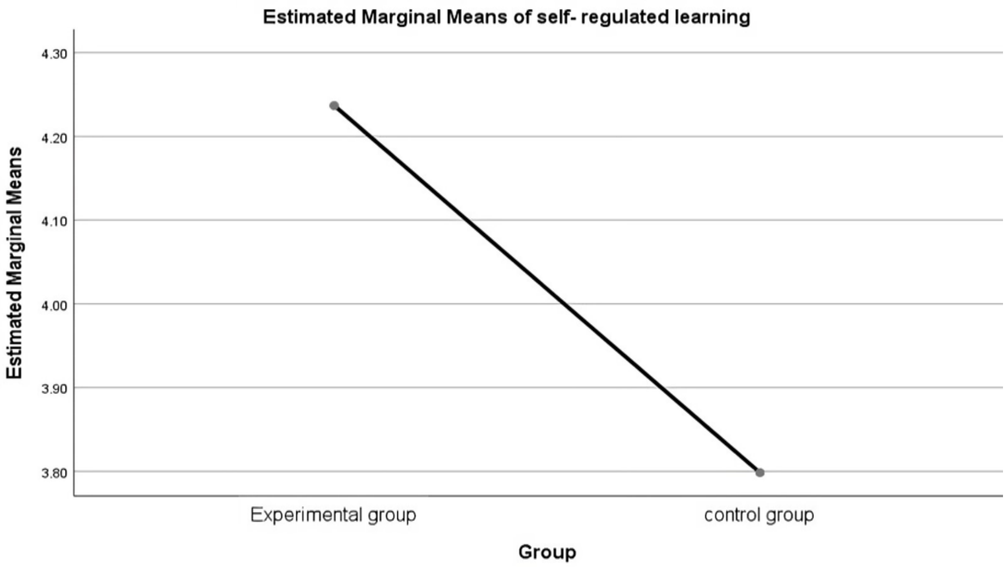


**Figure 7.** Estimated marginal means of self-regulated learning for control & experimental groups in post-test (this picture was created and owned by the first author)

**Table 4** shows that statistically significant differences exist between the pre- and post-test mean scores of the experimental group in three dimensions of SRL: Metacognitive self-regulation, effort regulation, peer learning; however, there is no significant difference between the pre- and post-test mean score of the experimental group in two dimensions of SRL: Self-efficacy for learning and performance; and time and study environment. On the other hand, there is no significant mean difference that can be observed between the pre- and post-test mean score of the control group in all dimensions of SRL.

Accordingly, there was a significant mean difference between the pre- and post-test in overall SRL of the experimental group, with the overall effect size of experimental group ($d^2$=0.9112) indicating a large effect size. This result indicates that the virtual laboratory has a large effect size in enhancing students' SRL.

To investigate the significance of the differences between the two groups, one-way MANOVA was applied. Findings are presented in **Table 5**. These findings demonstrate a significant difference between the experimental and control groups in metacognitive self-regulation, effort regulation and peer learning components and the overall SRL score.

However, the result shows that there was no significant difference between the experimental and control groups in self-efficacy for learning and performance, and time and study environment dimensions. Additionally, **Table 5** shows that the effect size of using a virtual laboratory for the study sample is large. 17.8% (partial $\eta^2$=0.178) of the total variation of the dependent variable (SRL improvement levels) is because of the independent variable (using the virtual lab). This percentage is higher than the one set by Cohen (15.0% or more) to consider the effect size of the independent variable on the dependent variable as large. Overall SRL estimated means is highlighted and shown in **Figure 7**.

**Figure 6** shows the overall estimated marginal means of virtual laboratory group and physical laboratory group in MSLQ post-test score, which indicates that the virtual laboratory was more effective in enhancing students' SRL than the physical laboratory group among 8th grade students.

## FINDINGS & DISCUSSION

This study investigated the effects of using a virtual laboratory on grade eight students' SRL. The result has shown an improvement in students' SRL from the pre-test in all dimensions of SRL in both groups, except in terms of metacognitive self-regulation dimension in the control group. However, the experimental group's SRL proved to be significantly better than the control group, showing that the students gained from learning in a virtual environment. Therefore, it was concluded that the virtual laboratory was more effective in enhancing students' SRL among the sample of the population than the physical laboratory.

This finding is well supported by different scholars and researchers who reported that virtual technologies and online learning enhanced students' SRL (Bahri et al., 2021; Dabbagh & Kitsantas, 2005; Schraw, 2007; Wang, 2011). Seyedeh and Masoud (2014) maintained that there is a direct relationship between ICT and SRL. Additionally, Onivehu et al. (2018) in their study found that there was a significant relationship between ICT utilization and SRL.

On the other hand, this study is not consistent with the results of Shen and Liu (2011). The purpose of their study was to design a web-based metacognitive skill training and further investigate its effects on learning metacognitive skills by employing a quasi-experimental pre-/post-test design. The results showed that there were no significant differences among the experimental group students in self-monitoring, self-modifying, self-evaluation, and the total score of the metacognitive skills evaluation questionnaire. The researchers justified this finding by pointing out that there was insufficient time to incorporate the cognitive processes including self-judgment, self-observation, and self-reaction that should always be included in the design of web-based training. However, in the present study, the web-based virtual lab was developed in a way that encouraged students to self-evaluate their learning.

There are many reasons behind the improvement in SRL for students who used the virtual laboratory that could be attributed to features embedded in the current study's virtual laboratory. Based on the suggestions of Zimmerman (2002), this study embedded various features in the virtual lab to facilitate learners in using self-regulatory learning behaviours to perform SRL. These features could enhance students' SRL strategies, such as goal orientation, metacognition, self-recording, self-experimentation, peer learning, self-efficacy, time management, feedback, effort regulation, and self-evaluation. It is worth acknowledging that different features in the virtual laboratory supported different SRL strategies.

For instance, this virtual laboratory was available to students online and therefore available anywhere and anytime and at their own pace; in other words, it improved their skills of self-instruction and self-efficacy. This argument is in line with Bhargava et al. (2006) who pointed out that virtual laboratories offer learners the chance to work at their own pace. In addition, the students used the virtual laboratory in three different ways: attending physically in the school computer lab with their teacher and classmates (about 50.0%), attending synchronous online sessions through Google Meet (about 40.0%), and asynchronous (about 10.0%) online sessions.

Although, it is recommended that the virtual lab practice sessions should be done together with the teacher since it is aimed to make the students understand how to obtain the data (Maulidah & Prima, 2018). However, sometimes the teacher does instruct the students to explore the virtual lab by themselves, carry out some experiments in asynchronous online sessions, and submit the learning activities of these experiments. Therefore, it can be said that learning using the virtual lab could enhance students' skills of self-instruction, self-recording, self-experimentation, and self-efficacy. This agrees with the findings of Makransky et al. (2019), who found that on the learning outcome test, students who were given the virtual biology laboratory simulation to complete at home on their own in an informal environment did just as well as those who utilised it in a formal classroom environment under a teacher's supervision.

In addition, Wästberg et al. (2019) reported that, in virtual manipulation, it is important to have a step-by-step procedure to follow to produce an observation that requires interpretation. In the present study, students were provided with guided instructional materials that contained step-by-step procedures to carry out the experiment and help students to practice different inquiry skills and record their ideas. These guided instructional materials were intended to be self-instructive learning to support students' self-instruction, effort regulation, and attention focusing. This was also supported by Efstathiou et al. (2018), who reported that the structure of the learning activity (worksheet) related to each experiment should be designed by breaking an experiment process into smaller, more easily manageable sub-processes to support students in designing experiments.

The positive findings in this study could also be interpreted as the result of the student's ability to use the virtual laboratory effectively and independently. Makransky et al. (2019) claimed that a virtual laboratory must be easy to use and navigate. In this study, the virtual laboratory homepage contained a well-labelled and clearly defined menu of contents to enable students to access any topic and perform any tasks in the virtual laboratory easily. Students could decide what to do next by navigating around the virtual lab and the website at their own pace, thereby developing their skills of effort regulation, attention focusing, and self-instruction.

Furthermore, Wästberg et al. (2019) reported that the purpose of the virtual laboratory and the context for its use should be very clear. It is crucial for students to be self-aware and mindful of their learning processes, including understanding why they are learning a certain subject and considering the best learning strategies (Delen & Liew, 2016). Thus, the main purpose of the current study's virtual laboratory was stated clearly on the homepage, and the learning outcomes of each experiment were defined clearly at the beginning of learning materials activities, hereby focusing on the skills of goal orientation and metacognition. This finding was in line with Johnson and Davies' (2014) who pointed out that students tend to be more motivated when they have reasonable obtainable goals to work toward than those who do not. This was also supported by Delen and Liew (2016), who argued that students who are aware of their learning goals can choose the most suitable self-regulation strategies to achieve those goals.

In this virtual lab, there was a combination of text, images, videos, and simulations as learning resources for students and a wide variety of activities, such as learning activities, self-assessment tasks, and chats. These multiple representations are particularly useful in supporting help-seeking skill (Dabbagh & Kitsantas, 2005). This finding is supported by earlier findings of Bahri et al. (2021) and Winters et al. (2008), who reported that several different representations of information aid students to gain more information, make them responsible for their learning and control their learning.

Another feature that was embedded in the Virtual Lab in this study is interactivity. According to Delen and Liew (2016), interactivity in online learning environments encourage learners to engage in self-regulatory behaviours. Moreover, it is essential that instructional designers create learning environments with interactivity in mind to provide students the chance to become actively involved in their learning and to spend more time on it, resulting in improved or significantly improved learning outcomes (Delen et al., 2014). In this study's virtual lab, there were different forms of interactivity to encourage learners to practice SRL strategies, including two-way communication, collaboration, control, navigation, self-assessment tasks, and instant feedback.

Firstly, two-way communication was achieved through various means of communication, such as classroom virtual meetings, chat, and email embedded within the virtual laboratory. For instance, students did many practical activities with their teacher in synchronous lessons via Google Meet. These features could have helped students to practice their skills of peer learning and goal orientation (Maulidah & Prima, 2018).

Secondly, students could navigate the virtual lab website at their own pace. They were also able to go through the virtual lab materials multiple times. Such features are useful for students to develop their skills of self-instruction, self-efficacy, time, and study environment management. This is supported by Wang (2011), who said in his report that e-learning environments require learners to learn independently. This finding is also supported by Winters et al. (2008), who found that there is a relation between the levels of learner control in online learning and their SRL.

Thirdly, there are other features of interactivity in this virtual lab that were embedded from which students could learn and use to become active and self-directed in their learning, such as self-assessment tasks and instant feedback. Such features are useful for learners to apply reinforcement and correction to improve learning and performance (Delen & Liew, 2016).

According to social cognitive theory, human behaviour is extensively motivated and regulated by the ongoing exercise of self-influence; moreover, people cannot influence their own motivation and actions very well if they do not pay adequate attention to their own performances, the conditions under which they occur, and the immediate and distal effects they produce (Bandura, 1991). Thus, in this study's virtual lab, students evaluated their own learning process by filling out the self-assessment form to monitor their thought processes and learning outcomes. They could control their learning by themselves through direct feedback from the online learning activities in addition to feedback from the teacher in the synchronous online sessions and face-to-face classes. This was supported by Wang (2011), who pointed out that in online learning, learners can evaluate their own performance, and the results of self-evaluation can serve as references for self-regulation. This is also in line with the findings of Johnson and Davies (2014), who claimed that such continuous evaluation allows students to modify their plans and strategies, as required. Therefore, it could be concluded that using the virtual laboratory had a positive impact on improving students' SRL.

### Limitations

The duration applied in the current study on students was slightly short. A nine-week period might not be enough to make a significant impact on all the components of SRL and participants could have benefitted from a longer time frame. In addition, all of the participants in this study were female students between the ages of 14 and 15. This might restrict the generalizability of our findings to a larger population. Future research could assess whether a virtual lab for male and female students of different ages and from different schools is effective.

The current study was limited in its quantitative findings that explore the effectiveness of virtual labs and further investigation may be needed using qualitative methods. For instance, SRL was measured using a self-report questionnaire, whereas qualitative research methods like video analysis and classroom observation can support the current findings.

## CONCLUSIONS, RECOMMENDATIONS, & IMPLICATION

This study examines the effects of using a virtual lab on SRL of 8th grade students and explains how the virtual lab enhanced students' SRL more than the physical lab. This finding can be linked to the study's virtual lab features. For instance, the virtual lab was available online and students could use it when and where they wanted to and at their own pace. Moreover, there were different forms of interactivity to encourage learners to practice SRL strategies, including two-way communication, collaboration, control, navigation, self-assessment tasks, and instant feedback. Consequently, the virtual laboratory can be employed by teachers to encourage students' SRL.

Teachers may find virtual labs a valuable resource that can be used whenever needed to fill the gap and overcome obstacles that occur when using a physical lab. In addition, it is recommended that teachers should try to establish a classroom environment that facilitates and improves students' SRL in their classes. From a teaching point of view, teachers should provide students with activities that encourage them to explore, develop and refine their own ideas, strategies, and techniques. The role of the teacher should be a facilitator rather than a dispenser of information.

Further research should be carried out with other students at different educational levels to establish whether the results of this study can be generalised to other research populations. Further research could consider the extension of the study for the whole 16-week semester, or even for the whole school year. Moreover, these findings need further investigation by using think-aloud interviews. Moreover, the present study can be extended by including variables, such as critical thinking skills and inquiry skills.

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**Ethical statement:** The authors stated that the study does not require any ethical approval. permission to conduct this research has been granted by Ministry of Education, Oman and school administration. Furthermore, the researchers obtained informed consent from students and their parents to participate in this study.

**Declaration of interest:** No conflict of interest is declared by authors.

**Data sharing statement:** Data supporting the findings and conclusions are available upon request from the corresponding author.

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