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THE GAINS, ISSUES, AND OPPORTUNITIES IN THE INTEGRATION OF VIRTUAL LABORATORY IN SCHOOL SCIENCE LABORATORY

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ABSTRACT

Virtual world seems to be taking on the physical world, and the education as it seeks to be dynamic and relevant to the current trends in ICT is also going through changes and advances. In the field of science pedagogy for instance, virtual laboratories and simulations are gaining ground through its facets of cutting-edge "real-like" augmentation of science experimentation and concept formation. This paper explores the possibility of using this technology in the school science classrooms of developing countries such as the Philippines. The paper used the systematic literature method to identify the theoretical underpinnings, gains, issues, and potential of virtual laboratory integration to school science laboratory. The reviewed literatures were synthesized, and the researchers found out that majority of virtual simulations used in education rely on the theoretical embodiment of experiential and constructivist learning approach particularly in guided inquiry-based science pedagogy. The paper also listed issues in the integration of virtual laboratories which are cognitive overload; critical formative assessment applications on virtual set-up; and inadequate resources. It was then concluded that the virtual laboratory integrations provides both advantages and disadvantages to science learning, hence, such integration shall be done with careful consideration to accommodate both the gains and issues. The findings of the paper also lead to the recommendation to not make virtual laboratories as substitutes but as a complementary tool to improve science learning in an actual science lab. Virtual laboratory integration shall only be done to accommodate difficult and improbable science activities such as those that are in a molecular scale.

KEYWORDS: ***Science Education, Science and Technology, Educational Technology, Virtual Laboratory, Computer Simulation, Gains, Issues, Potential of School Science Laboratory Integration, Philippines School Science Laboratory Integration***

INTRODUCTION

Education is progressing at a quicker stride than any other age in latest account (Google for Education, 2019). Because of this, it is vital for educators to stay abreast with the latest trend and emerging technologies that is being used in a 21st century classroom, especially in the new normal face to face learning brought about by the COVID-19 Pandemic. Learners of the 21st century are considered digital citizens; these learners are immersed with gadgets and computer tools from the day that they were born up to the day that they learn how to write and read. Thus, education shifts to keep up with the language of learning that these learners speak to further develop and educate these learners and help them be ready for the 21st century challenges and future careers.

Today, educational systems across the globe are undergoing efforts to move beyond the ways they operated at the beginning of the 20th century (Light, Pierson & Price, 2011), from traditional instructional practices, educators have gone through the efforts of incorporating different technology in the various teaching and learning process. The use of technology in education not only enhances the participation of students in the teaching and learning process, but also helps the teachers in saving time, effort, and resources in doing various task involved inside the classroom. The global pandemic even boosted the need for the said movement.

In science education, one important aspect of teaching and learning process where technology can extensively be used is through the integration of virtual laboratories. Web-based laboratories, also known as virtual laboratories, or simply virtual labs, or *cyberlabs*, have become complementary and, in some cases, alternatives to physical labs (Budnu, 2002). Virtual labs have become alternative to physical laboratories because of new emerging technologies such as computer graphics, augmented reality, computational dynamics, and virtual worlds that can overcome some of the potential difficulties in traditional physical laboratories (Potkonjak et al, 2016). Furthermore, virtual labs can be a central element in institutional efforts of expanding access to lab-based learning to more and various

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types of students, as well as efforts to establish contingency plans for natural disasters or other interruptions of campus activities (Bandillo & Londino-Smolar, 2020.)

In lieu of these conditions, virtual laboratories were beginning to be integrated in schools across the world including the schools in the Philippines where according to the study of Abas and Marasigan (2020), many public schools are challenged by the lack of physical science laboratory facilities and equipment, including learning materials. Consequently, the researchers who were science educators in the said country were compelled to explore the gains, issues, and opportunities in the integration of the said technology in the school science laboratories. The findings of the study could extend a basis in proper integration and use of the said technology in teaching and learning sciences for Filipino students.

OBJECTIVES

This paper explores and analyzes the gains, issues, and opportunities in the integration of virtual laboratory in the school science laboratories, utilizing the systematic literature review method. Specifically, this paper sought to answer the following research questions:

1) What are the theoretical underpinnings of virtual laboratory use in science education?
2) What are the gains from integrating virtual laboratories in school science laboratory?
3) What are the issues on integrating virtual laboratory in school science laboratory?
4) Given the advantages and disadvantages, what is the potential of virtual laboratory integration in school science laboratory?

METHODOLOGY

This paper employed the systematic literature review method of investigation. In this method, the researchers addressed specific research questions; and then identified, appraised, selected, and synthesized high-quality research evidence and arguments pertinent to those questions. In principle, a systematic literature review means "research about research" and applies the same process of reviewing literature that is normally done in primary research papers.

In this investigation, the Google Scholar search engine was used as the research tool. Such was utilized because the search engine contains repositories of quality and relevant educational research. Four combinations of search terms were used in browsing for appropriate literature to wit "virtual laboratory", "school science laboratory integration", "pros and cons", and "theoretical underpinnings". There were at least 18, 700 potentially relevant hits in all search results using at least three combinations of the keywords chosen, and so, the dataset was filtered to ten manuscripts based on the following criteria: 1) the articles must be written in English; 2) they must be studies and or conceptual manuscripts, and 3) they must be papers published in the last 10 years locally or internationally.

All 10 studies were thoroughly reviewed based on this paper's research questions. Each virtual lab's theoretical underpinnings were described in-detail to fulfill the first research question. Also, each virtual lab's studies about gains, the issues encountered by the said technology integration, and the challenges posed to involved stakeholders were elaborated to answer the second and third research questions. Lastly, inferences from the researchers, mainly covering each virtual lab's findings for potential school science laboratory integration in the future were identified to satisfy the fourth research question.

RESULTS AND DISCUSSION

Virtual Worlds developed to be an important tool in modern education practices as well as providing socialization, entertainment, and a laboratory for collaborative work (Duncan & Jiang, 2012); hence virtual laboratories (Vlab) are gaining grounds in the field of education, more so in the field of science.

Theoretical Underpinnings of using Vlab. Different pedagogical and andragogical approaches and theories determine the underlying concept of using Vlabs in the context of science education. Researches, mostly foreign have identified various theories and framework as viewing lenses in understanding the "how" and "why" of integrating the virtual reality or virtual "world" in the educative process.

For instance, the study of Duncan and Jiang (2012) analyzed the uses of virtual worlds for education in order to derive a taxonomical classification. The result of the said research included a figure to better understand the categorization of usage of virtual worlds in terms of education.

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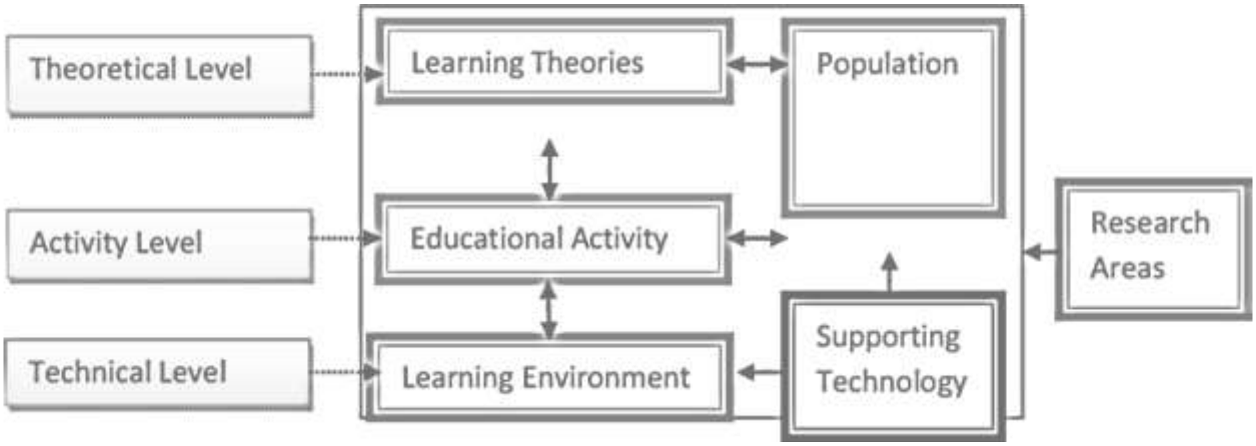

Figure 1. Duncan and Jiang's (2012) Hierarchy Relationships Between Categories Within the Taxonomy of Virtual World Usage in Education

There are six categories under the taxonomy of virtual world usage in education according to Duncan and Jiang (2012), these are population, educational activity, learning theory, learning environment, supporting technologies and research. These categories as can be learned from the figure were further classified as to theoretical, activity and technical levels. Moreover, the research established that the *population* identifies "who" the users are and on what specific discipline will the virtual world be used, the *education activities* identify "what" type of activities are the users performing, the *learning theories* identify "why" the users are doing particular activities, the *learning environment* identify "where" does the users seem to work on the activities, the *supporting technology* identifies "how" the system supports the users, lastly, the *research area* identifies other cases of learning specific research such as investigation on usability, grading or evaluation.

Consequently upon application of the mentioned taxonomy in Vlab, the population will cater science educators and students, the educational activities involved simulations and computer augmentation of laboratory science procedures, the learning environment of Vlab would be inside a simulated, digitized or virtual science laboratories where scientific apparatuses are present, the available supporting technology of Vlab are usually internet capable electronic and smart devices including its accessories such as desktop computers, mouse and headset.

On the other hand, to elaborate further on the learning theories involved in Vlab integration to science education, Duncan and Jiang (2012) mentioned that it was not surprising to note that the constructivist techniques such as problem-based learning and collaboration are collective practices used in virtual world education as these kinds of educational integrations allow experiential learning. The cited researchers also reiterated that there are still areas or research gaps that need to be addressed to appropriate and evaluate the blended learning resulting from virtual and real-world classroom and laboratories. Furthermore, the researchers claimed that one of the major motivations of using the virtual worlds in education is to support experiential learning, as time, cost, and place post challenges in achieving real world experiences that are vital to a meaningful learning experience, especially in science.

Supporting the above-mentioned claims on the experiential learning that underlies one of the education applications of Vlab is the study conducted by Konak, Clark, & Nasereddin (2014), which uses Kolb's experiential learning cycle to improve student learning in virtual computer laboratories. The study also presented a figure that illustrates the four stages of Kolb's experiential learning.

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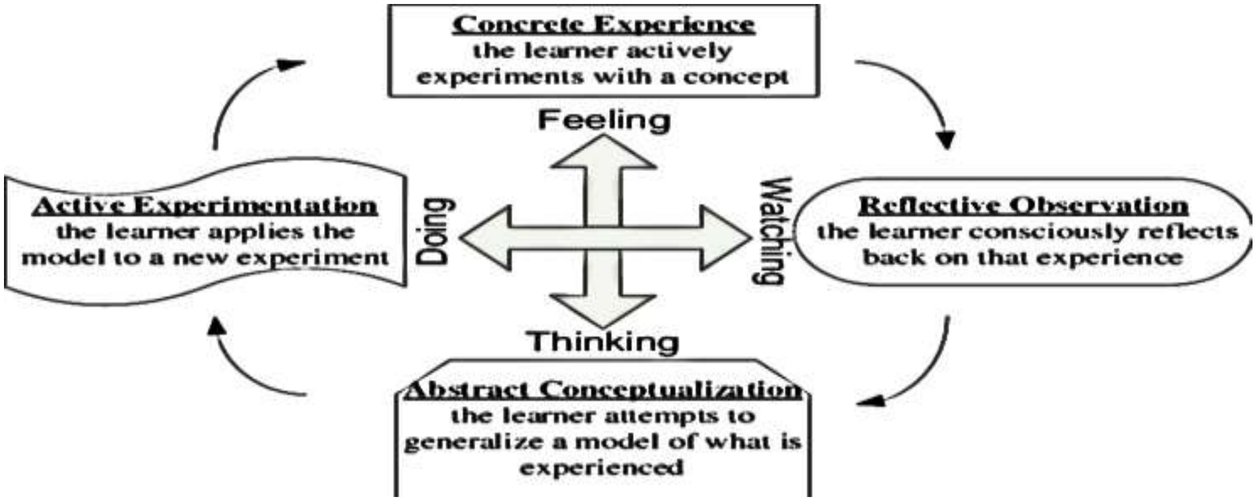

Figure 2: Konak, Clark, & Nasereddin's (2014) Four stages of the Kolb's Experiential Learning Cycle

The four stages of the Kolb's experiential learning cycle as mentioned by Konak, Clark, & Naserradin (2014) are *Concrete Experience (CE)* where a learner "feels" the learning experience through actively experimenting with a concept, *Reflective Observation (RO)* where a learner "watches" the learning experience by consciously reflecting back on that learning experience, *Abstract Conceptualization (AC)* where a learner "thinks" about the learning experience as the learner attempts to generalize a model of what is experienced, and *Active Experimentation (AE)* where a learner "does" the learning experience by applying the model to a new experiment.

The Kolb's learning cycle though has an integrated and connected stages, require completion of the whole cycle for an effective learning to take place. Vlabs can offer these kinds of experimentation and learning experiences when physical labs cannot due to some circumstances and factors such as safety, availability of resources and geographic or distance barriers.

In addition, as mentioned in the study of Brinson (2015), the supposition that only the physical operation or actual manipulation of objects can improve learning is not vital in either constructivist or cognitive learning theories as cognitive theory put emphases on the need for learners to actively process information and practice the target skill. Brinson (2015) also synthesized that neither a theoretical nor empirical justification exists that describes physical manipulation of objects as a condition for active processing and practice except when the focus skill is perceptual motor.

Accordingly, the presented pedagogical and andragogical underpinnings warrant the practicality and demand for Vlab in science education as it provides a meaningful, experiential, and convenient complementary material for actual science laboratories. Particularly as virtual laboratory technology is steadily progressing to be more manipulative, interactive, and "real", more so now that the future of technology is promising (Brinson, 2015).

Gains of Vlab Integration to School Science Laboratories. Technological advances have bridged and elevated various facets of today's living, and education is not an exemption. In terms of general science pedagogy, there are studies which offered evidence that Non-Traditional Learning (NTL) which includes virtual and remote learning were equally or more effective than the Traditional Learning (TL) at enabling use of the constructivist approach to teaching and learning which highlighted the importance of learners taking an active role in their own learning (Brinson, 2015).

In the comparative empirical study conducted by Brinson (2015), the KIPPAS categories of intended outcomes for laboratory learning were proven to be achievable at an equal or greater frequency with NTL/Vlab learning compared with the traditional labs. The mentioned KIPPAS categories are enumerated as Knowledge and Understanding, Inquiry Skills, Practical Skills, Perception, Analytical Skills, and Social and Scientific Communication. Moreover, as cited in the same study according to US's Department of Education, classes that integrated Vlab(NTL) with traditional learning were found to produce higher measure of outcomes than traditional techniques alone. These integrated conditions included additional learning time and instructional elements not received by students in another set-up. However, it is important to note that the positive effects associated with the integration should not necessarily be automatically attributed to the Vlab or media alone, but the integration is noted to be of one factor.

Even so, some conditions demand integration of Vlab integration, in fact, research documents how students struggle to explain observable phenomena with molecular level behaviors through traditional classroom and laboratory set-up. Even if physical laboratory experiences enable students to interact with observable scientific phenomena, the learners often fail to make connections with underlying molecular level behaviors (Chiu, DeJaegher & Chao, 2015). Vlab on the other hand may provide experiences and computer-based visualizations that will enable students to interact with unobservable scientific concepts.

To prove the claim, Chiu, DeJaegher, & Chao (2015) investigated on how Vlab integration improve the learning experiences of middle school students in understanding of gas properties at a molecular level. The researchers used FRAME, a sensor augmented Vlab that utilizes sensors as physical inputs to control scientific simulations. Through this Vlab integration, students experience direct involvement in experimenting with gas molecules. An example presented in the previously cited paper is when the learners put jars filled with warm water close to a temperature sensor to increase the temperature of the simulated gas, and the students can also manually push on the Frame to increase force on the force sensor which is then connected to the virtual piston in the simulation. Students can even manipulate the number of molecules in the simulation through a physical pump. These examples demonstrated how the simulation component of the FRAME offers an active conceptualization of molecular level behaviors through interactive components of augmented reality and application of Vlab which is not possible with traditional laboratories alone.

It is then expected that the results upon application of qualitative and quantitative analyses of data of the mentioned study above established that students using FRAME lab made progress developing molecular-level explanations of gas behavior and refining alternative and partial ideas into normative ideas about gases (Chiu, DeJaegher & Chao, 2015). This goes to say that technology-based integration of Vlab to the classroom science laboratories have been proven to step-up students 'conceptualization and learning outcomes.

Another gain worthy of mention through which Vlab integration to school science laboratories can be reflected is the support that it will provide to teachers' practices. The design and revisions of the technology were guided by the overall goal for use in authentic classrooms with teachers playing a large role in the design and refinement of the technologies (Chiu, DeJaegher & Chao, 2015). As the augmented Vlab proved to be generally beneficial for learning with some specific learning goals, teachers may apply for localization and specification of some learning outcomes as deemed necessary by the curriculum.

Vlab as part of educational technology was proven to boost the educational experience of both the teachers and the learners by various studies conducted to measure its effectiveness and applications such as those that were stated on this paper. The technological advantages of integrating Vlab to actual laboratories in school enhanced understanding of abstract concepts while the teachers still maintain the facilitation and control of the learning environment.

Issues of Vlab Integration to School Science Laboratories. Innovations in education like Vlab face challenges, issues and concerns upon its implementation and integration. It is inevitable for a practice, program, and material to face problems, but problems become solvable if dealt properly. In this regard, the researchers have synthesized the paramount issues facing Vlab integration, amongst these issues were availability of resources, critical application of formative assessment and cognitive overload for pure virtual utilization using virtual reality technologies.

Educators and advocates see technology as the panacea that has supported large portions of the developed countries in remote learning (Gamage et al, 2020). Indeed, technology allowed virtual classrooms and virtual learning managements systems including Vlab to become solutions that were rightly focused in delivering remote laboratory activities. However, still according to the study conducted by Gamage et al (2020) about online delivery of learning and laboratory practices that were used during pandemic, access to the resources such as internet and computers is far from equal across the world since only 19% of individuals in the least-developed countries have access to the said resources that will allow Vlab integration both in school science laboratories and remote or distant learning cases.

The cited study above highlighted the digital divide between developed and developing countries like the Philippines, the challenges in providing enough and cutting-edge resources for the use of the Vlab to school science laboratories must be one of the factors to consider in making sure that no single learner was left behind through the process of the said integration. It was also previously mentioned that many public schools in the Philippines are challenged by the lack of physical science laboratory facilities and equipment (Abas & Marasigan, 2020), hence this factor in the Vlab integration posit a weighing option of which resources will be more readily available and easier to find solution.

Another issue that needs to be solved is the challenge for the teachers in performing the formative assessment in both online and blended learning. As cited in the study of Purkayastha, et al (2019), formative assessments often know as "assessment for learning" are "high-impact instructional practice" that is an effective intervention to increase students understanding as it provides feedback during the process of learning. The study continued to assert that this type of assessment becomes challenging due to the differences in space-time between the teacher and the learners, trustworthiness and even lack of interaction in the formative assessment during Vlab integration. However, the said study also affirmed that this issue could be dealt with innovation in e-learning tools as well as processes for communication between the learners and the teachers.

For instance, still in the study of Purkayastha, et al (2019), the researchers developed Cyber POGIL (Process-Oriented Guided Inquiry Learning) a cyber formative assessment alternative which monitors the students' performances and activities through remote or blended learning. The study theorized that usual critical components of the teacher as a facilitator, specific POGIL activities that teach process skills, critical thinking and team-based learning strategies should be implemented in Cyber POGIL which may help in allowing

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active learning despite challenges in early assessment or formative assessment which is a call for the progression of the guided inquiry learning pedagogy in the future.

These development and studies showed how one challenge can be a point for another innovation which means that the issues in integration of Vlab also caters for an opportunity to present solutions that will accommodate the improvement of the current situation and event relevant to the educational innovation presented. Usually, factors and issues that were identified for the Vlab were coincided with probable solutions that will help manage and resolve the difficulties and challenges concerning the application of the said technology to the school science laboratories.

However, the proceeding reviewed study is in contrasts with the previously showcased gains of Vlab integration. The experimental study of Makransky et al (2019) investigated on the cognitive consequences of adding immersive virtual reality to virtual learning simulations. The study used Electroencephalogram (EEG) to measure the cognitive processing of student-respondents during learning. The student-respondents were reported to be more present in the virtual reality conditions as evident to their cognitive processes measure on EEG, but these students were found to have learned less through pre-post tests comparisons compared to the control group participants who were not immerse in virtual reality simulations. The study also pointed out that in spite of the motivating characteristics of virtual reality, integrating the said technology in learning science may overload and distract the learners as reflected in EEG measures of cognitive load.

The presented study of Makransky et al (2019) established a position of prudence in using too much virtual reality in science education specifically on simulated processes that could present on Vlab integration. It is imperative to take into account the cognitive load or the extent of information that the working memory of the students can hold. Still, this challenge in Vlab integration could be resolve by tailoring Vlab activities at a prescribe hours based on students age and cognitive abilities. This will demand another focus study or research that will improve Vlab as an innovation in school science laboratories in terms of the discussed factor.

Potential of Vlab Integration to School Science Laboratories. Considering the synthesized information on the theoretical underpinnings, gains, and issues of Vlab integration to science pedagogy and school science laboratories, this portion of this research will tackle and further review the potential of Vlab integration to physical laboratories. A developing topic in this ground is a method known as the "blended" or "hybrid" method to laboratory learning where both traditional and non-traditional modalities are combined in an effort to get the most out of the benefits of both approaches (Brinson, 2015). This potential lies on the presumption that Vlab provides opportunities to accomplish lab works that will otherwise post a challenge to an actual lab due to circumstances such as safety, cost, geographical and sometimes physiological barriers. A blended or integrated approach to using Vlab offers opportunity to maximize the declared benefits of Vlab, while also utilizing the presumed benefit of technical skills acquisition through actual and physical manipulations of objects in a traditional laboratory set-up.

The reviewed literature of Rutten et al (2012) provides robust evidence that computer simulations can enhance traditional instruction, especially as far as laboratory activities were concerned. The study categorized computer integration that are widely used in science education into enhancement of traditional instruction with computer simulation, comparison between different kinds of visualization, and comparison between different type of instructional support. Upon categorization, one of the suppositions of the reviewed research is that the acquisition of laboratory skills is often a learning goal that cannot be completely replaced by simulations. However, the study also clarified that in fields where simulations have already been widely accepted as a training facility, Vlab could be integrated and posited to be more effective as pre-lab. These preparatory lab activities done via Vlab will help students to integrate learned theoretical and conceptual knowledge into practice that will allow a room of reflection before actual application in the school science laboratories.

On the other hand, the study of Smetana, and Bell (2012) provided useful insights on how computer simulations support science teaching and learning. Computer simulations according to the directed study are most effective when used as supplements; when it is incorporated as high-quality support structures; when it encourages student reflection; and when it promotes cognitive dissonance, which may be resolved via science process skills. These findings suggested that Vlab computer simulations when used appropriately will help to engage students in inquiry-based, authentic science explorations. The study further recommended that as educational technologies continue to evolve, advantages such as flexibility, safety, and efficiency of such technological integration to education deserve attention.

Smetana, and Bell (2012) further argued that as with any other educational technology integration, the effectiveness of computer simulations which is a major component of Vlab will depend on how it is utilized in the classroom or actual laboratory set-up. Hence, the recommended best practice applications and usage of the said technology were presented. To highlight the importance of the said study to the synthesis of the potential of Vlab integration in school science laboratories, it is crucial to take note that the said simulations must only be supplements to concept learning; it must only be used as support structures for instructions in science education; it must encourage students' reflection of acquired skills, understanding and knowledge; lastly, it must promote cognitive dissonance that will challenge the students' critical thinking skills and encourages students' engagements and experimentation to solve such dissonance. Subsequently, the Vlab integration's potential

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must be carefully crafted to accommodate the given recommendation.

Going back to the study of Abas and Marasigan (2020), the Philippines has many public schools that are challenged by the lack of physical science laboratory facilities and equipment, the potential of the integration of Vlab to the school science laboratory may augment some of these challenges, but upon delving into details of how Vlab should be integrated appropriately to the science education of the country; this potential should be carefully put forward in order to accommodate careful considerations that will allow improvement of the current lab situation in public schools of the country. In conjecture, the Vlab integration on school science laboratories has potentially taken place in some advance science fields and schools, but the potential of its usage as integration to public schools science laboratory demand a special attention to make sure that it is not simply integrated as a replacement because studies reviewed herein divulge that Vlab will be more effective as a supplementary laboratory activities such as that of a pre-lab.

CONCLUSION

This paper presents the potential of virtual laboratories (Vlab) integration to school science laboratories. Vlab integration to school science laboratories exhibits gains and issues, as it stands on its theoretical underpinnings of providing experiential learning and engaging students toward a guided inquiry-based science pedagogy through its constructivist approach to skill acquisition and concept formation. The potential of Vlab integrations is promising as it offers possible solution to inadequate laboratory facilities in public schools of developing countries like the Philippines. The gains of Vlab integration allow students to experience concept formation at a personal level even for molecular and abstract concepts that would otherwise be challenging for a simple school science laboratory. Moreover, studies also showed that using Vlab resulted to greater laboratory learning outcomes and better understanding of concepts. On the other hand, the issues that were identified also corresponds for potential modification of using Vlab in science education which are cognitive overload, critical aspects of formative assessment application in a virtual set-up and insufficient technological resources such as computers and the internet.

Therefore, the researchers recommend in line with the reviewed studies that the Vlab integration to school science laboratories be viewed as a complementary tool to science laboratories and not a replacement for an actual working or physical laboratory facilities and equipment. The researchers had started this paper with a positive note that Vlab integration is an overall solution to school laboratory problems in the developing countries like the Philippines, however, upon contemplation with the reviewed and presented studies the researchers have come up with the conclusion that this integration is not a substitute to a school laboratory facility. The researchers further suggest that the school governing bodies must still invest in good laboratory facilities that will allow students to actually experience science experimentation and that Vlab could be a complementary tool for simulations in cases that such actual experimentation becomes ambitious due to safety and complexity or abstraction of concepts. The world, including education could be moving towards virtual worlds but the studies show that learning still take place in the physical realities of the universe, hence virtual simulations could be an aide but not an alternative to learning sciences in lieu of laboratory activities.

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Figure 1: *Duncan and Jiang's (2012) Hierarchy Relationships Between Categories Within the Taxonomy of Virtual World Usage in Education*

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Figure 2: *Konak, Clark, & Nasereddin's (2014) Four stages of the Kolb's Experiential Learning Cycle*

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