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Laboratory Utilization: The Effect on Knowledge Retention and Inquiry Skills in Secondary School Science

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Abstract: *This theoretical review analyses connection between use of labs and building up of knowledge retentions and questioning abilities in science students at the secondary school. Based on constructivist learning theory and question-driven learning models, the paper synthesizes the existing literature to explain how practical laboratory activities helps in meaningful science learning. The review examines four major thematic themes that include the contribution of laboratory activities to conceptual learning, how practical work and knowledge retention relate to each other, how practical work develops scientific inquiry skills when laboratories are used, and issues that hinder effective use of laboratories. The results have shown that well-designed laboratory tasks lead to a significant improvement in the ability of the students to memorize scientific knowledge and build necessary skills of inquiry. The success of this is however dependent on the availability of resources, teacher readiness, alignment of the curriculum, and the methods used. The review has led to a conclusion that the use of laboratories as a critical mediating variable suggests that science education and student achievement are related. It also gives recommendations to educational policy makers, school administrators, and science teachers on how to maximize the use of the laboratory instruction to enhance student performance in secondary school science education.*

Keywords: laboratory utilization, knowledge retention, inquiry skills, secondary school science, constructivism, hands-on learning

INTRODUCTION

The study of science has taken a centre stage in modern educational discourses and this is mainly because it is considered to be a fundamental part of equipping students to engage in an ever growing technology-oriented global society (Osborne and Dillon, 2008). Science education in high school level is a relatively important stage of the educational path of students, at this stage the basis of scientific knowledge, methodologies, and ethos of research are developed and honed (Taber, 2017).

In the larger context of science education, classroom teaching in laboratories has traditionally been viewed as an inseparable ingredient that makes science education shine among other educational subjects (Hofstein and Lunetta, 2004). The laboratory is the main sphere where theoretical information meets actual practice allowing students to observe, manipulate variables, collecting and analyzing data and coming to evidence-based conclusions (Millar, 2004).

The relevance of laboratory experiences in science education is not a new concept as scientific societies and educational reformers have been propounding the importance of practical works in school curricula since the nineteenth century (DeBoer, 1991). Throughout the last several decades, curriculum developers and educational scholars have strongly stressed the idea that the laboratory work is the only way in which students can build certain cognitive and psychomotor skills that cannot be sufficiently developed through the didactic teaching process (Hofstein and Mamlok-Naaman, 2007). When used appropriately, the laboratory setting provides an opportunity of active learning, collaborative inquiry and the ability to construct individual understanding using first hand experience with the scientific phenomenon (Tobin, 1990). Laboratory experiences could facilitate the Central science education goals such as development of mastery over subject matter, establishment of scientific reasoning skills, and nurturing an interest in science as Singer et al. (2006) found out.
Although the pedagogical role of the laboratory instruction is widely recognized, the current science education is characterized by issues related to the efficient use of the laboratory facilities (Lunetta et al., 2007). There are a lot of such secondary schools with inappropriate laboratories, inadequate equipments and consumables, teachers who lack proper training, crowded classes, and curricula that cover much content but not practical learning (Onwu & Stoffels, 2005). According to a study done by Ottander and Grelsson (2006), practical work in most schools has become a ritual where students are taught to work through given procedures without knowing the scientific principles.

Knowledge retention is one of the underlying issues in educational research and practice since the ultimate goal of teaching is not just to allow students to acquire information temporarily but to be able to retain and use the learned material in the long run (Willingham, 2009). Conceptual knowledge retention, in particular science education, is the necessary resource to enable students to develop more advanced forms of understanding with the advancement through the educational levels (Taber, 2014). Empirical studies indicate that the way of acquiring knowledge in the first place is a key determinant of knowledge persistence in the long-term memory (Bjork and Bjork, 2011). Theory LAB Due to their engagement of various sensory modalities and the fact that they are cognitively demanding, laboratory experiences are hypothesized to result in stronger memory traces compared to passive learning methods (Kontra et al., 2015).

Another important scientific education outcome which is not limited to content knowledge but also includes the procedural and epistemic aspects of scientific practice is inquiry skills (Crawford, 2014). These competencies include being able to develop research problems, develop research investigations, gather and interpret data, create evidence-based explanations, and effectively share the results (National Research Council, 2012). Inquiry skills are being given a growing priority in national and global standards of science instruction as a requirement of scientific literacy (American Association for the Advancement of Science, 2011). The laboratory activities offer the main

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environment in which students can genuinely participate in the inquiry process and become competent in the practices that define the work of scientists (Duschl and Bybee, 2014).

The theoretical review at hand is intended to analyze how laboratory use is related to two important learning outcomes, which are knowledge retention and inquiry skills development. There are 4 objectives of the study. The initial goal is to investigate the theoretical underpinnings that define the role of laboratory experiences in the process of learning science. The second goal is to examine the processes by which the laboratory activities improve the retention of scientific knowledge among the students. The third goal is to consider the impact of the involvement in laboratory work as the means of developing the scientific inquiry skills. The fourth goal will be to establish obstacles to effective laboratory use and reflect on their consequences to student learning.

To achieve these goals, the review deals with three research questions. To begin with, what are the theoretical explanations of the relationship between the utilization of laboratories and science learning outcomes? Second, is there any information provided in the existing literature regarding the impact of laboratory activities on knowledge retention and inquiry skills development of secondary school students? Third, what are the challenges associated with the use of laboratories in secondary schools, and what is the effects of the challenges on the learning of students? The answers to the questions obtained by systematic review of theoretical and empirical literature allow this review to add to the current discussion of the effective pedagogy of science and offer evidence-based information to the educational practice (Hodson, 2014).

LITERATURE REVIEW

Theoretical Framework

Constructivist Learning Theory

The constructivist learning theory is a very strong theoretical framework of how laboratory experiences can play a significant part in meaningful learning of science. Constructivism as a theory is based on the philosophical and psychological contributions of Jean Piaget, Lev Vygotsky, and other theorists who have influenced the development of the educational theory. It is based on the idea that knowledge is not being transmitted between the teacher and the student but it is being constructed by the learners through their experience, ideas, and interactions with others (Bada & Olusegun, 2015). Such view has significant consequences of undermining traditional models of transmission of education and has far reaching consequences to the conceptualising and implementation of science instruction especially laboratory work (Driver et al., 1994).

Cognitive constructivism has it that learners develop mental structures or schemas in the process of assimilation and accommodation in their interactions with the surrounding (Piaget, 1977). Students can experience phenomena which either reinforce existing schemas or induce cognitive disequilibrium which in turn requires modification of the schema when participating in laboratory activities. An example is the student with a misconception concerning density who may have a cognitive conflict when the unexpected results are observed in a laboratory investigation and rebuilding of cognition in a manner that is consistent with empirical evidence is done (Ultay and

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Calik, 2012). Studies by Vosniadou (2002) also revealed that conceptual change in the field of science usually involves experiences that can disrupt the current frameworks of the students and that laboratory activities are the best scenarios where such experiences can be experienced.

Vygotsky social constructivism builds on this theory by focusing on the extent of social interaction and cultural tools on cognitive development (Vygotsky, 1978). The laboratory work is usually collaborative in nature as students tend to work as groups, discuss their observations, negotiate meanings, and co-construct the explanation. These interactions among people take place in what Vygotsky called the zone of proximal development, in which learners with the help can do what they are not yet capable of doing independently (Amineh and Asl, 2015). Driver et al. (1994) consider that learning science entails the induction into the science culture, and laboratory conditions are genuine ones where the process of enculturation can occur.

According to the constructivist approach, laboratory work is not considered to be a sort of an addition to theoretical teaching but is a fundamental setting of knowledge construction (Hodson, 1996). By the process of manipulating materials, observing phenomena, and working with problems during the practical work, students actively construct the understanding instead of receiving information passively. The laboratory work gives tangible experiences on which the abstract concept is formed (Hofstein & Lunetta, 2004).

Inquiry-Based Learning Theory

Inquiry-based learning theory can be used along with constructivism because it offers a framework that directly deals with the way that students should acquire their scientific reasoning skills in the process of investigation and discovery. This theoretical orientation is based on the progressive educational philosophy of John Dewey and has been developed through decades of study of the most effective ways of teaching science to students (Barrow, 2006). Inquiry-based learning highlights the fact that students learn science optimally through processes that resemble activities of scientists in question asking, investigation design, data collection and analysis, explanation construction, and communication (Pedaste et al., 2015).

The in
quiry-based learning model conceptualizes the process of the student learning as taking place on a continuum of highly structured to totally open inquiry. Within structured inquiry, the teachers ask questions and research processes as students research and make conclusions. In guided inquiry, the teacher poses questions and the students develop procedures and create explanations. Students engage in open inquiry where they develop their own questions, develop investigations, analyze data, and communicate the findings with little to no teacher guidance (Banchi & Bell, 2008). A study done by Blanchard et al. (2010) revealed that guided inquiry laboratory activities generated far a better learning enhancement than verification laboratory methods.

The theory of inquiry-based learning assumes that participation in real-world scientific activities can lead to the acquisition of not only the content knowledge but also inquiry skills that can be transferred to a different context and subject matter (Minner et al., 2010). Empirical studies have shown that inquiry-based laboratory activities as a habitual practice among students show better acquisition of these skills than students receiving didactic instruction only (Furtak et al., 2012). Combining the constructivist learning theory and the inquiry-based learning theory offers a holistic approach to learning to understand how the use of laboratories influence the level of knowledge retention, as well as inquiry skills (Hmelo-Silver et al., 2007).

Empirical Literature Review

Laboratory Activities and Conceptual Understanding

The connection between science lab work and abstract cognitive knowledge has been widely studied in a variety of learning settings. Empirical studies have also shown that properly designed laboratory experiences are beneficial in developing sound and solid scientific conceptions by the students (Hofstein and Mamlok-Naaman, 2007). Millar (2004) arrived at the conclusion that the most efficient way of laboratory activity is to create clear connections between observations and explanations, so the students can learn the reasons as to why the phenomena happen and not just record what happens.

Abrahams and Millar (2008) explored the efficiency of practical work instruction in science lessons of secondary schools by systematic observation. According to their studies, most lab activities are effective in involving students in operating machinery and observing phenomena but fewer activities are effective in assisting students in drawing parallels between observations and scientific concepts. This observation shows the significance of learning design and implementation of laboratory activities by implicating that the presence of practical work is not an assurance of conceptual learning (Abrahams and Reiss, 2012).

A study made by Hofstad and Mamlok-Naaman (2007) looked at the role of laboratory work in encouraging conceptual change in students who are having misconceptions in science. Their review revealed that laboratory experiences may produce cognitive conflict which can stimulate the student to redefine his or her existing conceptions in cases where observations were inconsistent with expectations. Conceptual change is however not automatic after the laboratory exposure and necessitates pedagogical intervention that renders the previous conceptions of students explicit and directs students to scientifically acceptable conceptions (Posner et al., 1982).

Laboratory Experiences and Knowledge Retention

The role of laboratory experiences on knowledge retention is a crucial field of research considering in view of the end objective of education, which is to generate enduring learning (Bransford et al., 2000). Studies in cognitive psychology indicate that the information encoded in more than one modality and actively encoded information is more permanently stored in long-term memory as compared to passively processed information (Mayer, 2009). Laboratory work is intrinsically multimodal, and it is close to a mix of visual viewing, physical handling, vocal conversation, and active thinking (Bjork and Bjork, 2011).

Bernhard (2018) sought to examine how the secondary students involved in inquiry-based laboratory activities as opposed to students taught via conventional learning methods retained physics concepts in the long-term. It was found that students who took part in practical laboratory investigations showed a much higher level of retention of the main concepts of physics than their peers who received lectures as the main method of learning. The researchers explained this retention advantage by more in-depth preliminary processing, which is enabled by the active process of dealing with physical phenomena (Bernhard, 2018). The same was reported by Freedman (1997) who discovered that students, who were exposed to laboratory activities, not only they retained physics concepts longer than their counterparts who were exposed to teacher demonstrations.

A study by Kontra et al. (2015) showed that physical exposure to scientific phenomena results in the sensorimotor brain networks that facilitate the later recall and the thinking process of the same phenomena. In the process of making predictions, designing processes, and creating explanations throughout the laboratory activities, students are able to participate in an effortful cognitive processing that enhances encoding processes in memory (Roediger and Butler, 2011).

Development of Inquiry Skills Through Laboratory Engagement

Training scientific inquiry proficiency is one of the key reasons that lab work should be part of science curricula because such competency cannot be taught effectively as a result of theoretical training alone (National Research Council, 2012). Gormally et al. (2012) concluded that the students who had broad laboratory experience had significant improvements as compared to those who had limited exposure to practical work in various aspects of skills. Their study has pointed out that a consistent practice of authentic inquiry activities gradually builds the students to think and act in a scientific way.

Duschl and Bybee (2014) maintained that laboratory activities offer important contexts where students learn to become epistemic practitioners and this defines the authentic science. These practices consist of argumentation and assessment, synthesizing theory and evidence, and getting a sense of what scientific knowledge is. By participating in laboratory research, students get to know the difficulties and complications of empirical research first hand (Sandoval, 2005).

A study conducted by Crawford (2014) explored the teacher practices that could successfully facilitate the inquiry skill development using laboratory instruction. The research found some of the most important practices such as asking real-world questions, which need to be investigated, giving students the freedom to create their own procedures, giving time to think and discuss, and demonstrating the process of scientific reasoning. Those teachers who adopted such practices stated that students engaged more, and the behaviors of more complex inquiries were observed among the students throughout the lab tasks (Marshall et al., 2009).

Challenges Impeding Effective Laboratory Utilization

Although the benefits of laboratory instruction are well differentiated, there are many challenges that hinder effective use of laboratory resources in secondary schools across the globe (Hofstein and Lunetta, 2004). In a study conducted by Onwu and Stoffels (2005) on barriers to practical work in South African high schools, the researchers have identified a big number of facilities, lack of equipment and material, big classes, examination pressure, and lack of teacher confidence as a key barrier to the practical work. These resource limitations were especially severe in schools with disadvantaged populations, which equilibrates issues with equity regarding the inequitable access to good quality science education (Ramnarain, 2016).

A study conducted by Osborne (2015) that explored the impact of high-stakes examination systems on laboratory teaching established that assessment activities tend to affect real work by diverting the focus of practical work towards memorizing theoretical material as compared to the application of inquiry skills. In cases where the laboratory competencies are not sufficiently examined, the teachers might view practical work as a waste of time that could be spent on preparing exams (Donnelly et al., 2013).

Teacher education and teacher development are also other issues that influence the quality of laboratory instruction (Lunetta et al., 2007). A study by Nivalainen et al. (2010) suggested that a good number of teaching science educators are not properly prepared to plan and guide a successful laboratory experience. Education programs in pre-service teachers are usually unsuccessful in availing pre-service teachers to gain the skills in managing a laboratory environment (Windschitl, 2003). As a result of this, teachers can succumb to very constrained verification practices that reduce cognitive load and do not capitalize on the opportunities of the laboratory work (Volkmann and Abell, 2003).

METHODS

In this, a theoretical review methodology was employed in order to conduct a relationship study between the laboratory use and the knowledge retention and the inquiry skills of the students (learners in secondary schools). The approach of theoretical review was considered to be the most suitable one due to the necessity to synthesize and integrate the existing theoretical frameworks and empirical results that would allow building the overall knowledge of the studied phenomenon (Grant & Booth, 2009). Torraco (2005) further states that integrative theoretical reviews are especially useful when dealing with mature topics that need to be reconceptualized.

The literature search would have used numerous academic databases to cover all the relevant scholarship. Education Resources Information Center (ERIC), Scopus, Web of Science, and Google Scholar were major databases that were searched. The search terms were combinations, like laboratories teaching, practical laboratory work, retaining the knowledge, inquiry skills, science in secondary school, and science teaching (Booth et al., 2016). Search terms were combined using the Boolean operators.

The inclusion criteria included that the sources had to be on the topic of laboratory instruction in the context of science education, target the population of secondary schools, and be in peer-reviewed journals or trusted academic publishing houses, as well as written in English (Snyder, 2019). The literature published not earlier than two decades was preferred, though the seminal earlier works were also included in case they presented the fundamental concepts. The selection process ended with the inclusion of articles on theoretical works, empirical research articles, systematic reviews, and meta-analyses.

The method that was used to analyze it is thematic synthesis of the chosen literature (Thomas and Harden, 2008). The identifying of key themes was done inductively and according to the objectives of the research these themes were organized under coherent categories. These themes were theoretical basics of laboratory education, processes through which laboratory encounters are associated with knowledge acquisition, acquisition of inquiry skills, and obstacles to laboratory use. The critical analysis of literature was going to help build the areas of consensus, inconsistency, and gaps in the current knowledge (Braun & Clarke, 2006).

The high level of methodological rigor was ensured by a comprehensive report on the search and selection of articles, which ensures transparency and replicability (Fink, 2019). Critical evaluation of sources put into consideration some of the factors like quality of the methods used, relevance of the methods to the research questions and plausibility of the assertions presented. Triangulation ensured by the combination of several theoretical views and sources of evidence enhanced the validity of conclusions made (Maxwell, 2013).

RESULTS

Results of the theoretical analysis were findings derived in terms of four big themes, which were theoretical explanations of laboratory-learning relationships, knowledge retention enhancement mechanisms, inquiry skill development pathways, and challenges to laboratory use.

Theoretical Explanations for Laboratory-Learning Relationships

The results of the analysis demonstrated that there exists a great level of support of the contribution of laboratory activities to the science learning outcomes with the help of a theory. This contribution according to constructivist learning theory can be explained by the mechanism of active knowledge construction, meaning in which students can develop an understanding by direct contact with phenomena, not by the passive intake of information. The social aspect of constructivism, which relies on Vygotskian views, goes further in providing an explanation of how collaborative work in the laboratory allows learning based on the interaction with peers and meaning co-construction.
The theory of inquiry-based learning offers a complementary explanation by explaining how laboratory activities can involve students in a real-world of science practice which builds their content knowledge together with their procedural competencies. The sequence of structured to open inquiring can be linked to the developmental patterns of gaining scientific reasoning skills by students. Combined, these theoretical approaches provide a consistent explanation of why the idea of laboratory use can be considered an essential determinant of student learning.

Mechanisms Enhancing Knowledge Retention

The review found that there are a number of interrelated processes in which laboratory experiences contribute to knowledge retention. To begin with, multimodal interaction during the laboratory sessions forms many memory traces due to a visual, tactile, and kinesthetic processing of information at the same time. When students observe phenomena, handle equipment and work with materials in real life, they encode information using different senses.

Second, active predictions, explanations, and conclusions generated during laboratory work have a stronger memory encoding as compared to passive reception. This effect of generation describes why the student who builds his own knowledge by inquiry retains the knowledge better.

Third, due to the contextual peculiarities of laboratory experiences, it forms an interesting episodic memory, which acts as a retrieval cue towards related conceptual knowledge.

Fourth, laboratory work facilitates significant learning through creating bridges between the abstract and the concrete phenomena. Students feel the applicability of the theoretical topics when they see that their guess is either verified or disproved by the experiment outcomes. The combination of these processes, including multimodal interaction, active creation, richness of the context and deep meaningful engagement, is why the benefits of retention in effective laboratory instruction are so strong.

Pathways to Inquiry Skill Development

The review found that laboratory use was the main source in which the students in secondary schools learned scientific inquiry. The review discovered that inquiry skills cannot be sufficiently trained by theoretical training but need real-life involvement in investigation procedures. The laboratory activities present the needed backgrounds where the students learn how to develop questions, plan investigations, manipulate variables, gather data, interpret findings, and build explanations.

The review showed that the development of inquiry skills requires effective design and implementation of the laboratory activities. Those activities that only confirm pre-defined outcomes offer fewer chances of true inquiry, but those activities that ask real questions and permit the student to independently explore materials facilitate the development of substantive skills. There is a significant mediation between laboratory utilization and inquiry skill development through teacher practice.

Group laboratory activity helps in building inquiry skills using a social process. In group studies students are required to explain their thoughts, think in different ways, be able to negotiate processes and build collective explanations. Such collaboration processes not only form cognitional aspects of enquiry, but also communicative and interpersonal.

Challenges Affecting Laboratory Utilization

The review has indicated several classes of barriers to the effective use of laboratories. One of the challenges that became endemic was the resource constraints that included poor laboratory facilities, equipment and consumables, lack of space and time to prepare as well as funding. These are especially severe in schools with poorly off populations, and in third world countries.

Another major obstacle is teacher related. Most teachers of science at secondary schools are not well prepared in designing and facilitating successful laboratory experiences. Educators might not be confident to work with laboratory settings, respond to unpredictable outcomes, as well as support open-ended research. As a result of this, the teachers usually settle on highly structured verification tasks that limit the danger yet simultaneously limit cognitive load and inquiry.

Individual teacher and resource constraints are further added to by systemic and institutional challenges. Exam systems which are based on high-stakes and prioritize theoretical knowledge over practical skills generate a deterrent to laboratory learning. Educators who are under pressure to deliver students for examinations might feel that laboratory work is a waste of time. Also, there are logistical barriers to the implementation of laboratories due to overcrowded classrooms, inflexible scheduling, and insufficient technical support.

Discussion
The results give a lot of credence to the argument that the use of laboratories has a considerable influence on the knowledge retention and inquiry skills development in the science students of secondary schools. The interjection of theoretical models and empirical data suggest that properly designed and adequately executed lab activities have a significant impact on student learning outcomes by various interrelated processes.

The constructivist and inquiry-based learning frameworks have been described as being explanatorily powerful in terms of explaining the relationships between laboratories and learning. Constructivist concepts shed some light on the fact that active interaction with the phenomena in the laboratory work can help the students to build their personal knowledge, which is more significant and lasting than that obtained under the influence of some passive reception (Driver et al., 1994). Cognitive conflict and schema reconstruction focus is consistent with research findings on conceptual change via laboratory experiences (Posner et al., 1982).

The discovery of certain mechanisms through which laboratory experiences assist in better knowledge retention is a great contribution. The overlapping of multimodal interaction, active generation, and context-richness as well as meaningful connection offers a complex account of retention benefits, which have been reported in the empirical studies (Bernhard, 2018). These mechanistic pathways should be maximized in laboratory activities.

Special attention should be paid to the discovery that the development of inquiry skills is the pivotal issue of the pedagogical approach, but not a simple inclusion of laboratory activities (Abrahams and Millar, 2008). Verification activities that have established procedures give a little chance to do an authentic inquiry and the activities that involve the students in real investigation facilitate the development of the substantive skills (Blanchard et al., 2010). The science syllabus must state not only the fact that laboratory work is to be performed, but the type of inquiry participation is to be performed.

The influencing the laboratory usage are systemic obstacles and need joint actions on various levels of the educational system (Lunetta et al., 2007). The quality of instruction in the laboratories is not only determined by the resource constraints, but also by other factors. The competencies of the teachers, alignment of the curriculum and assessment and institutional supportive structures are also of vital importance in determining whether laboratory resources are being used effectively.

Equity of concerns about the use of laboratories should be put into words (Ramnararain, 2016). The problem of resource limitation favors schools in poor areas in unequal measure, and as such, access to good laboratory training is uneven (Onwu & Stoffels, 2005). In a situation where the laboratory experiences are a major source of knowledge retention and development of inquiry skills, then unequal access to laboratory experiences would mean the unequal access to learning opportunities with lasting implications.

CONCLUSION AND RECOMMENDATIONS

This theoretical review has discussed the connection between the use of laboratories and the level of knowledge retention and inquiry skills among the secondary school students by doing an in-depth analysis of the theoretical frameworks and available empirical studies. The evidence synthesis offers strong evidence of the contribution of well-designed lab experiences to the outcomes of learning science. The theories of constructivist and inquiry based learning provide consistent account of how practical learning activities about the phenomena of science help students to build significant knowledge and acquire genuine inquiry skills (Hofstein and Lunetta, 2004).

The review revealed several mechanisms multimodal engagement, active generation, contextual richness, and meaningful connection that can be used to explain the laboratory experiences that can increase knowledge retention (Bernhard, 2018). Moreover, the review showed that lab tasks offer critical contexts of training inquiry skills that cannot be effectively built with the help of theoretical teaching (National Research Council, 2012).

The review however also shows that the advantages of laboratory instruction are not self-evident and determine the manner in which activities are designed and executed (Abrahams & Millar, 2008). Activities that are found in laboratories and only check predetermined results are seen to offer little cognitive challenge. Good laboratory teaching involves problems that raise real questions, enable investigation on the part of the students and clearly relate the observations to fundamental concepts (Crawford, 2014).

According to the findings, some recommendations are provided. To educational policymakers, the review suggests that one of the priorities in the investment in the infrastructure and resources in laboratories should be valued as one of the key elements of quality science education, and the investment should be directed at the equity issues (Ramnarain, 2016). Policies on assessment ought to be revised to adequately review laboratory skills and investigation skills (Osborne, 2015). The science curriculum plans must clearly indicate the expectations of the engaged inquiry in the process of laboratory work.

The review advises school administrators to give adequate scheduling, time to prepare and technical assistance to facilitate normal and efficient laboratory teaching (Hofstein and Mamlok-Naaman, 2007). Science teachers need to be provided with professional development opportunities related to inquiry-based laboratory pedagogies (Luft and Hewson, 2014). Resource constraint, e.g., partnership with local business or universities, should be considered as a way of creative solutions.

In the case of science teachers, the review suggests students by designing laboratory activities which will involve students in a real inquiry as opposed to verification (Blanchard et al., 2010). Structured reflection and discussion should be used to support explicit links between the observations in the laboratory and the theoretical concepts. The teachers ought to adopt the progressive scaffolding which will help students to move towards more and more independence in scientific inquiry (Hmelo-Silver et al., 2007). Inquiry skills and practical competencies should be measured during assessment strategies along with content knowledge.

To researchers in future, the review suggests that they can carry out strong empirical studies across various cultural and institutional settings to reinforce the evidence base on laboratory use and outcomes of learning. The effectiveness of various forms of laboratory activities and pedagogical strategies should be researched effectively. Research needs to understand the application of technology such as virtual laboratories to supplement physical laboratory experiences.

To up, the usage of laboratory is one of the fundamental aspects of the knowledge that is retained and skills of inquiry that are developed in science education of secondary schools. The identification of the potential benefits presupposes the coordinated focus on the design of activities, teacher development, and assessment as well as the provision of the resources. Through these recommendations, the educational stakeholders will be in a position to deepen the role of laboratory experiences in the student learning outcomes and equip all students in a way that will enable them to contribute to an ever more scientific and technological society with a sense of knowledge.

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