Realism Experience in Virtual Learning Laboratory Environment

Romeo Kwame Bugyei, Clement Dzidonu
Accra Institute of Technology
Ghana
rbugyei@gmail.com, dzidonu@ait.edu.gh

ABSTACT: *There has been a lot of research work in relation to online laboratories, however the idea of students experiencing realism when performing experiments in such environments has not been the focus when setting up online or virtual Laboratories.*

The purpose of this paper is to find out the importance of realism experience (RE) in relation to laboratory experiments in a virtual environment, the process of identifying them, and how to ensure that they are present when developing virtual or online laboratories. A lot of research has been carried out on the understanding of subject content with virtual laboratories and there has been a lot of success with it, however, there are other experiences that must go with these experiments to enable students adapt to real life environment. In setting up a physical laboratory the idea of making sure students experience realism as part of the learning process is a matter of course and as such not much effort is put in when setting the objectives for the laboratory, however, the same cannot be said for setting up a virtual laboratory.

The paper concludes with the processes that must be followed in ensuring that realism experience is embedded in the process of performing the laboratory experiments in a virtual environment and also to be able to determine whether a physical laboratory experiment could be performed in a virtual environment without losing any of the learning experiences required to give the student total learning experience as indicated by the Bloom's taxonomy of learning domain.

Keywords: Realism Experience, Virtual/Online Laboratory, Virtual Learning Laboratory Environment

Received: 28 August 2013, Revised 27 September 2013, Accepted 30 September 2013

1. Introduction

The idea of teaching laboratory based subjects online, has become the focus of many researchers (Ulrich Harms, 2010) as a result of the growth of Distance Education (DE) (Spanias, A. (2005), Kennepohl, D. (2010), Kennepohl at el (2005)). Initially, DE basically comprised of non-laboratory based subjects. However with the advancement in technology, some institutions currently offer laboratory-based subjects to distance learners (Zubia, Alves (2011), Sanchez, at el (2002)). The issue of realism when it comes to performing laboratory experiments online has rather been a challenge especially when it comes to establishing a process for identifying what has to be created in the virtual environment. The central focus of this paper is to establish the importance of realism in Virtual Laboratory Learning Environment (VLLE) and how these realism experience (RE) could be identified and implemented. *Realism* as used in many research work in computer science or information technology has to do with '*How close computer generated images and processes*' are to reality (Pujol-Tost (2011), Johnson (2011)). Thus in this paper, realism will be used to describe how close equivalency could be created between experience of the learners performing physical laboratory work as against the one performing the same experiment in a virtual environment.

2. Realism Experience Within Virtual Laboratory Learning Environment

In many research works in relation to virtual systems, the definition of *realism* is assumed and as such not much thought is given to what it could actually represent. Realism is generally defined as '*The quality or fact of representing a person or thing in a way that is accurate and true to life*' (Oxford Dictionary (2010). This definition gives the notion of representing something that gives close resemblance to reality in such a way that it is difficult to distinguish the representation from reality. Creating equivalence of the reality that gives a '*feeling*' through sound, vision, movement, sensation etc. that '*deceives*' the human mind to believe that the equivalent is reality. This is what could be explained to be realism in relation to the Reality.

Experience as defined in Oxford Dictionary (2010) is '*the practical contact with and observation of fact and events*'. The focus here is '*contact with and observation of fact*'. The learner is expected to come into contact with and observe facts and events that invariably affect his or her understanding of theory and how it could be applied in real life.

Realism Experience (RE) therefore can be defined as the feelings, processes and consciousness that learners are expected to encounter to enhance their learning as they study in a virtual environment just as they would have in a physical environment. These REs are expected to enhance their cognitive, affective and psychomotor areas of learning. RE must of necessity be present in all these three learning areas in order to achieve the learning outcomes expected to be gained by the learner. As indicated by the Bloom's taxonomy of learning Domains, for total learning to be achieved, the learning process must have objectives set in all three learning domains (Krathwohl, 2002) and these are, the Cognitive, Affective and Psychomotor learning Domains. Thus for effective learning to occur in a virtual environment, it is imperative that equivalent objectives are set in all the three learning domains. This process of setting equivalent learning objectives will enable the creation of the necessary REs in the virtual environment to induce the expected learning experiences anticipated.

When it comes to laboratory work, it is important to consider the work done by Buckley and Kempa (Buckley, Kempa, 1971) and Kerr (1963). From their research, which is collaborated by many other researchers, the main aim of laboratory work is to encourage students in manipulative skills, observational skills, the ability to interpret experimental data, and the ability to plan experiments. Kerr adds some affective aims such as; interest in the subject, enjoyment of the subject and a feeling of reality for the phenomena discussed in theory. Without the feeling of reality for the phenomena discussed in theory the learner might not be able to relate theory to reality. Thus though it is important to have all the aims listed above incorporated in objectives set for laboratory work, the affective aims are crucial if learners are to relate theory better to reality when laboratory work are setup in the virtual environment.

The designing of computer graphics and processes (that is computer modules) to achieve these objectives is what is referred to in this paper as realism experience. The affective and psychomotor learning domain objectives become the main focus of providing the realism necessary for training the learners in the virtual environment. The manipulation of machines, sense of danger when performing dangerous experiments, the level of carefulness and diligence required when dealing with expensive reagents etc. can only be achieved by students when REs are created to mimic these experiences or '*feelings*' during the laboratory work. One can therefore safely conclude that without REs in a virtual Laboratory, the learners will miss out on some critical experiences, which will put the student learning in a virtual environment at a huge disadvantage. Thus appropriate REs must exist in a virtual laboratory for it to be considered as a Virtual Laboratory Learning Environment (*VLLE*). Therefore whenever a *VLLE* is designed, the designer must consider the REs that must be present to validate the learning environment as *VLLE*. The purpose of experiencing realism in this context is to aid learning, thus it is important to create not just anything that excites the mind but what truly enhances learning.

Every RE that is created in a virtual environment must enhance learning. In this paper the act of enhancing learning is referred to as Cognitive Value (CV). When the RE to be created will not enhance learning there is no value in creating such RE. When RE enhances learning the CV is considered to be greater than 1 else CV is less than 1. For RE with $CV < 1$ there is no value in creating such REs. The determination of the CV of an RE is very subjective and based on the experience of the designer of the online laboratory.

3. Identification Of Realism Experience

REs as indicated earlier, validate *VLLE*, as such it is necessary that all REs are properly identified and implemented for the Virtual Laboratory to be a *VLLE*. Virtual laboratories come in different forms, Online laboratory; that is pure online simulation software that mimic reality and can be used for training, remote laboratories; which are laboratories with physical equipment but controlled through the Internet. There could also be a combination of the two concepts. Whatever form that the virtual/online laboratory might takes, if the purpose is to use the laboratory for learning then experiences that learners go through using such systems must be equivalent to what they would have gone through performing the same experiment in the physical environment. Realism Experience modules as explained above therefore forms the basis of creating the equivalency between the two environments, that is, physical and virtual/online environment. Realism Experience, that is, the computer modules, both hardware and software, required to produce the REs must be carefully identified, developed and implemented to ensure that no learner performing an experiment in a virtual/online environment misses out any important experience necessary for total learning.

Borrowing from the field of education, total learning is achieved when the learner in the process of learning, it said to have gained new knowledge, has been affected by the process to have a change of attitude and in some instance developed a skill in handling equipment or processes and is in a position to articulate it naturally. This process is clearly identified and categorized by Bloom as the Bloom's taxonomy of learning Domain (Krathwohl, 2002).

The three domains as identified by Benjamin Bloom and his team are as follows;

1. Cognitive: Mental Learning skills (Knowledge)
2. Affective: growth in feeling and emotional Skill (attitudes)
3. Psychomotor: Manual or physical skills (Skills)

In developing REs to make certain that total learning is achieved as learners use the virtual/online laboratories, the designer of the online laboratory must have a systematic way of ensuring that all the expected experiences are identified and developed. Whatever experiences learners are expected to go through must meet the learning objectives for that particular experiment, thus the learning objective becomes the basis for RE development. To be able to create the equivalency learning experience between the physical and the virtual/online learning environments, the learning objectives in both environments must be equivalent. Please note that equivalency does not necessarily mean the same.

For total learning to be achieved, learning objectives, which represent what students are expected to learn after instruction (Krathwohl, 2002) must be set to cover all the three learning domains, that is, the cognitive, affective and psychomotor learning domains. Learning Objectives (*lobj*) must be set for each learning domain applicable to the experiement in question. It must be noted that the more detail the learning objectives are the easier it is to know if it is achievable. After identifying all lobjs in the physical laboratory, it is important to weigh them. That is to determine whether it is critical to the outcome of the experiment or just desirable. Critical learning objectives are those that are critical to the overall learning outcome of what the laboratory is meant to achieve. The desirable are the nice-to-have but do not take much from the overall learning outcome if not achieved. Learning Objective can therefore be ***Critical*** ($lobj_c$) or ***Desirable*** ($lobj_d$).

Based on the fact that we expect leaners to have equivalent learning experience between the two environments, equivalent-learning objectives must be developed for each learning objective stated in the physical environment. For each of the learning objective developed in the online/virtual environment, REs that will enable the achievement of the learning objective in the online environment must therefore be identified and developed.

In considering the objectives set in the virtual environment, the computer graphic and processes, that is REs, that will enable the learning objectives to be met must carefully be designed to ensure that the students learning in the virtual/online environment do not miss out on any necessary experience required for total learning. The REs therefore are derived from the Learning Objectives set in the virtual/online environment. REs must of necessity be designed for all critical but not necessarily for desirable objectives. Proper equivalence is established when REs can be designed for all lobjs identified in the physical laboratory environment for a specific experiment. For each objective set in the virtual environment there might be REs that must be designed to meet that objective.

That is for each $lobj_c$ in the virtual/online environment, REs necessary to achieve that objective must be identified for development,

> If $RE^{CV} < 1$ then
>
> *RE* **COULD** be dropped
>
> Else the proposed *RE* **MUST** be selected for development for equivalency to be achieved.

If the REs relate to $lobj_c$ (that is critical Learning Objective in the physical environment) then the expected learning outcome from that REs are very important, thus such REs must be created to maintain equivalency between the two environments. From the example given in table 1, objectives have been given on the various aspects that ought to be achieved by the learners. The objective ($lobj_{c4}$) requires that $RE_{c4..n}$ be developed to enable pungent smell for identification of some cations. If the REs identified ($RE_{c4..n}$) cannot be developed, then that will affect the equivalency of such $lobj_{c4}$ (in the physical environment) which is critical for total learning experience. Since REs for any virtual/online laboratory is the basis for meeting the learning objectives of the experiment, all REs that relates to a critical learning objective, that is $lobj_{c4}$ in this experiment, which has been identified **MUST** be developed for equivalency of learning outcome between the two environments. Figure 1 traces the process of identifying the REs necessary for any online/virtual laboratory to achieve equivalency with a physical laboratory, which leads to equivalency in learning experience.

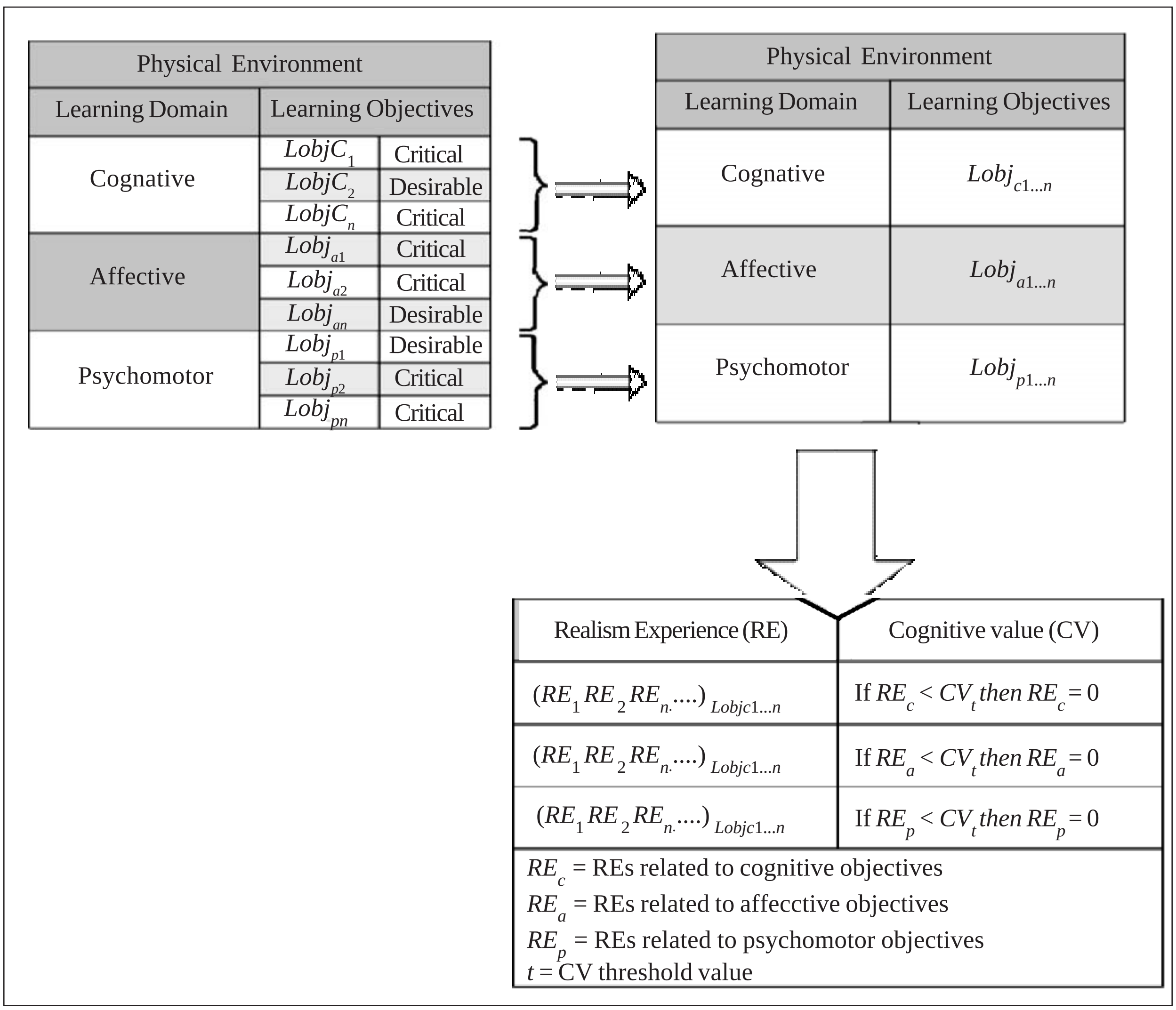

Figure 1. Process of identifying REs

Main Objective (Aim)	To identify the presence of the following individual cations in a solution: $NH_4 + Mg^{2+}, Al^{3+}, Pb^{2+}, Zn^{2+}, Mn^{2+}$ and Ba^{2+}		
Learning Domain	Learning Objective (Physical Env.)	Learning Objective Virtual (Env.)	Realism Experience
	Identify presence of cations in solutions ($lobj_{c1}$)	Identify presence of cations in solutions $lobj_{c1}$)	Create REs to provide visual identification of cations. ($RE_{c1..n}$)
			Create REs that enable colour changes that identifies specific cation that the colour symbolises the specific cation ($RE_{c1..n}$)
Cognitive Domain	Object$_{c1}$	Object$_{c1}$	
	To be able to separate cations from mixture of solutions ($lobj_{c2}$)	To be able to separate cations from mixture of solutions ($lobj_{c2}$)	Design REs that enable addition of solution to another ($RE_{c2..n}$)
			Design REs for heating ($RE_{c2..n}$)
			Design REs for passing bubbles of gas into a solution ($RE_{c2..n}$)
	Object$_{c..n}$	Object$_{c..n}$	RE_1
			RE_2
			RE_3
			RE_4
			RE_5
			RE_n
Affective Domain	Observe colour changes in solution ($lobj_{c3}$)	Observe colour changes in solution ($lobj_{c3}$)	Develop REs that gives the ability to change colour as experiment is done, close to reality ($RE_{c3..n}$)
	Observe pungent smell ($lobj_{c4}$)	Observe pungent smell ($lobj_{c4}$)	Develop REs for artificial smell ($RE_{c4..n}$)
			Develop REs for artificial pungent smell ($RE_{c4..n}$)
	Observe heat when warming ($lobj_{c5}$)	Observe heat when warming ($lobj_{c5}$)	Develop REs to simulate heat by observation ($RE_{c5..n}$)
			Develop REs to simulate heat by touch ($RE_{c5..n}$)
	Observe colour change in litmus paper ($lobj_{c6}$)	Observe colour change in litmus paper ($lobj_{c6}$)	Develop REs for colour change when litmus paper is used ($RE_{c6..n}$)
	Observe different flame colours to identify different cations in solution ($lobj_{c7}$)	Observe different flame colours to identify different cations in solution ($lobj_{c7}$)	($RE_{c7..n}$)
	……. (other objectives)		

	Ability to accurately measure solution ($lobj_{c8}$)	Ability to accurately measure solution ($lobj_{c8}$)	Develop REs for measuring liquid by handling with sensors to be able to measure accurately ($RE_{c8..n}$)
			RE_1
		$Object_1$	RE_1
		$Object_n$	RE_n
Psychomotor Domain	Ability to pour HCL into aliquot of cation provided ($lobj_{c9}$)	Ability to pour HCL into aliquot of cation provided ($lobj_{c9}$)	REs that mimic pouring of liquid with the movement of the hand ($RE_{c9..n}$)
	Ability to Bubble H_2S gas through the acidified solution ($lobj_{c10}$)	Ability to Bubble H_2S gas through the acidified solution ($lobj_{c10}$)	REs that enable simulation of bubbling of gas through a solution ($RE_{c10..n}$)
	Ability to handle liquids without spilling ($lobj_{c11}$)	Ability to handle liquids without spilling ($lobj_{c11}$)	REs that mimic pouring of liquids and sensitive such that if not handled properly it could spill. ($RE_{c11..n}$)
			REs that enable the selection of beakers and test tubes. Hold and tilt. ($RE_{c11..n}$)
			($RE_{1..n}$)

Table 1. Development of Res for Identifying Cations in a Solution

4. Implementation of Realism Experience

After the identification and creation of the REs from the learning objectives as describes above, it is important that REs are implemented in such a way as to ensure that the learning outcomes and experiences gained by learners are equivalent to leaners performing the same laboratory experiment in a physical environment. To ensure that equivalency is established in the process, the Kolb's Experiential Learning Cycle will be adopted. Abdul Wahed and Nagy (2009) in their paper 'Applying Kolb's Experiential Learning Cycle for Laboratory Education', demonstrate how the use of the Kolb's learning theory ensures a better learning outcome when physical laboratory is combined with online laboratory. The Kolb's learning theory as depicted in the figure 2 below, can be expanded for the implementation of REs to ensure better learning outcome and experience. The Kolb's experiential learning theory provides a clear mechanism of teaching and learning design and also supports constructivist view of acquiring knowledge (Abdulwahed, Nagy, 2009). Using the four types of abilities suggested by Kolb, that is, Concrete Experience ability (CE), Reflective Observation ability (RO), Abstract Conceptualization ability (AC) and Active Experimentation ability (AE) (Kolb, 1984), Kolb argues that an individual ought to detect, depict, or grasp knowledge, for knowledge construction to take place. The construction is the transformation of the acquired knowledge through experiencing knowledge. Kolb breaks the knowledge acquisition in two parts, that is, apprehension and comprehension. Apprehension through the Concrete Experience and Abstract Conceptualization and comprehension through Reflection Observation and Active Experimentation.

Implementing REs in virtual laboratories should therefore not just be focused on Active Experimentation but all the four stages on the Kolb's experiential theory to ensure that the learners are not disadvantaged in any way. REs must be implemented in such a way as to ensure that learners experience each of the stages of learning according to Kolb. Most online labs, as normal labs, concentrate on just the last stage of the kolb's learning cycle, that is, the Active Experimentation and assume the other stages. This cannot be so when one is dealing with distance learners who might not necessarily have all these stages of learning available to them. It is therefore proposed that in implementing the REs for online labs with the Kolb's learning cycle, REs are used to explain the theoretical base of the experiment to be done (Concrete Experience). This will ensure that learners are made to appreciate the basis of the experiment to be performed. Learners normally would have acquired this understanding in a typical

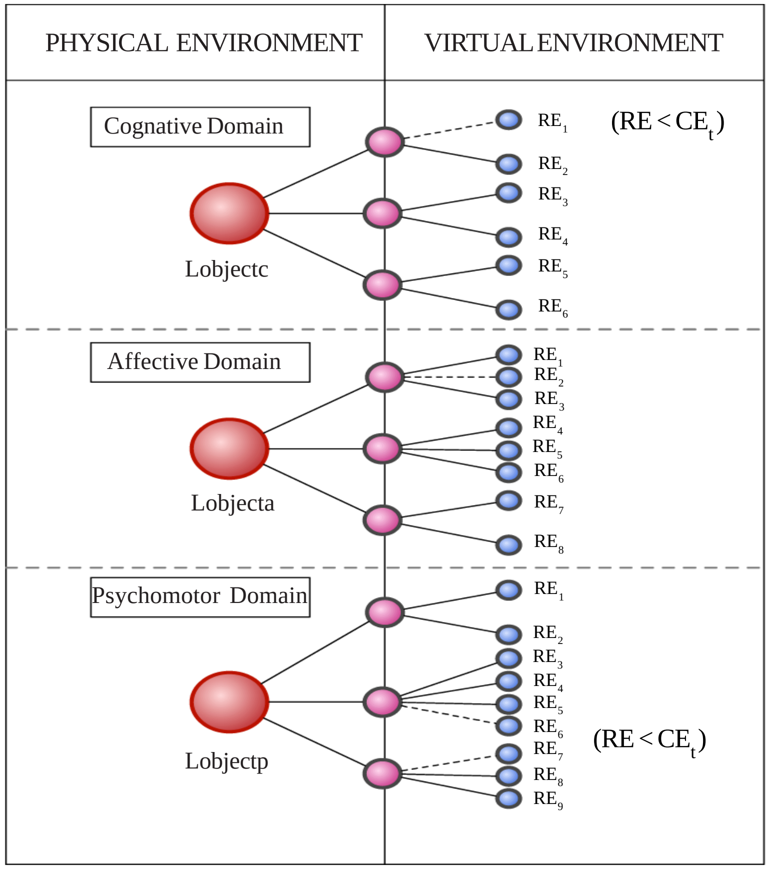

Figure 2. Flow diagram of REs identification

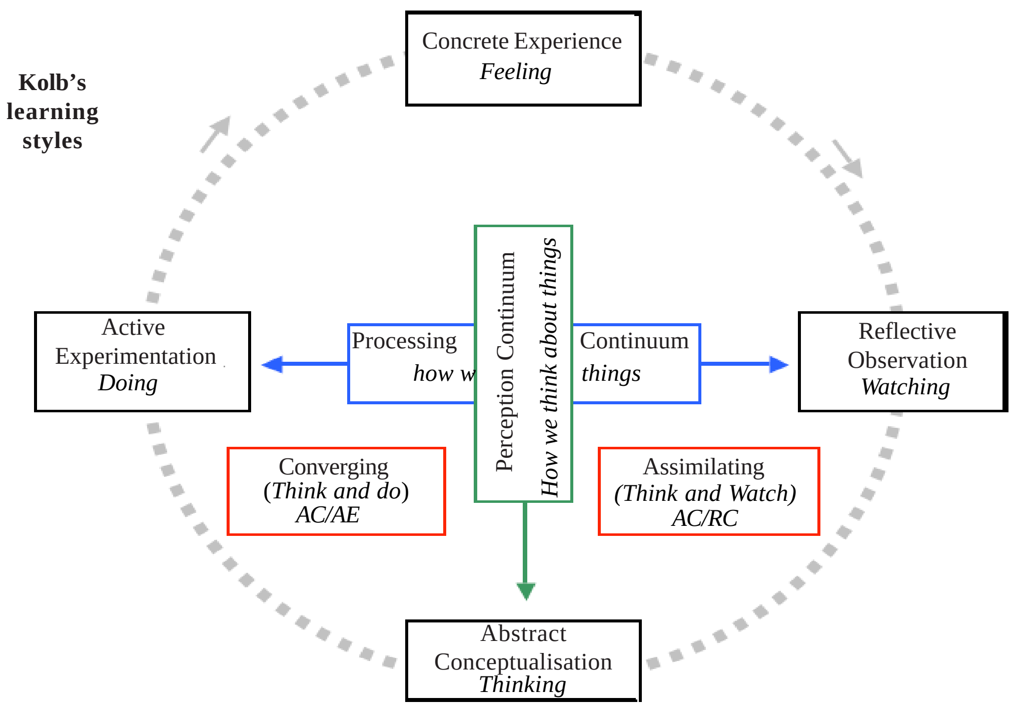

Figure 3.

classroom before moving on to perform the experiement. But as indicated earlier, since there is a possibility of distance learners using the laboratory, in the process of building the online system, care must be taken to enforce the theories that forms the basis of the experiment to be conducted in the online/virtual environment. The REs used in ensuring CE must be linked with the Actual Conceptualization (AC). These two stages ensure that the learner benefit from the apprehension of knowledge acquisition. In implementing REs with respect to the Cognitive Learning domain, such as, $RE_{c1..n}$, the developer combines the REs in such a way that the learner can conceptualize how the theories affect real life situation as he/she uses the online laboratory.

Considering the example above, when implementing $RE_{c1..n}$ to identify specific cation, the process must have content that will explain the theories behind the color change REs and why it happen. This process will help the learner appreciate the purpose of the color change being observed and why. In performing the experiment, REs must be implemented in an interactive manner that encourages not just active participation of learners, but also to be reflective in their observation as they perform the experiment, which is a fundamental skill that must be acquired by learners when performing experiment. For Reflective Observation ability to be achieved by the learners, REs must be implemented in such a way as to create scenarios that cause the learners to reflect in various outcome of the experiment. The process of performing the experiment is implemented at the stage of the AE thus REs that ensures active interaction with the simulation of the various equipment and procedures get implemented. REs implemented in this way enforce the various learning stages which invariably produces good learning outcome and experience necessary in bridging the gab between the physical and the virtual/online environments.

5. Conclusion

Virtual laboratories are very important in extending laboratory experiment to distance students who might never have the opportunity to use face-to-face laboratory equipment but also need to be trained in laboratory based subjects. Virtual/online laboratories as described in literature has always focused on it usage. The concept virtual/online laboratory in education and general training in industry have been enormous, however the process of putting it together to ensure that users, especially in education can have equivalent experience has not been properly formulated. The importance of having realism in a virtual laboratory environment has been discussed as well as the process of identifying and implementing them. When designing virtual/online laboratories one ought to be sure that the design and it's implementation meet general standard of experience necessary for ensuring that there is equivalency between the physical laboratory being replicated in the virtual laboratory irrespective of the form that the laboratory will take. The proposed Virtual Laboratory Learning Environment based on the Kolb's experiential learning theory and the Bloom's Taxonomy of Learning Domains as discussed in this paper helps in formalising the process of identifying REs that ought to be created in the virtual laboratory environment and implemented to enable distance learners or in general users gain all the necessary experience required for their training. For leaners using online or virtual laboratories to experience total learning, Realism Experience must be the basis of the entire system development. The developed REs must be derived from the learning Objective of the equivalent physical laboratory to create equivalent learning experience between the physical and the online/virtual environment. The implementation of the REs, that is, the process of linking the REs together to create the required processes and content, as indicated above must follow the Kolb's cycle to ensure that the REs developed are linked in such away as to bring all the learning stages as discussed in Kolb's learning cycle. If for any reason the REs that are linked to a critical learning objective cannot be developed due to cost or lack of technology then the equivalent online laboratory cannot to used to train leaners to provide the equivalent learning experience as compared to the physical laboratory environment. There is no doubt that when students gain realism in a virtual environment with the right processes it will go a long way to bridge the gap between reality and virtual environments enabling distance or online learners to be trained in laboratory based subjects without missing out on the experience necessary for laboratory training.

References

[1] Ulrich Harms, Virtual and Remote labs in Physics education (Extended abstract). (2010). http://discoverlab.com/References/harms1.pdf retrieved January.

[2] Engineering Outreach, Distance Education: An Overview. (1995). http://www.uidaho.edu/eo.

[3] Andreas Spanias, Fellow, IEEE, Venkatraman Atti, Student Member, *IEEE*. (2005). *IEEE Transactions On Education*, 8 (4), November.

[4] Dietmar Kennepohl and Lawton Shaw. (2010). Published by AU Press, Athabasca University, 1200, 10011 - 109, Street Edmonton, AB T5J 3S8.

[5] Javier García Zubía, Gustavo R. Alves (eds.). (2011). Using Remote Labs in Education, two little Ducks in remote experimentation, University of Deusto.

[6] Oxford Dictionary of English, Oxford University Press. (2010).

[7] Krathwohl, D. (2002). A revision of Bloom's taxonomy: An overview. Theory Into Practice, 41 (4) 212-218. Retrieved from http:/ /www.unco.edu/cetl/sir/stating_outcome/documents/Krathwohl.pdf

[8] Buckley, J .G., Kempa, R.F. (1971). *School Science Review,* 53 (182) 24.

[9] UNESCO Institute for Statistics, ISBN 978-92-9189-110-8. (2012).

[10] Mergel, B. (1998). *Instructional Design and Learning Theory*, retrieved December 16, 2004 from http://www.usask.ca/ education/coursework/802papers/mergel/brenda.htm.

[11] Birkenholz, Robert J. (1999). *Effective Adult Learning.* Danville, Illinois: Interstate Publishers, Inc.

[12] Alex Koohan, Keith Harman. (2007). Advancing sustainability of open Educational Resource, Issues in Informing Science and Information Technology, 4.

[13] Kerr, J.F. (1963). *Practical work in school science: An account of an inquiry into the nature and purpose of practical work in school science teaching in England and Wales*, Leicester University Press, Leicester.

[14] George Siemens. (2004), file:///C|/Documents and Settings/Jesper Johan/Dokumenter/...ce_ Connectivism A Learning Theory for the Digital Age.htm (1 of 6)

[15] Marcin Lawenda, Norbert Meyer, Tomasz Rajtar, Marcin Okon, Dominik Stoklosa, Maciej Stroinski, Lukasz Popenda, Zofia Gdaniec, Ryszard W. Adamiak. (2004). General Conception of the virtual Laboratory ICCS, LNCS 3038, p. 1013-1016.

[16] Craig Locatis, Anibal Vega, Medha Bhagwat, Wei-Li Liu, Jose Conde. (2008). virtual computer lab for distance biomedical technology education, *BMC Medical Education*.

[17] Dietmar Kennepohl, Jit Baran, Martin Connors, Kieron Quigley, Ron Currie. (2005). Remote Access to Instrumental Analysis for Distance Education in Science *International Review of Research in Open and Distance Learning*, 6 (3).

[18] Sánchez, J., Morilla, F., Dormido, S., Aranda, J., Ruipérez, P. (2002). Virtual and Remote Control Labs Using Java: Qualitative Approach, *IEEE Control Systems Magazine*.

[19] Tracey A. Stuckey-Mickell, Bridget D. Stuckey-Danner, Brandon C. Taylor. (2007). Virtual Labs in the Online Biology Course Student Perceptions and Implications for Policy and Practice : Tracey A. Stuckey-Mickell, TCC Proceedings.

[20] Jens Josephsen, Agnieszka Kosminska Kristensen. (2006). Simulation of laboratory assignments to support students learning of introductory inorganic chemistry -by Jens Josephsen, Education Research and Practice, 7 (4), 266-279.

[21] John Olson. (2006). Virtual Labs are equivalent to Authentic Labs (Pro) Secondary Education 625, October 11.

[22] Lyle D. Feisel, Albert J. Rosa. (2005). The Role of the Laboratory in Undergraduate Engineering Education, *Journal of Engineering Education*.

[23] Rebecca, K. Scheckler. (2003). Virtual labs: a substitute for traditional labs?, Int. J. Dev. Biol. 47: 231-236.

[24] O. B. Akinwale, K. P. Ayodele, A. M. Jubril, L. O. Kehinde, O. Osasona, O. Akinwunmi, Arthur Tumusiime Asiimwe, Cosmas Mwikirize, Paul Isaac Musasizi, Sandy-Stevens Tickodri Togboa, Andrew Katumba, Julius Butime, Josiah P. Nombo, Maiseli M. Baraka, Sapula Teyana, Mwambela J. Alfred, Kissaka M. Musa, Online Laboratories: Enhancing the Quality of Higher Education in Africa,

[25] Jimmy Reeves, Doris Kimbrough. (2004). Solving The Laboratory Dilemma In Distance Learning General Chemistry, Jaln, 8 (3), June.

[26] Nils Jensen, Stefan Seipel, Gabriele von Voigt, Heuristic Evaluation of a Virtual Lab System.

[27] Stiles, M J. (2000). Effective Learning and the Virtual Learning Environment, EUNIS 2000 - Towards Virtual Universities, Instytut Informatyki Politechniki Poznanskiej, Poznan April.

[28] Nagy Z K., Abdulwahed, M. (2008). TriLab – a combined remote, virtual and hands-on laboratory as a novel reusable learning object (RLO) for Supporting Engineering Laboratory Education. AIChE Annual meeting, November 16-21, Philadelphia, USA.

[29] Micah K. Johnson, Kevin Dale, Shai Avidan, Hanspeter Pfister, William T. Freeman, Wojciech Matusik. (2011). CG2Real: Improving the Realism of Computer Generated Images Using a Large Collection of Photographs, Visualization and Computer Graphics, *IEEE Transaction*.

[30] Laia Pujol-Tost. (2011). Realism in Virtual Reality applications for Cultural Heritage, *The International Journal of Virtual Reality*, 10 (3) 41-49.

[31] Harold Pashler, Mark McDaniel, Doug Rohrer, Robert Bjork. (2008). Learning Styles: Concepts and Evidence, Psychological Science in The Public interest, 9 (3), December.

[32] Krathwohl, D. (2002). A revision of Bloom's taxonomy: An overview. Theory Into Practice, 41 (4) 212-218. Retrieved from http://www.unco.edu/cetl/sir/stating_outcome/documents/Krathwohl.pdf.

[33] Jerzy Rutkowski, Katarzyna Moscinska, Piotr Jantos, Application of Bloom's taxonomy for increasing teaching efficiency – case study, Silesian University of Technology, Gliwice, Poland, International Conference on Engineering Education ICEE-2010

[34] Two Little Ducks in Remote Experimentation. (2011). University of Deusto.

[35] Brian F. Woodfield, Heidi R. Catlin. (2004). The Virtual ChemLab Projec: A Realistic and Sophisticated Simulation of Inorganic Qualitative Analysis, *Journal of Chemical Education*, 81(11), November.

[36] Moses O. Onyesolu. (2009). Virtual Reality Laboratories: An Ideal Solution to the Problems Facing Laboratory Setup and Management, *In*: Proceedings of the World Congress on Engineering and Computer Science, I WCECS, October 20-22, San Francisco, USA

[37] Mahmoud Abdulwahed, Zoltan K. Nagy. (2009). Applying Kolb's Experiential Learning Cycle for Laboratory Education, *Journal of Engineering Education*, July.

[38] Beatriz U. Ramirez. (2011). The sensory modality used for learning effect grades, *Advance Physiol Educ*, 35: 270-274.