Educational Administration: Theory and Practice
2024, 30(2), 709-717
ISSN: 2148-2403
https://kuey.net/

Research Article

Effect of Virtual Lab-Enabled Active Learning Method on Academic Achievement of Secondary Stage Students in Physics

Mamta Pal[1*]

[1*]Assistant Professor, School of Education, Devi Ahilya Vishvavidyalaya, Indore (MP), India.
Email: mamta11pal@gmail.com

Citation: Mamta Pal, (2024), Effect of Virtual Lab-Enabled Active Learning Method on Academic Achievement of Secondary Stage Students in Physics, *Educational Administration: Theory and Practice*, *30*(4), 709-717, Doi:10.53555/kuey.v30i2.1802

ARTICLE INFO

ABSTRACT

The faulty teaching methods hamper the applicability of physics concepts. Henceforth, this study was conducted. Sixty students of class tenth were selected randomly from a conveniently selected CBSE board school. The students were then assigned randomly to experimental and control groups by intact grouping. In the study, quasi-experimental pre-test post-test research design was implemented. PhET simulations were used for instructional purposes and academic achievement was assessed through an Academic Achievement Test. It was revealed that virtual lab-enabled active learning was more effective whilst both male and female students had similar achievements when virtual lab-enabled active learning was used for instruction.

Keywords: Virtual lab, Active Learning, Academic Achievement, Secondary stage, Physics

Introduction

Academic achievement is a construct that is greatly influenced by the teaching method. As per the National Achievement Survey of class tenth in the academic year, 2017-18 of cycle 2, the national-level achievement in science was distressing. It was remarkably below the state-level achievement in science. The national average achievement in science was merely 34% whilst that of the state average was 51%. Going by gender, both the boys and the girls performed equally well in science and their percentages were found to be 51%. The low level of achievement in science may be attributed to many factors, one being the faulty and futile methods of teaching.

Henceforth there is a need to employ such methods of teaching that keep the students engaged in their learning process and are constructivist. The active learning method is one such method. Bonwell and Eisson (1991) defined active learning strategies as "instructional activities involving students in doing things and thinking about what they are doing". So active learning methods are those instructional methods in which the students remain engrossed in their learning processes. Additionally, they remain active while making the meaning of their learning.

The students remain active mostly when ICT is used to teach them. Virtual labs are such technological advancements that remove abstraction in the concepts and increase visualization (Shih et al. 2016). When these are used in sync with other active learning strategies, optimize students' achievements (Zacharia and Constantinou, 2008; Chen, 2010), and higher-order thinking skills to a large extent (McElhaney, 2007; Sun, Lin, and Yu, 2008; Chen, 2010), remarkably enhances acquisition of concepts (Triona and Klahr, 2003, Klahr, Triona, and Williams, 2007) and make the learning more meaningful (Darrah et al., 2014).

In this present era, it is required that students be taught in such a way that they take part in their learning process rather than just remain passive learners. Learners are expected to actively construct their knowledge based on their prior experiences as propounded by Jean Piaget (1971) rather than cramming and rote memorization. So if students have to be equipped with 21st-century skills then they have to be masters of their learning process rather than mere listeners. So to achieve these students must be actively engaged in their learning process. John Dewey (1983) has propounded that students learn more by doing. Therefore, teachers

must involve the learners in classroom activities and keep them active throughout their learning process. Hence educators must plan activities and exercises that keep them active.
Active learning exercises are the activities that the teachers adopt in their teaching that keep the students active. The students do not merely listen passively, rather they act (Bonwell and Eison, 1991). These activities have several evident benefits.
So this study was conducted to see the effect of virtual lab-enabled active learning exercises on the academic achievement of secondary-stage students in physics.

Review of related literature

The roots of active learning lie in evidence-based education and student-centered education that has been there for a century. According to Dewey (1916), "learning is something that the individual does when he is studying. He also added that it is an active and personally conducted affair". So he was one of the most influential and early advocates of active learning (Pesavento et al. 2015). Active learning methods have been reasonably used in diverse scientific domains. It was found to advance the academic performance of the underrepresented groups in STEM in courses like introductory mathematics and aerospace engineering using flipped classrooms (Aji and Khan, 2019). In line with this, students believed that activity-based learning was very effective because it enhanced their understanding apart from increasing their sense of accountability, creating an attractive learning environment, and increasing achievement (Albadi and David, 2019).
Nonetheless, for the accomplishment of the active learning method, active learning environments play a foremost role. In this regard, problem-based learning and project-based learning are some of the learning environments that promote active learning (Silberman, 1996; Duch, Groh and Allen, 2001; McConnell, Steers and Owens, 2003; Prince, 2004). Likewise, Technology-rich environments also play a substantial share in endorsing active learning (Hassan and Puteh, 2017). One such environment is a technology-enabled virtual lab (Nair et al. 2012). Virtual labs are the prototypes of physically existing real labs without walls (Babateen, 2011). These labs have been evidenced to be useful in increasing achievement in chemistry (Tatli and Ayas, 2013), and biology (Azizah and Aloysiuh, 2021) and are widely used in medical fields such as nursing for training them for real situations (Padilha et al. 2019). Similarly, these labs have been profoundly used in various engineering streams such as electrical, chemical, etc. (Muthusamy, Kumar, Rosfashida and Latif, 2005).
These labs provide a lot of avenues for the students to be active in such environments. Henceforth, these labs can be used in various ways. They can further be used to train the students before going to the wet labs. Moreover, after performing experiments in the virtual labs, increased student learning gains have been witnessed in addition to student engagement, self-efficacy, motivation, and achievement (Goudsouzian et al. 2018; Reece and Butler, 2017; Su and Cheng 2019; Dyrberg et al. 2017). These benchmark discoveries and findings will enable the identification of more beleaguered ways that will assist the instructors in their endeavors to embrace active learning instructional practices that will in consequence endorse widespread instructional alterations (Pelch and McConnell 2016; Lund and Stains, 2015).
Genders differ in their response to active learning methods (Aguillon, Siegmund, Petipas, Drake, Cotner and Ballen, 2020). An analogous inclination was witnessed when virtual lab-enabled active learning was brought into consideration. This drift was predominantly evident in the mastery of the concepts wherein male students were promulgated to have mastered the concepts which were of higher order more than the female students whose concept mastery was of subordinate levels only (Gunawan, Suranti, Nisrina and Ekasari, 2018). Further, virtual labs were anticipated to be more significant in increasing the creativity of the males than the females (Gunawan, Susilawati, Dewi, Herayanti, Lestari and Fathoroni, 2020). Likewise, the labs were advocated to be reasonably more effective in improving the cognitive load (CL) and laboratory skills (LS) of males than the counterparts (Ibrahem, Alsaif, Alblaihed, Ahmed, Alshrif, Abdulkader and Diab, 2022). Contrary to these studies, certain studies revealed better results in favor of females in terms of creativity (Gunawan, Suranti, Nisrina, Herayanti, Rahmatiah, 2018), and attitude (Keter, Wachanga, and Anditi, 2016). Concomitantly some studies professed that virtual labs had no significant impact on either academic achievement or attitude (Ambusaidi, Musawi, Al-Balushi and Al-Balushi, 2018). Further, it was propounded that students had similar attitudes in chemistry practicals in both virtual labs (Vlabs) and physical labs (PLabs) (Ratamun and Osman, 2018). Furthermore, the achievement of male and female students was reported to be similar when taught chemistry using the virtual lab in collaborative settings (Gambari, Obielodan and Kawu, 2017). Additionally, researchers have argued that instructions carried through virtual laboratories increase academic achievement (Dalgarno, Bishop, Adlong and Bedgood, 2009; Yu, Brown, and Billet, 2005; Tatli and Ayas, 2013). But at the same time, some other studies cited that the virtual labs were insignificant to academic achievement (Ambusidi, Musawi, Al-Balushi and Al-Balushi, 2018). Henceforth no conclusive remark could be drawn from the studies conducted so far.
The above review of the literature divulges that there is a gap as no study was found that was done to understand the effect of virtual lab-enabled active learning methods on the academic achievement of secondary-stage students in physics. But studies were done to see the effect of the active learning method on academic achievement in various STEM subjects. Also, the reviewed literature illustrates that most studies were concerted on engineering and medical education but school education was in a dismal state. So studies need to be carried out to address school education predominantly secondary education that lays the

groundwork for taking it further and streamlining them towards their goals as either doctors or engineers and scientists in prominent institutions of the country. Moreover, no such study has been conducted in Lucknow over the years, so given the changing dynamics of society, such studies are the dire need of the hour.

Objectives

1. To compare the effect of the virtual lab-enabled active learning method and traditional teaching method on scores of academic achievement of secondary stage students in physics.
2. To compare the effect of the virtual lab-enabled active learning method and traditional teaching method on scores of academic achievement of male and female students of the secondary stage in physics.

Hypotheses

The following hypotheses were formulated for the objective of the present study-
H01: There is no significant difference between the virtual lab-enabled active learning and the traditional teaching method on mean scores of academic achievement of secondary-stage students in physics.
H02: There is no significant difference between the virtual lab-enabled active learning and traditional teaching method on mean scores of academic achievement of male and female students of the secondary stage in physics.

Methodology

The study is quasi-experimental research that employs a pre-test and post-test equivalent group design. In the present study dependent variable was academic achievement while the independent variable was active learning enabled virtual lab method and traditional teaching method (teaching approach). The population is comprised of CBSE board secondary stage students of Lucknow City. In the present study, 60 students comprised the sample that was selected conveniently using intact grouping. Males and females were both parts of the sample. Sampling was done at two levels: School was selected conveniently while two sections of class 10^{th} were selected randomly and were assigned to experimental and control groups randomly by intact grouping.

Tools used in the study

The following are the tools used in the study:

Active learning experience

An active learning experience was given to the students by the experimenter or through small group discussions. The active learning experience was based on the topics of physics and was taught for a month. Here the active learning experience was provided to the students through the virtual lab simulations. So it was the simulated virtual lab that was used to give active learning experiences to the students. Here the simulated virtual lab that was used was the PhET simulations. The PhET simulations are open-access simulations of the project of the University of Colorado. Here the teachers and instructors could also contribute their simulations. The electricity chapter was taught to the students for one month with virtual lab simulations. The topics covered were:
Current, Voltage, Resistance, Resistivity, Ohm's law, Construction of a basic circuit, Series and parallel connection.

Academic achievement test

For the study, the physics achievement test was prepared for the students of the secondary level. The test comprised 25 questions related to the topic taught through active learning. Four options were given for each question and students had to choose the correct answer. This test was prepared by the investigator to measure the achievement of students of class 10^{th} in physics subject. The test was prepared on the topic- Electricity. The test was validated by experts for content. The reliability of the test was found to be 0.75 using the Kuder-Richardson formula and found that the tool was fairly reliable.

Results of the study

The following virtual lab simulations were used to explain the concepts of Current, Voltage, Resistance, Resistivity, and Ohm's law, Construction of a basic circuit, and Series and parallel connection as shown in Figure 1. In these simulations, the students had to first assemble the various parts of the circuit and then vary various parameters to see the effect on the other on the screen.

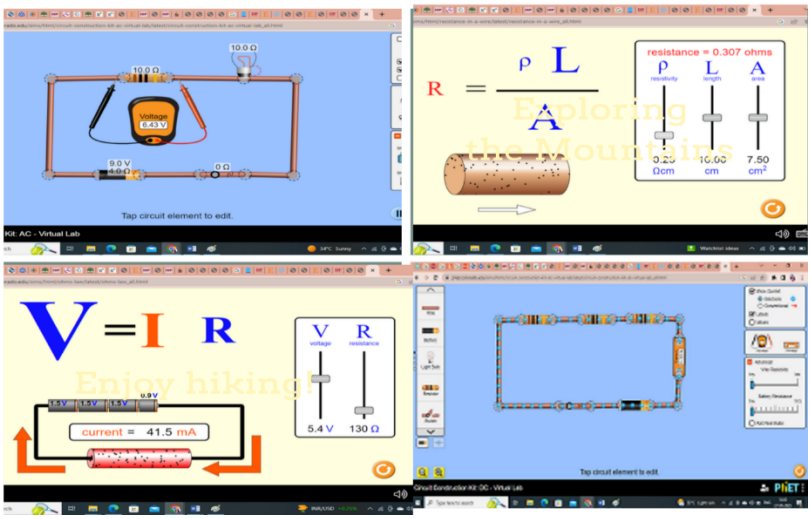

Figure 1. A screenshot of the various virtual lab simulations used by the students

After the collection of data, the data were subjected to statistical analysis. The data were analyzed using ANCOVA.

Effect of virtual lab enabled active learning on academic achievement of secondary stage students

The first objective was to compare the effect of the virtual lab-enabled active learning method and traditional teaching method on scores of academic achievement of secondary-stage students in physics. So a research hypothesis was formulated which was kept as an alternative to the null hypothesis "There is no significant difference between the virtual lab-enabled active learning method and the traditional teaching method on mean scores of academic achievement of secondary stage students in physics."

Table 1 *Summary of One Way ANCOVA of academic achievement in physics of secondary stage students by considering their pre-academic achievement scores in physics as the covariate*

Source	df	SS	$M_{y.x}$	$F_{y.x}$	Remarks
Group	1	184.67	184.67	14.35	p<0.01
Error	57	733.72	12.87		
Total	60	26136.00			

**Significant at 0.01 level.

The adjusted F-value is 14.35 which is significant at 0.01 level with df = 1/57 (Table 1). It indicates that there is a significant difference in adjusted mean scores of academic achievement in physics of the students taught physics through the virtual lab-enabled active learning and traditional methods when their pre-academic achievement scores in physics are considered as the covariate. Thus the null hypothesis that there is no significant difference in adjusted mean scores of academic achievement in physics of the students taught physics through virtual lab-enabled active learning and traditional methods by considering their pre-academic achievement scores in physics as the covariate is rejected. The adjusted mean scores are given in Table 2.

Table 2 *Teaching method-wise $M_{y.x}$, SE_D and N of students*

Teaching method	N	SE_D	$M_{y.x}$
Virtual lab	30	0.47	32.39
Traditional	30	0.47	25.84

Further, the adjusted mean score of academic achievement in physics of the students taught through the virtual lab-enabled active learning method is 32.39 which is significantly higher than that of the students taught through the traditional method whose adjusted mean score of academic achievement in physics is 25.84 when their pre-academic achievement scores are considered as the covariate. It may, therefore, be said that the virtual lab-enabled active learning method was found to be significantly more effective in comparison to the traditional method when their pre-academic achievement scores are considered as the covariate.

Effect of virtual lab enabled active learning on academic achievement of male and female students at the secondary stage

The objective was to compare the effect of the virtual lab-enabled active learning method and traditional teaching method on scores of academic achievement of male and female students of the secondary stage in physics. So a research hypothesis was formulated which was kept as an alternative against the null hypothesis

stated as "There is no significant difference between the virtual lab-enabled active learning method and the traditional teaching method on academic achievement of male and female students of the secondary stage in physics".

Table 3 *Teaching method wise N, M and SD*

Teaching method	Gender	N	M	SD
Virtual lab enabled active learning	Female	12	21.08	4.17
	Male	18	23.67	5.09
Traditional	Female	14	18.50	2.71
	Male	16	21.69	4.60

Since the teaching method has two levels virtual lab and traditional lab while the gender has two levels- male and female. Therefore, the data were analyzed using 2×2 Factorial design ANCOVA of academic achievement in physics of male and female secondary stage students by considering their pre-academic achievement scores in physics as the covariate and the results are given in Table 4.

Table 4 *Summary of 2×2 Factorial design ANCOVA of academic achievement in physics of male and female secondary stage students by considering their pre-academic achievement scores in physics as the covariate*

Sources of variance	df	$SS_{y.x}$	$MSS_{y.x}$	$F_{y.x\text{-}Value}$	Remarks
Teaching method (A)	1	53.86	53.86	3.25	n.s
Gender (B)	1	75.66	75.66	4.56**	p<0.01
A×B	1	0.02	0.02	0.20	n.s
Error	55	911.71	16.58		
Total	60	28779.00			

n.s = Not Significant
** = Significant at 0.01

Effect of groups on academic achievement of male and female students in physics when their pre-academic achievement scores are taken as covariate

From Table 3, it can be seen that the adjusted F-value for the ability group is 4.56 which is significant. It indicates that the adjusted mean scores of academic achievement in physics of male and female students differ significantly. So there was a significant effect of groups on the academic achievement of male and female students in physics taking their pre-retention of academic achievement scores as a covariate. Thus the null hypothesis that there is no significant difference in the effectiveness of virtual lab-enabled active learning and traditional teaching methods on adjusted mean scores of academic achievement of male and female students in physics at the secondary stage is rejected. It may, therefore, be said that the virtual lab method of teaching has a significant effect on the academic achievement of secondary-stage students in physics.

Table 5 *Teaching method-wise N, SE and $M_{y.x}$ of academic achievement*

Teaching method	Gender	N	SE	$M_{y.x}$
Virtual lab-enabled active learning	Female	12	1.12	21.09
	Male	18	0.97	23.37
Traditional	Female	14	1.11	19.13
	Male	16	1.02	21.47

Further from Table 4, it can be seen that the adjusted mean score of academic achievement of the virtual lab-enabled active learning method females is 21.09 which is significantly higher than the traditional method group having an adjusted mean score of academic achievement of 19.13. Similarly, the adjusted mean score of academic achievement of the virtual lab-enabled active learning method males is 23.37 which is significantly higher than the traditional method group having an adjusted mean score of academic achievement of 21.47. It may, therefore, be said that the students taught through the virtual lab-enabled active learning method were found to have academic achievement superior to the students taught through traditional methods.

Effect of methods of interaction between groups and gender when their pre-academic achievement is taken as covariate

The adjusted F-value for interaction between methods of teaching and gender is 0.20 which is not significant (Table 4). It indicates that the adjusted mean scores of academic achievement of the students in physics taught through virtual lab-enabled active learning and traditional methods have no significant effect on genders. So there was no significant effect of interaction between groups and gender on the academic achievement of the students in physics when their pre-academic achievement scores are considered as a covariate. Thus the null hypothesis that there is no significant effect of interaction between methods of teaching and academic achievement of male and female students in physics when their pre-academic achievement scores are

considered as a covariate is not rejected. It may, therefore, be said that there is no significant effect of interaction between groups and gender on the academic achievement of the students in physics at the higher secondary stage.

Discussion of the findings

The findings reveal that there is a positive impact of active learning experiences on Physics subject achievement of students of secondary level. The students who are taught through virtual lab enabled- active learning experiences show better academic achievement as compared to those who were not taught through this.
The virtual lab-enabled active learning method was found to be significantly more effective in comparison to the traditional method when their pre-academic achievement scores are considered as the covariate. Virtual lab-enabled active learning was effective in increasing the academic achievement of the students in the secondary stage. This is because virtual labs are capable of providing visualization and thus reducing abstraction. This finding is similar to the studies conducted by Raja et al. (2021). However, the results contradict the results of Ambusaidi et al. (2018). So this study recommends the use of virtual labs to make the students think critically, developing higher-order thinking skills and inquiry processes (Rajendran, Veilumuthu and Divya, 2010). Likewise, active learning methods must be encouraged by the instructors. They should make concerted efforts to encourage inclusive innovative strategies for the equitable participation of all.
The virtual lab-enabled active learning method was found to be significantly more effective in comparison to the traditional method when their pre-academic achievement scores were considered as the covariate. It was also found to be significantly more effective on male and female students in comparison to the traditional method when their pre-academic achievement scores are considered as the covariate. The virtual lab-enabled active learning was regarded to be relatively more effective for males than females which corroborated with the studies (Moss-Racusin et al. 2018; Oser, 2013). The results of the study contradicted the outcomes of the study (Koksal and Berberoglu, 2014). However, there is no significant effect of interaction between groups and gender on the academic achievement of the students in physics at the higher secondary stage. Although the difference between male and female academic achievements was conveyed to be small nonetheless there was no significant effect of interaction between methods of teaching and gender (Ratamun and Osman, 2018).

Conclusion

In the present piece of work, the researcher tried to study the effect of virtual lab-enabled-active learning experiences on the academic achievement of physics students studying at the secondary level. The present study has brought to light the importance of virtual lab-enabled-active learning experiences in teaching physics as well as its impact on their achievement.
Henceforth, the study may pave the way for more research on the various strategies that may be employed in such virtual and technology-rich environments that may promote active learning among the students. Likewise, the study was conducted for a short duration of time on a small sample. So the study could be conducted for a prolonged period on a larger sample. Additionally, future studies may be conducted in consideration of diverse boards, and the location of the students.

Declaration

1. **Funding**: No funding was received for conducting the study.
2. **Conflict of interest:** The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Aguillon, S.M., Siegmund, G.-F., Petipas, R.H., Drake, A.B., Cotner, S., & Ballen, C.J. (2020). Gender differences in student participation in an active-learning classroom, *CBE Life Sciences Education, 19*(2), 1-19. https://doi.org/10.1187/cbe.19-03-0048
2. Albadi, A., & David, S.A. (2019). The impact of activity-based learning on student's motivation and academic achievement: A study among 12th-grade science and environment students in a public school in Oman, *Special Journal of Knowledge Management, 4*(4), 44-53. Retrieved from https://www.researchgate.net/publication/339503612_The_Impact_of_Activity_Based_Learning_on_Students'_Motivation_and_Academic_Achievement_A_study_among_12_th_Grade_Science_and_Environment_Students_in_A_Public_School_in_Oman
3. Ambusaidi, A., Musawi, A.A., Al-Balushi, S., & Al-Balushi, K. (2018). The impact of virtual lab learning experiences on 9th-grade students' achievement and their attitudes towards science and learning by virtual lab, *Journal of Turkish Science Education, 15*(2), 13-29. Retrieved from https://files.eric.ed.gov/fulltext/EJ1313744.pdf

4. Azizah, N., & Aloysius, S. (2021). The effects of virtual laboratory on biology learning achievement: a literature review, *Advances in Social Science, Education and Humanities Research, 541(0), 107-116*. DOI: 10.2991/assehr.k.210326.015
5. Babateen, H.M. (2011, September 16-18). The role of virtual laboratories in science education [Conference Paper Presentation]. 5th International Conference on *Distance Learning and Education (ICDLE 2011)*, IPCSIT, 12. IACSIT Press, Singapore. Retrieved from http://www.ipcsit.com/vol12/19-ICDLE2011E10013.pdf
6. Bonwell, C.C., & Eison, J.A. (1991). *Active Learning: Creating Excitement in the Classroom* AEHE-ERIC Higher Education Report No. 1. Washington, D.C.: Jossey-Bass. Accessed on 20 May 2023 from https://files.eric.ed.gov/fulltext/ED336049.pdf.
7. Chen, S. (2010). The view of scientific inquiry conveyed by simulation-based virtual laboratories, *Computers & Education, 55*(3), 1123–1130. https://doi.org/10.1016/j.compedu.2010.05.009
8. Dalgarno, B., Bishop, A.G., Adlong, W., & Bedgood, D.R. (2009). Effectiveness of a virtual laboratory as a preparatory resource for distance education chemistry students, *Computers & Education, 53*(3), 853–865. DOI: 10.1016/j.compedu.2009.05.005
9. Darrah, M., Humbert, R., Finstein, J., Simon, M., & Hopkins, J. (2014). Are virtual labs as effective as hands-on labs for undergraduate physics? A comparative study at two major universities, *Journal of Science Education and Technology, 23*(0), 803-814. https://doi.org/10.1007/s10956-014-9513-9
10. Dewey, J. (1983). *Experience and Education*, Kappa Delta Pi Lecture Series. Retrieved from https://www.schoolofeducators.com/wp-content/uploads/2011/12/EXPERIENCE-EDUCATION-JOHN-DEWEY.pdf
11. Duch, B., Groh, S., & Allen, D. (2001). *The Power of Problem-Based Learning: A Practical 'How To' for Teaching Undergraduate Courses in Any Discipline,* Stylus Publishing LLC.
12. Dyrberg, N.R., Treusch, A.H., & Wiegand, C. (2017). Virtual laboratories in science education: students' motivation and experiences in two tertiary biology courses, *Journal of Biological Education, 51*(4), 358-374. https://doi.org/10.1080/00219266.2016.1257498
13. Gambari, A.I., Obielodan, O.O., & Kawu, H. (2017). Effects of virtual laboratory on achievement levels and gender of secondary school chemistry students in individualized and collaborative settings in Minna, Nigeria, *The Online Journal of New Horizons in Education, 7*(1), 86-102. Retrieved from https://www.tojned.net/journals/tojned/articles/v07i01/v07i01-11.pdf
14. Goudsouzian, L.K., Riola, P., Ruggles, K., Gupta, P., & Mondoux, M.A. (2018). Integrating cell and molecular biology concepts: Comparing learning gains and self-efficacy in corresponding live and virtual undergraduate laboratory experiences, *Biochemistry and Molecular Biology Education, 46*(4), 361-372. https://doi.org/10.1002/bmb.21133
15. Gunawan, G., Suranti, N.M.Y., Nisrina, N., & Ekasari, R.R. (2018). The effect of virtual labs toward students' understanding of physics based on gender, *Journal of Physics: Conference Series, 1108* (0), 0120431- 0120437. DOI:10.1088/1742-6596/1108/1/012043
16. Gunawan, G., Suranti, N.M.Y., Nisrina, N., Herayanti, L., & Rahmatiah, R. (2018). The effect of virtual lab and gender toward students' creativity of physics in senior high school, *Journal of Physics Conference Series, 1108*(1), 0120431- 0120437. DOI: 10.1088/1742-6596/1108/1/012043
17. Gunawan, G., Susilawati, Dewi, S.M., Herayanti, L., Lestari, P.A.S., & Fathoroni, F. (2020). Gender influence on students creativity in physics learning with virtual laboratory, *Journal of Physics: Conference Series, 1471*(1), 0120361-0120366. DOI:10.1088/1742-6596/1471/1/012036
18. Hassan, F., Puteh, S., & Buharic, R. (2015). Student understanding through the application of technology-enabled active learning in practical training, *Procedia - Social and Behavioral Sciences, 204(0)*, 318-325. https://doi.org/10.1016/j.sbspro.2015.08.158
19. Ibrahem, U.M., Alsaif, B.S., Alblaihed, M., Ahmed, S.S.I., Alshrif, H.A., Abdulkader, R.A., & Diab, H.M. (2022). Interaction between cognitive styles and genders when using virtual laboratories and its influence on students of health college's laboratory skills and cognitive load during the corona pandemic, *Heliyon, 8*(4), 1-8. https://doi.org/10.1016/j.heliyon.2022.e09213
20. Keter, J.K., Wachanga, S.W., & Anditi, Z.O. (2016). Effect of gender on motivation in chemistry lessons when students are taught through computer based cooperative mastery learning (CBCML) in Bomet County, Kenya, *Journal of Educational Policy and Entrepreneurial Research, 3*(11), 24-35. Retrieved from https://pdfs.semanticscholar.org/33a0/f64de219ab3f95433828b433ee02aaa5cb71.pdf
21. Khan, K., Majoka, M.I., Khurshid, K., & Shah, S.M.H. (2017). Impact of active learning method on students academic achievement in physics at secondary school level in Pakistan, *Journal of Education and Social Sciences, 5*(2), 134-151. DOI: 10.20547/jess0521705204
22. Klahr, D., Triona, L.M., & Williams, C. (2007). Hands-on what? The relative effectiveness of physical versus virtual materials in an engineering design project by middle school children, *Journal of Research in Science Teaching, 44*(1), 183-203. https://doi.org/10.1002/tea.20152
23. Koksal, E.A., & Berberoglu, G. (2014). The effect of guided-inquiry instruction on 6th-grade Turkish students' achievement, science process skills, and attitudes toward science, *International Journal of Science Education, 36(0*, 66-78. https://doi.org/10.1080/09500693.2012.721942

24. Lund, T.J., & Stains, M. (2015). The importance of context: an exploration of factors influencing the adoption of student-centered teaching among chemistry, biology, and physics faculty, *International Journal of STEM Education, 2*(13), 1-21. https://doi.org/10.1186/s40594-015-0026-8
25. McConnell, D., Steers, D. & Owens, K. (2003). Assessment and active learning strategies for introductory Geology courses, *Journal of Geoscience Education, 51(0)*, 205-216. https://doi.org/10.5408/1089-9995-51.2.205
26. McElhaney, K.W. (2007, April 9-13). Learning kinematics by experimenting with visualizations in diverse classroom contexts [Paper presentation]. (AERA) annual meeting on *The World of Educational Quality*, Chicago, Illinois.
27. Moss-Racusin, C.A., Sanzari, C., Caluori, N. & Rabasco, H. (2018). Gender bias produces gender gaps in STEM engagement, *Sex Roles, 79*, 651-670. https://doi.org/10.1007/s11199-018-0902-z
28. Muthusamy, K., Kumar, P.R., Rosfashida, Sh., & Latif, S.A. (2005). Virtual laboratories in engineering Education, *Asian Journal of Distance Education, 3*(2), 55-58. Retrieved from https://www.researchgate.net/publication/229036317_Virtual_laboratories_in_Engineering_education
29. Nair et al. (2012). Role of ICT-enabled visualization-oriented virtual laboratories in Universities for enhancing biotechnology education - VALUE initiative: Case study and impacts, *Formamente-Anno, VII*, 209-228. Retrieved from https://amrita.edu/wp-content/uploads/2017/06/role-of-ict-enabled-visualization-oriented-virtual-laboratories-in-universities-for-enhancing-biotechnology-education-value-initiative-casestudy-and-impacts.pdf
30. National Achievement Survey- class X (2017-18). http://www.ncert.nic.in/programmes/NAS/NAS.html
31. Oser, R.R. (2013). *Effectiveness of Virtual Laboratories in Terms of Achievement, Attitudes, and Learning Environment among High School Science Students* [Doctoral Thesis], Curtin University. Retrieved from https://core.ac.uk/download/pdf/195631589.pdf
32. Padilha, J.M., Machado, P.P., Ribeiro, A., Ramos, J., & Costa, P. (2019). Clinical virtual simulation in nursing education: randomized controlled trial, *Journal of Medical Internet Research, 21*(3). DOI: 10.2196/11529
33. Pelch, M.A., & McConnell, D.A. (2016). Challenging instructors to change: a mixed methods investigation on the effects of material development on the pedagogical beliefs of geoscience instructors, *International Journal of STEM Education, 3*(5), 1-18. https://doi.org/10.1186/s40594-016-0039-y
34. Piaget, J. (1971). The theory of stages in cognitive development. In D. Green, M. P. Ford, & G. B. Flamer (Eds.), *Measurement and Piaget*. New York, NY: McGraw-Hill.
35. Prince, M. (2004). Does active learning work? A review of the research, *Journal of Engineering Education, 93*(3), 223-231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x
36. Ratamun, M.M., & Osman, K. (2018). The effectiveness comparison of virtual laboratory and physical laboratory in nurturing students' attitude towards chemistry, *Creative Education, 9*(9), 1411-1425. https://doi.org/10.4236/ce.2018.99105
37. Reece, A.J., & Butler, M.B. (2017). Virtually the same: A comparison of stem students content knowledge, course performance, and motivation to learn in virtual and face-to-face introductory biology laboratories, *Journal of College Science Teaching, 46*(3), 83-89. DOI: 10.2505/4/JCST17_046_03_83
38. Shih, K.J., Singh, S., & Hoiem, D. (2016). Where to Look: Focus Regions for Visual Question Answering, *Computers Vision and Pattern Recognition, 1*(1), 4613–4621. Retrieved from https://arxiv.org/pdf/1511.07394.pdf
39. Silberman, M. (1996). *Active Learning: 101 Strategies to Teach Any Subject*. Prentice-Hall.
40. Su, C.H., & Cheng, T.W. (2019). A sustainability innovation experiential learning model for virtual reality chemistry laboratory: An empirical study with PLS-SEM and IPMA, *Sustainability, 11*(4), 1-24**.** https://doi.org/10.3390/su11041027
41. Sun, K.T., Lin, Y.C., & Yu, C.J. (2008). A study on learning effect among different learning styles in a web-based lab of science for elementary school students, *Computers & Education, 50*(4), 1411–1422. https://doi.org/10.1016/j.compedu.2007.01.003
42. Tatli, Z., & Ayas, A. (2012). Virtual chemistry laboratory: Effect of constructivist learning environment, *Turkish Online Journal of Distance Education, 13*(1), 183-199. Retrieved from https://chemistrynetwork.pixel-online.org/data/SUE_db/doc/68_7-virtual%20chem%20lab.pdf
43. Triona, L.M., & Klahr, D. (2003). Point and click or grab and heft: comparing the influence of physical and virtual instructional materials on elementary school students' ability to design experiments, *Cognition and Instruction, 21*(2), 149-173. https://doi.org/10.1207/S1532690XCI2102_02
44. Yu, J.Q., Brown, D.J., & Billet, E.E. (2005). Development of virtual laboratory experiment for biology, *European Journal of Open, Distance and E-Learning,* 1-14. Retrieved from https://sciendo.com/journal/EURODL
45. Zacharia, Z.C., & Constantinou, C.P. (2008). Comparing the influence of physical and virtual manipulatives in the context of the physics by inquiry curriculum: the case of undergraduate students' conceptual understanding of heat and temperature, *American Journal of Physics, 76*(4), 425-430. https://doi.org/10.1119/1.2885059

46. Zotou, E.S. (2018). Innovative education: Virtual labs, *Open Schools Journal for Open Science, 1*(1), 9-17. https://doi.org/10.12681/osj.17377