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## Effect of Activity Based Learning on Achievement in Biology among Grade 11 Students

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**Abstract:** Activity-based learning (ABL) is a pedagogical approach focusing on learning through experiences and hands-on experience that help students to be knowledge constructors, develop critical thinking, interpersonal skills etc. With a collaborative approach for creating a positive teaching-learning environment, this learning strategy also has potential of developing the experience and confidence of teachers. In the present paper, the students of Grade 11 were taught the topic 'Electron Transport Chain (ETC)', from the unit 'Cellular Respiration' using ABL. A one group pretest – posttest design of pre-experimental design was used to study its effectiveness on the student's achievement in biology. Purposive sampling technique was used for selecting the sample. The score on the previous achievement test was taken as the pretest score and after the intervention, posttest score was taken. It was found that there was a significant difference in the achievement in biology of secondary level students as a result of ABL as the mean post test scores are higher than the pretest scores, which means that the ABL has improved the achievement in science. It also examines the students' feedback on ABL. The study highlights the importance of interactive learning strategies and provides recommendations for educators to implement ABL effectively.

**Keywords:** Activity-based learning, Electron transport chain, Achievement in biology

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### INTRODUCTION

Activity-based learning (ABL) engages students through hand-on activities, group discussions, visual aids, making complex concepts easier to grasp. Educational technologists and researchers have continually expressed concern over the great divide between theory and practice in teaching. They have constantly tried to bring together current thinking in psychology of learning to facilitate classroom learning. The constructivist approach to learning emphasizes the principle of "learning by doing," asserting that individuals become more proficient through repeated practice. Central to this approach is the active engagement of learners in their educational experiences, where they construct new knowledge

by interacting with their environment and reflecting on these interactions. This method fosters the development of critical thinking, problem-solving, and analytical skills, which are essential attributes for students (Hussain & Sultan, 2010). Learners create new knowledge with the help of these skills which is based on their involvement in the learning process and previous experiences (Li, 2001). Activity based learning is a teaching approach which places students at the center laying strong emphasis on active learning via investigation, questioning and problem solving. Research indicates that activity-based learning encourages critical thinking, teamwork, deeper understanding of complex scientific concepts and collaboration among learners.

Edgar Dale's Cone of Experience integrates multiple learning theories to illustrate that learners retain more when they actively engage—doing—rather than simply hearing, reading, or observing (Lee & Reeves, 2007). This model led to the concept of experiential or action learning, highlighting that direct participation boosts information retention—sometimes cited as high as 90%. Dale emphasized the importance of sensory-rich instruction. The more senses learners use—sight, sound, touch, and more—the better they can internalize material. Therefore, educators are encouraged to design lessons that incorporate real-life, hands-on experiences, making learning immersive and effective.

### **Review of Literature**

Studies on human learning gives rise to several learning theories among which the most common and well known are constructivism and behaviorism. The foundations of these learning theories have profoundly shaped educational systems and teaching practices: activity-based learning draws from constructivist philosophy, while skills-based learning is rooted in behaviorist principles. Behaviorist learning assumptions suggest that learning comes across a structure of behavior in which the learner should go through to acquire new learning (Thorndike 1913; Watson 1924; Hull 1935; Pavlov 1960). The behaviorist school has profoundly shaped teaching and learning by emphasizing structured techniques such as drilling, repetition, individualized instruction, and group-based learning. These methods leverage both operant conditioning—through positive reinforcement (like praise or rewards) and negative reinforcement—and punishment to motivate and guide students. By systematically applying stimulus-response strategies and clear, measurable learning objectives, educators ensure that desirable behaviors are reinforced and undesirable ones are discouraged. This can take the form of immediate feedback, routine-based learning, token economies, and precision teaching—all tools rooted firmly in behaviorist principles. In contrast, the constructivist school, which emerged in the early 20th century, has its foundations in physiology and psychology (Driscoll, 1994). Constructivist theory asserts that social interaction is vital for cognitive growth, as emphasized by Piaget (1970) and Vygotsky (1978), who argued that learners develop understanding most effectively when they engage with others and their cultural context. A central constructivist idea is that individuals grasp concepts more deeply through active participation in meaningful tasks: by being directly involved in an activity, learners gradually internalize its meaning and take ownership of their learning, leading to richer comprehension. In classroom practice, teachers employ diverse, creative, and innovative strategies to introduce new notions—methods that build on students' prior knowledge and experiences. Meanwhile, connectivism offers a framework for understanding learning in the digital age. It highlights how knowledge exists not only within individuals, but also in the myriad connections between information sources—networks, databases, and communities. Learning, in this sense, becomes the act of navigating, recognizing patterns, and nurturing connections across these digital platforms—offering both unprecedented opportunities and new challenges for education today (IGI Global, 2020).

According to Prince (2004), “active learning is generally defined as any instructional method that engages students in the learning process”. Contributing to the debate, Teo and Wang (2000) revealed that traditional instruction often lacks opportunities for students to connect newly learned materials to their previous knowledge. Haghghi et al. (2005) suggested that conventional teaching methods are predominantly lecture-based where learners may be cognitively engaged but remain physically inactive. Ravi and Xavier (2007), described “activity-based learning as an approach in which students are actively engaged both physically and mentally with subject matter through real world simulations,

manipulation of tools and materials associated with the world of work or performance of a real work task.” Azuka (2013) claims that activity-based learning enables students to be active participant in the educational process instead of being a passive learner. With activity-based instruction, students are engaged in analyzing and solving mathematical problems as well as involved in reading, discussion and practical activities (Festus, 2013). Celik (2018) opines that the theory underpinning activity-based learning is based on the principle that children learn more effectively by doing rather than merely observing.

Qahtani (2016) described teachers as facilitators, delegators, and personal role models, emphasizing the importance of their expertise in teaching methodologies. He recommended that educators adopt a range of teaching styles as per the requirements of a diverse group of students with different learning needs. Similarly, Bhalli, Sattar, and Asif (2016) argued that teachers should select instructional methods that promote active student participation and engagement, balancing both student-centered and teacher-centered approaches to effectively transfer knowledge. Albadi and David (2019) supported the concept of engaged teaching, advocating for the use of activity-based learning to foster student involvement. In a related study, Alasi (2018) examined the effects of activity-based learning strategies on second-grade students’ academic performance. The findings from the study pointed to the fact that students better understood the relationships between data and models when they actively participated in learning tasks. Kupcu (2012) also reported that students taught through activity-based methods achieved significantly higher academic success compared to those taught via traditional methods. Supporting this, Birgin et al. (2010) compared activity-based and traditional approaches and found that activity-oriented strategies had a more positive impact on students’ conceptual understanding. This method not only enhanced learning outcomes but also made the educational experience more enjoyable and meaningful for students.

Noreen and Khan (2019) emphasized that experiential learning is very essential in knowledge acquisition because research indicated that more one involves senses in an activity, more one learns and remembers. The activity-based style of instruction is founded on the notion that learning should involve hands-on activities that enable students to relate abstract and hypothetical ideas to real-life situations. Learning by doing enhances comprehension and retention. It also enhances students' self-esteem and allows for solo and group work (Arioder et al., 2020). Activity-based learning enhances social skills by allowing students to work cooperatively and jointly. It promotes creativity in people (Camargo et al., 2020). It also strengthens work-life balance and utilizes child-friendly educational tools (Faikhamta, 2018; Camargo et al., 2020; Chauca et al., 2021).

### **Objectives of the Study**

1. To investigate whether activity-based learning helps in improving achievement in biology among grade 11 students.
2. To know the opinion of students on activity-based learning.

### **Hypothesis of the Study**

There is a significant difference in achievement in biology of grade 11 students as a result of activity-based learning.

**Research Question:** What is the opinion of students towards activity-based learning?

### **Methodology**

In this study, a one group pretest posttest design was used. An activity on the electron transport chain was designed for class 11<sup>th</sup> biology students and conducted at Central Hindu Boys School, Kamachha in Varanasi, Uttar Pradesh, India A total of 38 students participated in this study. The scores obtained by the students in their previous Biology test paper were considered as the pretest scores. The activity of the electron transport chain was conducted in the class and post-test was assigned after the activity. Electron transport activity was conducted in the class by teachers by dividing the students into different

groups and assigning them as the protein complex. Students were explained the steps involved in the electron transport system at the beginning. Teacher also discusses the cellular respiration in eukaryotes and particularly focusing on the electron transport system. Four students in each group participated in a relay race.

1. Each student denoted a protein complex.
2. One student worked as a judge (F0-F1 Particle).
3. One student carried electrons.
4. The activity started as a relay race between two groups to form ATP.
5. Individual students explained their role and played the game of relay race.

The team which was able to generate ATP wins. The teacher watches the game so that students play the game properly and follow the rules and instructions. After the intervention, the posttest on awareness and understanding about electron transport chain was administered to the students. The previous test scores of students in Biology were taken as the pre-test scores.

#### **(a) Tools**

Two tools were developed for the study:

1. Achievement test in Biology
2. An opinionnaire on the activity-based method followed in the class.

#### **(b) Achievement test in Biology**

Ten items were developed from the topic Electron Transport Chain of grade 11 contents. There were items of knowledge level, understanding level and also from application level. Each item had four options from which the respondent had to choose the correct answer. Each correct answer was assigned two marks each. All the test items were validated by taking the expert opinion.

#### **(c) Opinionnaire about activity-based learning**

Twelve items were developed in the Opinionnaire about activity-based learning to know about the student's reaction and opinion about activity-based learning.

#### **(d) Sampling**

Purposive sampling technique was used in the present study. Only the students who have taken Biology as their subject in grade 11 were considered in the study. The intact class of grade 11<sup>th</sup> Biology group were selected as such since it was not feasible to select students randomly from the class.

#### **(e) Analysis of the Data**

To investigate the effectiveness of ABL in improving the achievement in Biology of grade 11 students as a result of activity-based learning, the following hypothesis was formulated:

*There exists a significant difference in achievement in biology of grade 11 students as a result of activity-based learning.*

In order to statistically test the hypothesis, the correlated t-test also known as paired samples test was calculated on the achievement test scores which was administered as the post-test. The scores obtained for the students in their previous biology test was taken as the pretest score. The number of individuals in the group was 38.

## Results

The mean score for pre-test scores on Achievement test and post test scores on Achievement test were 13.68 and 16.63 respectively (Table 1). Also, the standard deviation for pre-test scores on Achievement test and post test scores on Achievement test were 3.721 and 2.794 respectively. The correlation between pre-test scores on Achievement test and post-test scores on Achievement test is 0.202 which is not significant at 0.05 level of significance (Table 2). The calculated T value is 4.349 which is greater than the table value of 2.02 at df 37 and 0.05 level of significance (Table 3). Since the calculated T value is greater than the table value, it is significant at 0.05 level of significance. Hence, the hypothesis stating that '*there is a significant difference in achievement in biology of grade 11 as a result of activity-based learning*' is accepted. Further, it was found from table 1 and graph 1 that the mean score of post test scores on Achievement test (16.63) was greater than that of the pre-test scores on achievement test (13.68). Hence, it can be concluded that the achievement of students who underwent teaching through activity-based learning has improved their achievement in biology as a result of the intervention.

**Table 1: Paired Samples Statistics on Pre-test scores on Achievement test and Post test scores on Achievement test in Biology**

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-Test Score	13.68	38	3.721	.604
	Post Test Score	16.63	38	2.794	.453

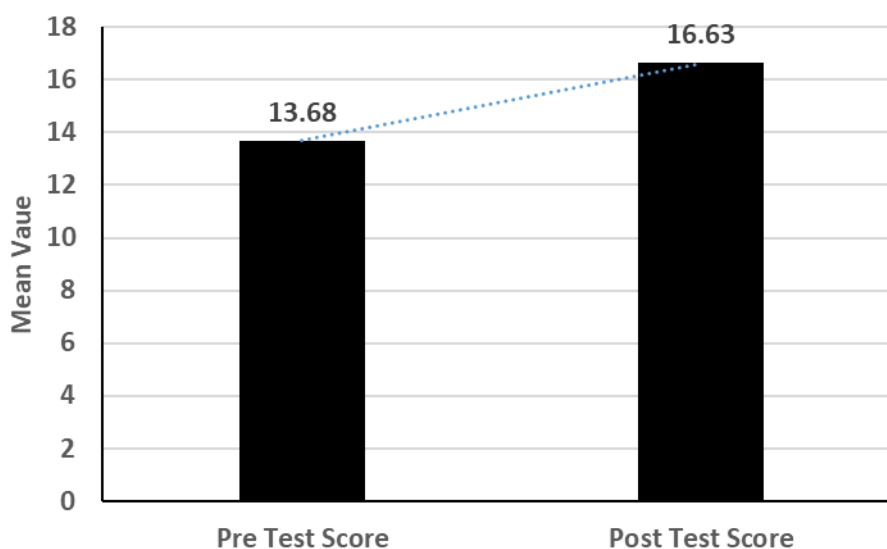
**Table 2: Paired Samples Correlations on Pre-test scores on Achievement test and Post test scores on Achievement test in Biology**

Paired Samples Correlations				
		N	Correlation	Sig.
Pair 1	Pre Test Score & Post Test Score	38	.202	.225

**Table 3: Paired Samples Test on Pre-test scores on Achievement test and Post test scores on Achievement test**

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-Test Score - Post Test Score	-2.947	4.178	.678	-4.321	-1.574	4.349	37	.000

**Graph 1: The mean value of pre-test and post-test on Achievement Test in Biology**



### Analysis of the Opinionnaire

The data collected using the Opinionnaire to know about the feedback of students regarding ABL is analyzed in Table 4.

**Table 4: Analysis of questionnaire responses**

S. No.	Questions	Responses	%	Interpretation of the data
1.	How did you like the activity?	Excellent Good Average Poor	56.6% 33.3% 10% -	It was revealed from the results that 56.6% students responded that they liked the activity to an excellent level and 33.3% responded as good, 10% as average.
2.	The activity was engaging and interesting?	Yes Somewhat No	100% - -	It was revealed from the data that 100% of the students found the activity engaging and interesting.
3.	Did the activity help you understand the topic better?	Yes Somewhat No	98.3% 1.66% -	It was observed from the result that 98.3% students responded that the activity helped them to understand the topic better and 1.66% students responded that only sometimes the activity helped them to understand the topic better
4.	How clear were the instructions provided for the activity?	Very clear Somewhat Not clear	96.6% 3.33% -	It was observed from the data that 96.6% of the students responded that the instructions for the activity were very clear while 3.33% responded that the instructions were somewhat clear.

S. No.	Questions	Responses	%	Interpretation of the data
5.	Did this activity improve your following skills? a) Teamwork skills  b) Problem-solving skills  c) Creativity  d) Critical thinking	Yes  No Yes  No Yes  No Yes  No Not attempted	100%  -  100%  -  85% 15%  48.33%  - 51.66%	The analysis showed that 100% students responded that the activities helped in improving their teamwork skills and problem-solving skills.  85% students responded that it helped in improving their creativity while 15% responded that the activity did not help in improving their creativity.  48.33% responded that the activity helped in improving their critical thinking whereas 51.66% did not answer this item
6.	Did the activity connect theoretical knowledge with practical application?	Strongly agree  Agree  Neutral  Disagree  Not Attempted	48.33%  50%  -  -  1.66%	The analysis revealed that 48.33% of students strongly agreed and 50% agreed that the activity helped in connecting theoretical knowledge with practical application.
7.	What challenges did you face during the activity? a) Understanding the topic  b) Time management  c) Group coordination  d) Resource availability	Yes  No Yes  No Yes  No Yes  No	95%  -  80%  20%  83.33%  11.66%  36.6%  63.3%	It was found from the data, that 95% of students faced challenges in understanding the topic, 80% faced challenges in time management, 83.3% faced challenges in group coordination and, 63.33% responded that they did not find any difficulty with resource availability and 36.6% responded that resource availability was a challenge during the activity.
8.	Did the activity encourage collaboration and teamwork among students?	Yes  Somewhat  No  Not attempted	96.6%  1.66%  -  1.66%	It was found from the analysed data that 96.6% of students responded that the activity encouraged collaboration and teamwork among students

S. No.	Questions	Responses	%	Interpretation of the data
9.	Did you feel more confident after the activity?	Yes Somewhat No Not attempted	96.66% 1.66% - 1.66%	The analysis revealed that 96.6% of students felt more confident after the activity
10.	How would you rate the overall experience of the PBL activity?	Excellent Good Average Poor Not attempted	68.33% 23.33% 6.66% - 1.66%	The analysis shows that 68.33% students rated as excellent for the overall experience of the PBL activity, and 23.3% responded that their overall experience of the PBL activity was good.
11.	Would you like more such project-based learning activities?	Yes May be No Not attempted	96.66% 1.66% - 1.66%	It was found from the data that 96.6% of students like to include more such project based learning activities.
12.	Rate your overall experience of the activity.	Excellent Good Average Poor Not attempted	68.33% 23.33% 3.33% - 1.66%	It was analysed that 68.33% students rated the overall experience of the activity as excellent, 23.3% as good, and 3.33% as average.

## Findings

The major findings from the Achievement test in Biology and Analysis of the Opinionnaire demonstrate the fact that the achievement of the students in subject Biology who underwent teaching through activity-based learning improved significantly. Moreover, the students found the activity engaging and interesting, helping them to understand the topic electron transport system better, helped to develop teamwork skills, problem-solving skills, creativity and critical thinking. The activity also connected theoretical knowledge with practical application and encouraged collaboration and teamwork among the students.

## Discussion

Present study demonstrates that ABL contributes significantly in improving the achievement of the students in subject Biology. Similar findings were reported in a study conducted by Ateş and Eryilmaz (2011), who found that hands-on activities can improve academic achievement in Physics. Similarly, in a study conducted by Hussain and Akhtar (2013), it was reported that the average science achievement was better for students using hands-on activity compared to students using non-hands-on activity. Stohr-Hunt (1996) studied the role of frequency of hands-on activities on a daily, weekly, monthly and never basis in influencing the eighth-grade students' science achievement. The results clearly identified that hands-on activities done frequently on a daily or weekly basis significantly improved the science

achievement of students compared to hands-on activities done on a monthly basis or never. The findings of our study are also similar with those studies done by Freedman (1997) and Turpin's (2000) wherein it was observed that compared to students using a traditional science curriculum, the students using activity-based science curriculum had significantly higher scores.

Findings from a meta-analysis have also exhibited similar findings. An analysis of 57 studies based on activity-based learning by Bredderman (1983) reported a positive impact on student achievement compared with traditional science programs. Another meta-analysis conducted by Shymansky et al. (1983) involving 105 studies also reported a positive impact on student achievement compared with traditional science programs. A study by Schwichow et al. (2016) evaluated the role of hands-on activities on procedural abilities of the students and observed a positive correlation. However, no association was observed with conceptual understanding of the students. Furthermore, studies were also conducted to evaluate the impact of hands-on teaching methods. A study by Bristow (2000) examined the effectiveness of hands-on teaching methods compared to the traditional methods. It was observed that though there was no significant difference in the performance of students in both groups, there was more positive attitude for science amongst the students receiving hands-on instruction. Similar observations were also found in various other studies exhibiting better attitude for science amongst the students receiving the hands-on teaching compared to those receiving traditional teaching (Jaus, 1977; Bredderman, 1983; Kyle, Bonnsetter, & Gadsten, 1988; Bristow, 2000; Bilgin, 2006).

Our results also align with the findings of previous research comparing the effects of ABL and traditional learning on academic achievement of the student. For instance, Al Muhaimed (2013) conducted a similar study in Saudi Arabia focused on teaching English. His study concluded that ABL significantly improved English language acquisition of the student by boosting their achievement scores. Similarly, Batdi (2014) reported that both quantitative and qualitative data from his research demonstrated the positive impact of ABL on academic performance. The current findings also support those of Celik (2018) and Camaci (2012), who examined the effects of activity-based learning in mathematics. Their studies concluded that this approach enhances students' academic success and leads to better understanding of the subject matter. Furthermore, Rubin et al. (2014) found that activity-enriched teaching positively influences students' perceptions of learning, a finding echoed by Kosterelioğlu and Yapici (2016).

A qualitative method based on twelve items developed in the Opinionnaire was employed to explore students' opinions on the activity-based learning approach. Feedback revealed generally positive feelings and perceptions toward this method. Based on these findings, it can be inferred that activity-based learning may enhance both student achievement and their overall perception of the learning experience, compared to traditional methods. Students attributed this improvement to several factors, including better understanding through hands-on experiences that promote long-term retention, collaborative learning among peers, and the engaging and enjoyable classroom environment created by activity-based lessons.

The results obtained in this study suggest that teachers should incorporate ABL strategies more frequently when teaching subject biology, as the findings indicate a notable improvement in students' achievement compared to traditional teaching methods. This study opens new dimensions for more investigations into the effectiveness of activity-based learning strategies, which may contribute valuable data for researchers and educators. Future studies could consider expanding the sample population, extending the duration of the intervention, or exploring additional dependent variables to gain deeper insights.

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**Conflict of Interest Statement:** The authors declare no conflict of interest.

**Data Availability Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

## References

- Alasi, W. (2018). The effectiveness of teaching using active learning strategies on second grade students' acquisition of national and life knowledge. *IUG Journal of Educational and Psychology Science*, 27(1), 135-151.
- Al Muhaimed, S. (2013). Task-based language teaching vs. traditional way of English language teaching in Saudi intermediate schools: A comparative study. Ph.D. Thesis. Kent State University College.
- Albadi, A., & David, S.A. (2019). The Impact of Activity Based Learning on Students' Motivation and Academic Achievement: A study among 12th Grade Science and Environment Students in A Public School in Oman. *Specialty Journal of Knowledge Management*, 4 (4), 44-53.
- Arioder, L. J. Q., Arioder, V. Q., Quintana, V. V., & Dagamac, N. H. (2020). Application of constructivist teaching approach in introducing new environmental concepts to young elementary students in the Philippines: A small class sized experience from slime moulds modeling, *Interdisciplinary Journal of Environmental and Science Education*, 16(2), e2214.
- Ateş Ö., & Eryilmaz, A. (2011) Effectiveness of hands-on and minds-on activities on students' achievement and attitudes towards physics. *Asia-Pacific Forum on Science Learning and Teaching*, 12(1), 1–22.
- Azuka, B. F. (2013). Activity-based learning strategies in mathematics classrooms. *Journal of Education and Practice*, 4(13).
- Batdi, V. (2014). The effect of activity-based learning approach on academic achievement (A meta-analytic and thematic study). *E-International Journal of Educational Research*, 1(1), 39-55.
- Bhalli, M., Sattar, A. & Asif, M. (2016). Teaching strategies; perception of medical students used in basic science year. *The Professional Medical Journal*, 23 (05), 614-619.
- Bilgin, İ. (2006). The effects of hands-on activities incorporating a cooperative learning approach on eight grade students' science process skills and attitudes towards science. *Journal of Baltic Science Education*, 1(9), 27-37.
- Birgin, O., Baloglu, M., Catlioglu, H. & Gurbuz, R. (2010). An investigation of mathematics anxiety among sixth through eighth grade students in Turkey. *Learning and Individual Differences*, 20 (6), 654- 658.
- Bredderman, T. (1983). Effects of activity-based elementary science on students' outcomes: A qualitative synthesis. *Review of Educational Research*, 53(4), 499-518.
- Bristow, B. R. (2000). The effects of hands-on instruction on 6th grade students' understanding of electricity and magnetism. *Dissertation Abstracts International*, 39(01), 30A (UMI No. AAT 1400301).
- Camaci, F. (2012). Effects of activity-based teaching grounded on active learning on students' academic skills and learning process. Master Dissertation. Adiyaman University.
- Camargo, C., Brancaliao, L., Goncalves, J., Lima, J., Ramos, M., Fernandes, L., Trovisco, M., Conde, M. (2020). Emídio Garcia School Pilot description: A Robosteam Erasmus+ Project Activity based on a Challenge based Learning Approach. *2020 IEEE Global Engineering Education Conference (EDUCON)*, 290–294.
- Çelik, H. C. (2018). The effects of activity-based learning on sixth grade students' achievement and attitudes towards mathematics activities. *Eurasia Journal of Mathematics, Science and Technology Education*, 14(5), 1963–1977.

- Chauca, M., Phun, Y., Curro, O., Chauca, C., Yallico, R., & Quispe, V. (2021). Disruptive Innovation in Active Activity-Based Learning Methodologies through Digital Transformation, *International Journal of Information and Education Technology*, 11(4).
- David, S.A., & Abukari, A. (2019). Perspectives of teachers on the selection and the development of the school leaders in the United Arab Emirates. *International Journal of Educational Management*. 34(1), 56-69.16. David, S.A.
- Driscoll, M. P. (1994). *Psychology of learning for instruction*. Massachusetts: Allyn & Bacon.
- Education: Innovation & Technology (CSEIT) 2010, Global Science and Technology Forum, Singapore City.
- Faikhamta, C., Ketsing, J., Tanak, A., & Chamrat, S. (2018). Science teacher education in Thailand: a challenging journey. *Asia-Pacific Science Education*, 4(1), 3.
- Festus, A. B. (2013). Activity-based learning strategies in the Mathematics classroom. *Journal of Education and Practice*, 8-14. 4(13).
- Freedman, M. P. (1997). Relationships among laboratory instruction, attitude toward science, and achievement in science knowledge. *Journal of Research in Science Teaching*, 34(4), 343-357.
- Haghighi, A. M., Vakil, R. & Weitba, J. K. (2005). Reverse-traditional/hands-on: An alternative method of teaching statistics. *Application and applied mathematics (AAM)*. 1, (2006).
- Hull, C. (1935). *Principles of behavior*. New York: Appleton-Century-Crofts.
- Hussain, I. & Sultan, S. 2010. "Learning by Doing: Outcomes of Teaching a Research Course through Group Activities", *Proceedings of the Annual International Conference on Computer Science*.
- Hussain, M., & Akhtar, M (2013). Impact of hands-on activities on students' achievement in science: Experimental evidence from Pakistan. *Middle East Journal of Scientific Research* 16(5), 626–632.
- IGI Global (2020). What is Connectivism? Accessed 21 Jan 2020 at <https://www.igiglobal.com>.
- Innovation in Active Activity-Based Teaching Methodologies through Digital Transformation. *International Journal of Information and Education Technology*, 11(4), 200–204.
- Kosterelioglu, I. & Yapici, M. (2016). The effects of activity-based learning process on prospective teachers' perceptions of constructivist learning environment. *International Journal of Human Sciences*, 13 (1), 1342-1354.
- Kupcu, A. R. (2012). The effects of activity-based teaching approach on the proportion related problem-solving success of middle school students. *Journal of Kırşehir Education Faculty*, 13 (3), 175-206.
- Kyle, W. C., Bonnsetter, R. J., & Gadsten, T. (1988). An implementation study: an analysis of elementary students' and teachers' attitudes toward science in process-approach vs. traditional science classes. *Journal of Research in Science Teaching*, 25(2), 103-120.
- Lee, S. J., & Reeves, T. C. (2007). Edgar Dale: A significant contributor to the field of educational technology. *Educational Technology*, 47(6), 56.
- Li, W. (2001). Constructivist learning systems: A new paradigm. *International Conference on Advanced Learning Techniques*, Madison, 6-8 August 2001.
- Noreen, R., & Khan Rana, A. M. (2019). Activity-based teaching versus traditional method of teaching in mathematics at elementary level. *Bulletin of Education and Research*, 41(2), 145-159.
- Pavlov, I. (1960). *Conditioned reflexes*. New York: Dover.

- Piaget, J. (1970). *Science of education and the psychology of the child*. New York: Viking.
- Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93(3), 223–231.
- Qahtani, M. (2016). Comparing teaching methods in Saudi Arabia and The United States. Master Dissertation. Graduate School of Mississippi College.
- Ravi, R., & Xavier, P. (2007). Activity based learning as self-accessing strategy to promote learners' autonomy. *I-manager's Journal on Educational Psychology*, 1(2), 7-9.
- Rubin, R. J., Marcelino, J., Mortel, R. & Lapinid, R. C. (2014). Activity-based teaching of integer concepts and its operations: DLSU Research Congress. De La Salle University, Manila, 6-8 March 2014.
- Schwichow, M., Zimmerman, C., Croker, S., & Härtig, H. (2016). What students learn from hands-on activities. *Journal of Research in Science Teaching*, 53(7), 980–1002. <https://doi.org/10.1002/tea.21320>
- Shymansky J. A., Kyle, W. C., & Alport, J. M. (1983). The effects of new science curricula on student performance. *Journal of Research in Science Teaching*, 20(5), 387-404.
- Stohr-Hunt, P. M. (1996). An analysis of frequency of hands-on experience and science achievement. *Journal of Research in Science Teaching*, 33(1), 101-109.
- Teo, R., & Wong, A. (2000). Does problem-based learning create a better student: A reflection? Paper presented at the 2nd Asia Pacific Conference on problem-based learning: Education across disciplines, December 4-7, 2000, Singapore.
- Thorndike, E. (1913). *The psychology of learning*. New York: Teacher College, Columbia University.
- Turpin, T. J. (2000). A study of the effects of an integrated, activity-based science curriculum on student achievement, science process skills, and science attitudes. *Dissertation Abstracts International*, 61(11), 4329A (UMI No. AAT 9993727).
- Vygotsky, L. (1978). *Mind in society: the development of higher psychological processes*. Cambridge: Harvard University Press.
- Watson, J. (1924). *Behaviorism*. New York: Norton.

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