TPM Vol. 32, No. S8, 2025
ISSN: 1972-6325
https://www.tpmap.org/

Open Access

EFFECT OF STEM EDUCATION BASED INSTRUCTIONAL STRATEGIES ON HIGHER ORDER THINKING SKILLS OF SECONDARY STAGE STUDENTS

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Abstract
The technology and science are expanding too fast. For humans to obtain everyday knowledge, it is increasingly becoming a basic need. Students in STEM education look for answers to issues that arise in the real world. A single discipline's knowledge and abilities are insufficient to solve the multidisciplinary difficulties that arise in real life. In the present study, the researcher explored the effect on higher order thinking skills of secondary stage students. Quasi-experimental research method and Two group Pre-test and Post-test Experimental Design was adopted. Sample was comprised of class IX 80 students (male & female) of Agra city. For data collection; Self-developed tool viz. HOTS-TS was employed. Data was analyzed by using Descriptive Statistics (Mean, & SD) and Inferential statistics (ANCOVA). Results revealed that the significant effect of STEM Education based Instructional Strategies on higher order thinking skills of secondary stage students. Therefore, it can be concluded on the basis of the conclusion drawn from present study that STEM Education based Instructional Strategies has a great deal of potential to improve and advance our educational settings.
Keywords: STEM Education, Instructional Strategies, Higher Order Thinking Skills, and Secondary Stage Students.

INTRODUCTION:

In the changing paradigm of educational system, it can be observed that the academic goals are forwarding to a holistic perspective (Bybee, R. W., 2010). People must adjust and adopt the innovations to deal with the fast advancements in information and technology. Among 21st century abilities & skills that are crucial for people to have to embrace to innovations include creative, critical thinking skills, research, questioning, problem solving, and teamwork (Morrison, 2006). STEM Education' students look for answers to issues that arise in current scenario. A single discipline's understanding, and abilities are insufficient to clarify the interdisciplinary difficulties that are part of the current era. Therefore, now many nations are working to strengthen the educational frameworks and emphasize the significance of teaching STEM Education approach. This is considered to be the most important element of the educational scenario for innovation (Daempfle, P., 2003).

STEM (Science, Technology, Engineering and Mathematics) Education: STEM blends the four disciplines into a coherent learning paradigm focused on real-world applications, as opposed to teaching them as distinct, standalone subjects (Hom, E. J., 2014). The fields of STEM were combined by the National Science Foundation (NSF) in the 1990s to create the abbreviation STEM, a multidisciplinary strategy that was first offered in the US under the umbrella of SMET (Science, Mathematics, Engineering, and Technology). Within the last ten years, the phrase STEM has become mostly common in educational scenario at every educational level to create innovation regarding the discipline of education and all other sectors. (Maass, K., Geiger, V., Ariza, M. R., & Goos, M., 2019).

Higher Order Thinking Skills: When making decisions and addressing problems, thinking abilities help people to think critically and creatively. These kinds of mental abilities are referred to as higher order thinking skills (HOTS). When making decisions and addressing problems, thinking abilities help people to think critically and creatively. Higher order thinking skills (HOTS) are the name given to such cognitive abilities. The idea of higher order thinking skills originated by Bloom's Taxonomy (1956). According to Afandi and Sajidan (2017), there are six orders in Bloom's Taxonomy: memorization, comprehension, application, analysis, evaluation, and creation. Thinking talents were divided into higher order and lower order categories by Bloom's Taxonomy. The category LOTS include memorization, comprehension, and application; HOTS include analysis, evaluation, and creation (Anderson et al., 2010).

Objectives: The current study's objectives were as follows:

1. To study the effect of STEM Education based Instructional Strategies on Higher Order Thinking Skills of Secondary Stage Students.
2. To assess the effect of STEM Education based Instructional Strategies on Analytical Skills.
3. To identify the effect of STEM Education based Instructional Strategies on Evaluative Skills.
4. To analyze the effect of STEM Education based Instructional Strategies on Creative Skills.

Hypothesis: For the current study the following alternative hypothesis has been formulated:
Ha: There will be a significant effect of STEM Education based Instructional Strategies on Higher Order Thinking Skills of Secondary Stage Students.
Delimitations: The study is delimited to the following points:
• The study is delimited to Secondary School of Agra city only.
• The study is delimited to UP Board only.
• The study is conducted on class IX students.
• The study is delimited to science subject only.
Research Method: To fulfill the objectives, the researcher used Quasi-Experimental Research method. Quasi-Experimental method was employed because it is not possible to have full control over the variables or experimental situations in behavioral sciences. In such situations the researcher used the quasi-experimental research method that would provide as much as possible control over existing situations (Kohl, 2009).
Research Design: In the existing study, to attain its objectives Pre & Post-test two group research design was adopted. There were two groups included i.e., Experimental group (EG) and Control group (CG). HOTS-TS was executed on the learners of EG and CG. Learners in EG was treated with STEM Education based Instructional Strategies and learners in Control group was treated with traditional method. After the intervention program the HOTS-TS was executed on the learners of EG and CG.
Sample of the Study: For the present study, Class IX students of UP Board of Agra was selected as a population. To execute the intervention program, Mahendra Singh Inter College, Hanuman Nagar, Agra was chosen through purposive sampling from class IX students of Uttar Pradesh (UP) board of Agra city. In Mahendra singh inter college, Hanuman Nagar, Agra; there were 80 students (girls and boys) registered in Class IX in two sections; i.e., section A and section B. Section A was taken as experimental group (N=40) and section B was taken as control group (N=40) through intact group sampling.
Tools Used: The main objective of HOTS Test in Science was to measure the level of HOTS of Secondary Stage Students. The present tool of HOTS was self-constructed by the researcher. The tool consists of three main dimensions depend upon the levels of the HOTS i.e., (1) Analyzing, (2) Evaluating and (3) Creating. In final draft, 30 items were selected out of 45 items. The duration of completion of test was fixed for 30 minutes. Correct response kept one mark for each and zero for incorrect response. The Cronbach Alpha reliability was found to be 0.79 and CVR value was obtained 0.88.
Data Analysis: Before applying suitable statistical techniques, the distribution of data needs to be determined. Normality check is the prior step to understand the scores' dispersion of dependent variables. In the current study, normality testing can be done using both numerical and visual methods.

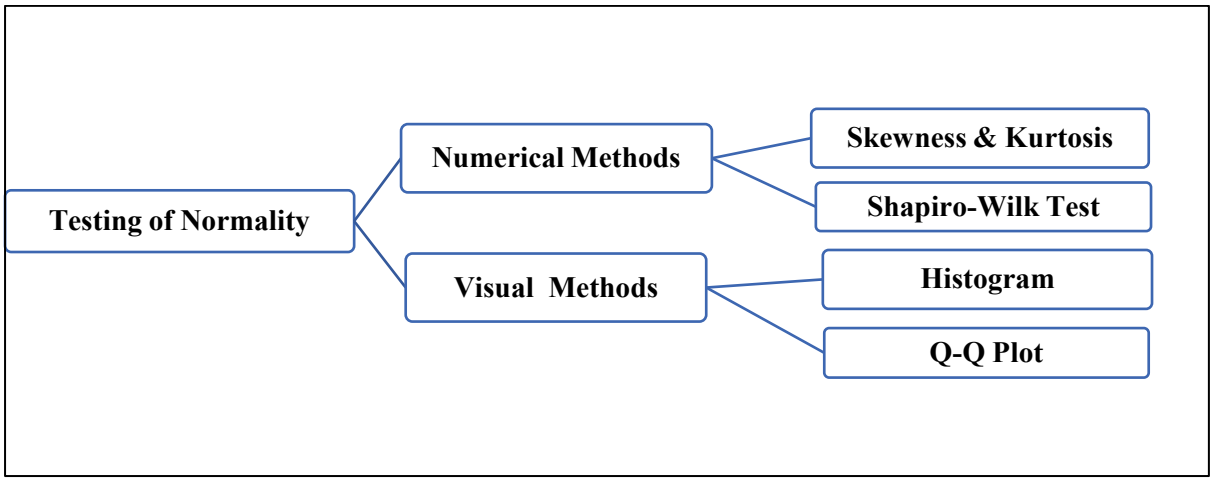


Figure 1.1 Methods of Analyzing the Nature of Data Distribution

A) Analyzing the Distribution of Residuals of Gain Scores of HOTS Test
The distribution of residuals of gain scores of Higher Order Thinking Skills Test obtained by students of EG and CG was determined by the numerical and visual methods.
i) Numerical Method for Analyzing the Distribution of Residuals of Gain Scores of HOTS Test
To test normality numerically, p-value of Shapiro-Wilk Test, z-value of Skewness and Kurtosis were used. Skewness & Kurtosis statistics' value obtained on Higher Order Thinking Skills scores of tests of the EG and CG have been considering in Table 1.1.

Table 1.1 Exhibits the Skewness & Kurtosis statistics' value on Higher Order Thinking Skills Test scores of the EG and CG.

Groups	Skewness			Kurtosis		
	Statistic	Standard Error	Z- Value	Statistic	Standard Error	Z- Value
EG	.142	.374	0.37	-.612	.733	-0.83
CG	.018	.374	0.04	.020	.733	0.02

Table 1.2 Exhibits the Shapiro-Wilk Test statistics' value on Higher Order Thinking Skills Test scores of the EG and CG

Groups	Shapiro-Wilk Test (S-W Test)		
	Statistics	df	Sig (p-value)
EG	.952	40	.087
CG	.981	40	.724

It is visible from table 1.1, that z-value of skewness of EG (0.37) and CG (0.04) and kurtosis of EG (-0.83) and CG (0.02) were found between ±3.29 [acceptable value for 50≤N≥ 300, {Kim,2013}], hence based on z-value of skewness and kurtosis the data is normally distributed. From table 1.2, the p-value of S-W Test of EG (.087) and CG (.724) were found more than 0.05, which was larger than alpha value at 0.05 level of significance; which confirms that residuals of gain scores of Higher Order Thinking skills (HOTS) Test of both the groups were found to be normally distributed.

ii) Visual Method for Examining the Distribution of HOTS Test of EG

To test normalcy visually for examining the distribution of HOTS test of EG, Box Plot and Quantile-Quantile Plot (Q-Q Plot) were used.

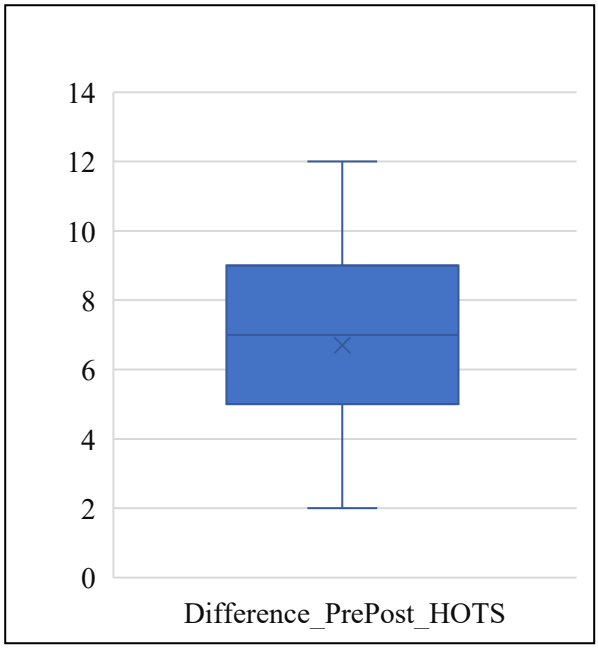


Figure 1.2 Box plot depicts the distribution of Residuals of Gain Scores of HOTS Test

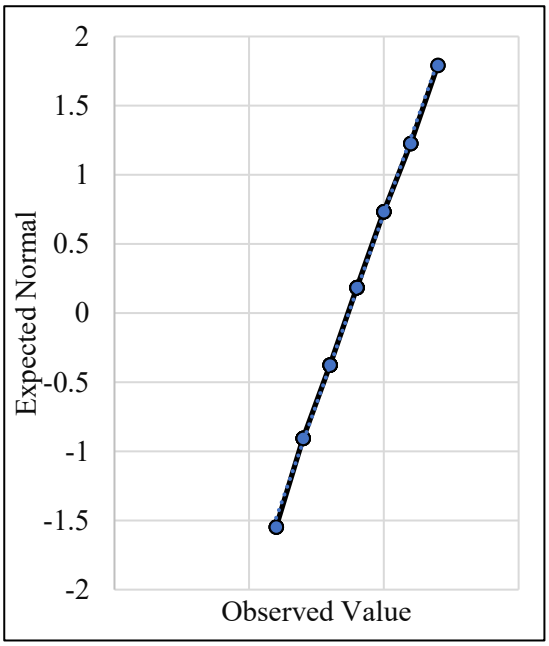


Figure 1.3 Normal Q-Q plot depicts the distribution of Residuals of Gain Scores of HOTS Test

It can be seen in the Figure 1.2; the Box plot, the line divides the box approximately from the center. There is no dot found outer the boundary shows an outlier. In figure 1.3; it can be seen that the Q-Q Plot dots are approximately aligned with a straight line. It is not deviated from normal line of theoretical distribution which indicates that residuals of gain scores of Higher Order Thinking skills (HOTS) Test of Experimental Group were distributed normally.

iii) Visual Method for evaluating the Distribution of HOTS Test of CG

To test normalcy visually for examining the distribution of HOTS test of CG, Box Plot and Quantile-Quantile Plot (Q-Q Plot) were used.

Figure 1.4 Box plot depicts the distribution of residuals of gain scores of Higher Order Thinking skills (HOTS) test of Control Group

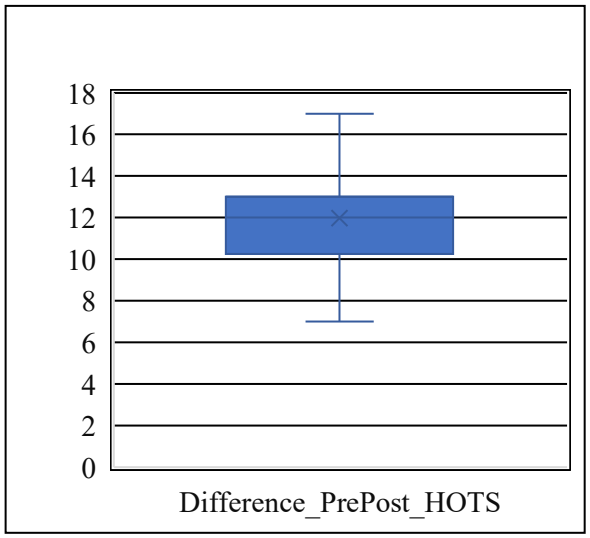
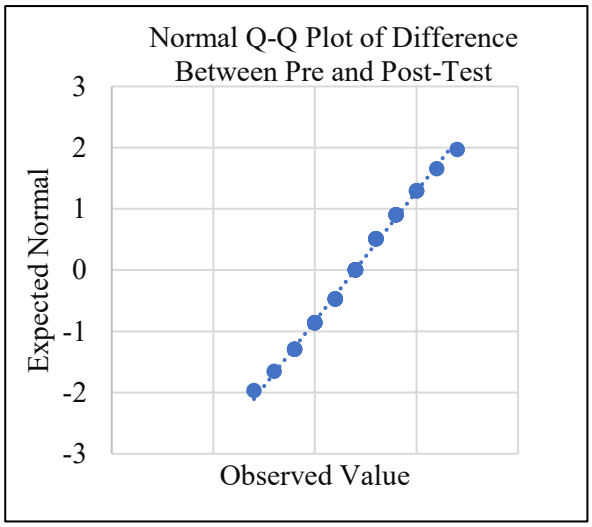


Figure 1.5 Normal Q-Q Plot depicts the distribution of residuals of gain scores of Higher Order Thinking skills (HOTS) test of Control Group



Objective-wise Analysis:

The scores' distribution related to Higher Order Thinking Skills Test in science (HOTS-TS) was met the criteria of normalcy therefore parametric statistics; Analysis of Covariance (ANCOVA) was utilized for objective wise analysis in this current study.

Objective 1: To study the effect of STEM Education based Instructional Strategies on Higher Order Thinking Skills of Secondary Stage Students

ANCOVA summary represents mean difference between the both groups on higher order thinking skills post-test scores considering the effect of pre-test scores (covariate) adjusted. The analysis of ANCOVA for the Higher Order Thinking Skills Test scores post-adjusted scores in EG and CG is given in Table 1.3.

Table 1.3: Shows the Summary of ANCOVA on Higher Order Thinking Skills Post-Adjusted Scores in Experimental and Control Groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	334.990[a]	2	167.495	66.545	.000	.633
Intercept	118.108	1	118.108	46.924	.000	.379
covariate	14.990	1	14.990	5.955	.017	.072
Groups	324.653	1	324.653	128.983	.000	.626
Error	193.810	77	2.517			
Total	4120.000	80				
Corrected Total	528.800	79				

The table 1.3, exhibits the summary of ANCOVA for finding out the significance of the difference between EG and CG for HOTS, keeping pre-test scores as adjusted. From row 4 of table 1.3 representing the significance value for the difference in experimental and control groups. The F-value (128.983) and p-value (.000) were found. The p-value is less than Alpha value (.05). The value of Partial Eta Square (ηp^2) =.626 (62.6% if multiplied by 100). This range comes under of moderate category range of effect size as suggested by the Cohen's guidelines. As per Cohen, 1988; the interpretation of range of effect size are 0-0.20 weak effect, 0.21-0.50 modest effect, 0.50-1.00 moderate effect and >1.00 strong effect. The partial eta squared value shows 62.6 % of the variance in the higher order thinking skills.

Objective 2: To assess the effect of STEM Education based Instructional Strategies on Analytical Skills (Level A)

The analysis of ANCOVA for the Analytical Skills scores post-adjusted scores in experimental and control groups is given in Table 1.4.

Table 1.4 Shows the Summary of ANCOVA on Analytical Skills Post-Adjusted Scores in EG and CG

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	220.014[a]	2	110.007	70.369	.000	.646
Intercept	774.294	1	774.294	495.296	.000	.865
Covariate	71.501	1	71.501	45.738	.000	.373
Groups	46.922	1	46.922	30.015	.000	.280
Error	120.374	77	1.563			
Total	2411.000	80				
Corrected Total	340.388	79				

The table 1.4, exhibits the summary of ANCOVA for finding out the significance of the difference between EG and CG for Analytical Skills, keeping pre-test scores as adjusted. From row 4 of table 1.4 representing the significance value for the difference in experimental and control groups. The F-value (30.015) and p-value (.001) were found. The p-value is less than Alpha value (.05). The value of Partial Eta Square (ηp^2) =.280 (28% if multiplied by 100). This range comes under of modest category range of effect size as suggested by the Cohen's guidelines.

Objective 3: To identify the effect of STEM Education based Instructional Strategies on Evaluative Skills (Level B)

The result of ANCOVA for the scores of the Evaluative Skills Test is given in Table 1.5.

Table 1.5 Shows the Summary of ANCOVA on Evaluative Skills Post-Adjusted Scores in Experimental and Control Groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	265.135[a]	2	132.568	83.115	.000	.683
Intercept	647.801	1	647.801	406.145	.000	.841
Covariate	85.135	1	85.135	53.376	.000	.409
Groups	68.179	1	68.179	42.745	.001	.357
Error	122.815	77	1.595			
Total	1816.000	80				
Corrected Total	387.950	79				

From row 4 of table 1.5 representing the significance value for the difference in experimental and control groups. The F-value (42.745) and p-value (.001) were found. The p-value is less than Alpha value (.05). The value of Partial Eta Square (ηp^2) =.375 (37.5% if multiplied by 100). This range comes under of modest category range of effect size as suggested by the Cohen's guidelines.

Objective 3: To analyze the effect of STEM Education based Instructional Strategies on Creative Skills (Level C)

In last, ANCOVA summary represents mean difference between the both groups i.e., EG and CG on creative skills post-test scores considering the effect of pre-test scores (covariate) adjusted. The result of ANCOVA for the scores of the Creative Skills Test is given in Table 1.6.

Table 1.6: Shows the Summary of ANCOVA on Creative Skills Post-Adjusted Scores in Experimental and Control Groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	372.132[a]	2	186.066	144.618	.000	.790
Intercept	782.319	1	782.319	608.051	.000	.888
Covariate	90.882	1	90.882	70.637	.000	.478
Groups	92.917	1	92.917	72.219	.001	.484
Error	99.068	77	1.287			
Total	2164.000	80				
Corrected Total	471.200	79				

The table 1.6, exhibits the summary of ANCOVA for finding out the significance of the difference between EG and CG for Creative Skills, keeping pre-test scores as adjusted. From row 4 of table 1.6 representing the significance value for the difference in experimental and control groups. The F-value (72.219) and p-value (.001) were found. The p-value is not more than Alpha value (.05). The Partial Eta Square' value (ηp^2) =.484 (48.4% if

multiplied by 100). This range comes under of modest category range of effect size as suggested by the Cohen's guidelines.

FINDINGS AND CONCLUSION OF THE STUDY:

The alternative hypothesis (Ha) i.e., "There is a significant effect of STEM Education based Instructional Strategies on higher order thinking skills of secondary stage students" was accepted. Hence, it can be said that a significant effect of STEM Education based Instructional Strategies was found on higher order thinking skills.
The discussion of the findings made it evident that STEM Education based instructional strategies effected the students' higher order thinking skills to a great extent. The developed lesson plans based on STEM Education also promoted the levels of higher order thinking skills i.e., analytical skills, evaluative skills, and creative skills. These skills enable students to become problem-solver, original thinker, and prepare them for the real world. It can create the interest of the learners throughout the class for promoting their higher order thinking skills. From the findings, it can be affirmed that STEM Education based instructional strategies enhance the higher order thinking skills of secondary stage students.
The study' s findings revealed that STEM Education based learning have a major role in teaching learning process and confirmed the effectiveness of STEM Education based learning as a highly effective pedagogical instrument.

REFERENCES

1. Afandi, & Sjidan. (2017), Stimulasi Keterampilan Berpikir Kritis. Surakarta: UNS Press.
2. Anderson, L. W., & Krathwohl, D. R. (2001). A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives: Complete Edition. New York: Longman.
3. Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. Technology and Engineering Teacher, 70(1), 30 35.
4. Bloom, B.S. (1956). Taxonomy of Educational Objectives: The Classification of Educational Goals Handbook Cognitive Domain. London: Longmans Inc.
5. Bloom, B. S., & Krathwohl, D. R. (1956). Taxonomy of educational objectives; the classification of educational goals by a committee of college and university examiners. Handbook I: Cognitive Domain. New York, NY; Longmans, Green.
6. Cohen, J. (1988). Statistical Power Analysis for the Behavioural Sciences. Second Edition, Hillscate, N: Lawrence Earborne Associates.
7. Daempfle, P. (2003). An analysis of the high attrition rates among first year college science, math, and engineering majors. Journal of College Student Retention: Research, Theory and Practice, 5(1), 37 52.
8. Gupta, R. D. & Shekhar, C. (2011). Achievement Motivation across Gender & Different Academic Streams. Indian Journal of Social Science Researches, 8(1), 116-121.
9. Hom, E. J. (2014). What is STEM education? Livescience, Retrieved from http://www.livescience.com/43296-what-is-stem-education.html
10. Hulleman, C.S., Barron, K.E., Kosovich, J.J., & Lazowski, R.A. (2016). Student motivation: Current theories, constructs, and interventions within an expectancy-value framework. Springer International Publishing, 1(1), 241-278. https://doi.org/10.1007/978-3-319- 28606-8_10
11. Kim, J. (2013). Introduction of Education Measurement. Boston: Houghton Mifflin.
12. Kohl, H. (2009). Research in Education (10th ed.). Pearson.
13. Mass, K., Geiger, V., Ariza, M. R., & Goos, M. (2019). The role of mathematics in inter disciplinary STEM education. ZDM Mathematics Education, 51(1), 869–884. https://doi.org/10.1007/s11858-019-01100-5
14. Morrison, J. (2006). TIES STEM education monograph series, attributes of STEM education. Baltimore, MD: TIES.