Effectiveness of STEAM-Based Learning in Enhancing the Creative Thinking of Secondary School Students

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***Abstract*— The study examined the effectiveness of STEAM-Based Learning in enhancing the creative thinking of secondary school students. The study adopted a pre-experimental single-group pre-test–treatment–post-test design. The sample consisted of 48 secondary school students from Thiruvananthapuram district in Kerala selected through multistage cluster sampling. Creative thinking was assessed using a Creative Thinking Test consisting of 40 open-ended items distributed under four components, namely Fluency, Flexibility, Originality, and Elaboration, and scored through a five-point rubric. After the administration of the pre-test, the students were exposed to an interdisciplinary and activity-based STEAM-Based Learning intervention. On completion of the intervention, the same test was administered as a post-test. The collected data were analysed using EDUSTAT. Descriptive statistics such as mean and standard deviation were used, and the paired-samples t test was employed to test the significance of the difference between the mean pre-test and post-test scores. The magnitude of the treatment effect was estimated using Subin's E effect size. The results revealed significant improvement in total creative thinking as well as in the four components of creative thinking. The obtained effect sizes ranged from strong to very strong. The findings showed that STEAM-Based Learning was effective in enhancing the creative thinking of secondary school students and that it provided a meaningful pedagogic framework for promoting fluency, flexibility, originality, and elaboration in school learning.**

Keywords*— *STEAM-Based Learning, Creative Thinking, Fluency, Flexibility, Originality, Elaboration, Secondary School Students

I. Introduction

Education in the contemporary world is expected to nurture learners who can think beyond the reproduction of textbook knowledge and respond productively to unfamiliar situations. Recent educational frameworks have increasingly emphasized higher-order capacities such as creativity, critical thinking, problem solving, communication, and adaptability. In the school context, creative thinking is now viewed not as a rare talent confined to a few learners, but as a developable educational outcome that can be fostered through purposeful classroom experiences and assessment practices (Ministry of Education, 2020; National Council of Educational Research and Training [NCERT], 2005; OECD, 2023, 2024).

The OECD framework for PISA 2022 described creative thinking as the competence to engage productively in the generation, evaluation, and improvement of ideas that can lead to original and effective solutions, advances in knowledge, and impactful expressions of imagination (OECD, 2023). This understanding is especially relevant for secondary school education, where learners are expected to move beyond rote learning and demonstrate independence, imagination, and flexibility in their thinking.

Within the educational measurement tradition, creative thinking has often been examined through dimensions such as fluency, flexibility, originality, and elaboration. These dimensions refer respectively to the ability to produce many relevant ideas, to shift across categories or perspectives, to generate novel responses, and to develop ideas in a detailed and meaningful manner. These dimensions continue to be widely recognized in creativity assessment and in the Torrance tradition of educational creativity research (Alabbasi et al., 2022; Torrance, 1974).

II Background of the Study

A persistent concern in school education is that conventional classroom practices often privilege uniform answers, memorisation, and procedural completion while offering limited scope for divergent thinking and imaginative problem solving. Indian curricular thought has long argued for a more flexible, child-centred, and creativity-supportive approach. The National Curriculum Framework 2005 highlighted creativity, transfer of learning, communication, and aesthetics as important educational concerns, and the National Education Policy 2020 as well as the National Curriculum Framework for School Education 2023 further emphasized holistic, multidisciplinary, inquiry-based, and experiential learning (Ministry of Education, 2020; NCERT, 2005, 2023).

It is within this larger pedagogic shift that STEAM-Based Learning has gained prominence. STEAM-Based Learning refers to an interdisciplinary approach that integrates Science, Technology, Engineering, Arts, and Mathematics in meaningful learning experiences. STEAM extends STEM by integrating the arts with science, technology, engineering, and mathematics, and it is generally understood as an interdisciplinary approach intended to support meaningful learning, innovation, and engagement across domains. Scholars have pointed out that STEAM is not merely the addition of art to STEM as a separate element, but a mode of teaching and learning in which concepts, methods, and forms of expression

are connected through inquiry, design, and problem solving (Boice et al., 2024; de Vries, 2021).

The educational promise of STEAM is closely related to creativity. Recent reviews and empirical studies have indicated that STEAM-based instruction can positively influence achievement, affective factors, and developmental skills, including creativity. Amanova et al. (2025) concluded in their systematic review that the implementation of STEAM education in schools positively affected learners' learning performance, affective factors, and developmental skills. Likewise, Filipe et al. (2024) showed that integrated STEAM education contributed to students' creativity development.

At the secondary school stage, such an approach assumes particular importance because students at this level are capable of engaging in interdisciplinary exploration, collaborative inquiry, design-oriented tasks, and open-ended problem solving. When students are given opportunities to ask questions, generate alternatives, design solutions, and present ideas in varied forms, they are more likely to demonstrate fluency, flexibility, originality, and elaboration in their thinking. In this context, the present study assumed significance as an attempt to examine whether STEAM-Based Learning could effectively enhance the creative thinking of secondary school students.

III Research Questions

1. Is STEAM-Based Learning effective in enhancing the creative thinking of secondary school students?
2. Is STEAM-Based Learning effective in enhancing fluency, flexibility, originality, and elaboration among secondary school students?

IV Research Objectives

1. To examine the effectiveness of STEAM-Based Learning in enhancing the creative thinking of secondary school students.
2. To examine the effectiveness of STEAM-Based Learning in enhancing fluency, flexibility, originality, and elaboration among secondary school students.

V Hypotheses

The following hypotheses were formulated for the study.

1. STEAM-Based Learning is effective in enhancing the creative thinking of secondary school students.
2. STEAM-Based Learning is effective in enhancing fluency, flexibility, originality, and elaboration among secondary school students.

For statistical testing, the following null hypotheses were considered.

H01: There is no significant difference between the mean pre-test and post-test scores of creative thinking among secondary school students.

H02: There is no significant difference between the mean pre-test and post-test scores of fluency, flexibility, originality, and elaboration among secondary school students.

Methodology

The study adopted a pre-experimental method with a single-group pre-test–treatment–post-test design in order to examine the effectiveness of STEAM-Based Learning in enhancing the creative thinking of secondary school students. In this design, the same group of students was tested before the introduction of the STEAM-Based Learning intervention and again after the completion of the treatment. The difference between the pre-test and post-test scores was taken as the basis for determining the effectiveness of the intervention.

The sample for the study consisted of 48 secondary school students drawn from Thiruvananthapuram district in Kerala. The sample was selected through multistage cluster sampling. The selected students formed a single experimental group for the study. Since the study focused on measuring change in the same group over two occasions, no separate control group was included.

The tool used for data collection was the Creative Thinking Test prepared for measuring the creative thinking of secondary school students. The test measured four components of creative thinking, namely Fluency, Flexibility, Originality, and Elaboration. The test consisted of 40 open-ended items, with 10 items under each component. Each item was scored using a five-point rubric ranging from 0 to 5. Thus, each component carried a maximum score of 50, and the total maximum score of the test was 200. Higher scores indicated a higher level of creative thinking.

The investigator first administered the Creative Thinking Test as a pre-test to the selected students in order to assess their initial level of creative thinking. After the administration of the pre-test, the STEAM-Based Learning intervention was implemented as an interdisciplinary and activity-based instructional programme designed to enhance the creative thinking of the students. The intervention integrated the domains of science, technology, engineering, arts, and mathematics through problem-centred and project-based learning experiences. During the intervention period, the students were engaged in structured activities based on real-life themes and classroom situations appropriate to their level. The activities encouraged observation, questioning, discussion, idea generation, planning, designing, construction of models or solutions, testing, modification, and presentation. The students worked individually as well as in small groups, while the teacher acted as a facilitator by providing guidance, learning materials, and opportunities for exploration and creative expression. Particular emphasis was given to the development of fluency, flexibility, originality, and elaboration by encouraging the students to generate multiple ideas, approach tasks from different perspectives, produce novel responses, and refine their work with adequate detail. On completion of the treatment, the same test was administered again as a post-test.

The scores obtained in the pre-test and post-test were tabulated systematically for each of the four components and for the total creative thinking score. The collected data were analysed using EDUSTAT. Descriptive statistics such as mean and standard deviation were used to describe the pre-test and post-test performance of the students. In order to test the significance of the difference between the mean pre-test and post-test scores, the paired-samples t test was used. Since the same group of students was assessed on two occasions, the paired t test was found appropriate for the analysis. In addition to testing statistical significance, the magnitude of the

treatment effect was estimated using Subin's E effect size for the total creative thinking score and for each of its components.

VI Data Analysis and Interpretation

To examine the effectiveness of STEAM-Based Learning in enhancing the creative thinking of secondary school students, the pre-test and post-test scores of the same group of 48 students were compared. Since the same students were assessed before and after the treatment, the paired-samples t test was used for testing the significance of difference between the mean scores. In addition to significance testing, the magnitude of change was estimated using Subin's E effect size.

Table 1

Descriptive Statistics of Pre-test and Post-test Scores of Creative Thinking and Its Components among Secondary School Students

Variable	N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	Mean Gain
Fluency	48	16.15	3.48	30.40	3.97	14.25
Flexibility	48	18.02	3.21	28.21	2.95	10.19
Originality	48	17.04	2.95	30.92	3.33	13.88
Elaboration	48	19.40	2.14	27.50	2.89	8.10
Total Creative Thinking	48	70.60	11.71	117.02	13.10	46.42

The table shows that the mean post-test scores are higher than the mean pre-test scores for total creative thinking as well as for all the four components. In Fluency, the mean score increased from 16.15 to 30.40. In Flexibility, it increased from 18.02 to 28.21. In Originality, it increased from 17.04 to 30.92. In Elaboration, it increased from 19.40 to 27.50. The total creative thinking score increased from 70.60 in the pre-test to 117.02 in the post-test. The mean gain scores also show considerable improvement after the intervention. These descriptive results indicate that STEAM-Based Learning contributed positively to the enhancement of creative thinking among secondary school students.

Table 2

Paired-Samples t Test of Pre-test and Post-test Scores of Total Creative Thinking among Secondary School Students

Variable	N	Mean Pre-test	Mean Post-test	Mean Gain	SD of Gain Scores	t value	df	p value
Total Creative Thinking	48	70.60	117.02	46.42	3.93	81.84	47	< 0.001

The table reveals that the mean post-test score of total creative thinking (117.02) is much higher than the mean pre-test score (70.60), with a mean gain of 46.42. The obtained t value is 81.84, which is significant at the 0.01 level. This shows that there is a significant difference between the pre-test and post-test scores of total creative thinking among secondary school students. Hence, the null hypothesis H_{01}, stating that there is no significant difference between the mean pre-test and post-test scores of creative thinking, is rejected. This indicates that STEAM-Based Learning was effective in enhancing the creative thinking of secondary school students.

Table 3

Paired-Samples t Test of Pre-test and Post-test Scores of the Components of Creative Thinking among Secondary School Students

Component	N	Mean Pre-test	Mean Post-test	Mean Gain	SD of Gain Scores	t value	df	p value	Decision
Fluency	48	16.15	30.40	14.25	1.36	72.56	47	< 0.001	Rejected
Flexibility	48	18.02	28.21	10.19	1.07	66.27	47	< 0.001	Rejected
Originality	48	17.04	30.92	13.88	1.02	93.91	47	< 0.001	Rejected

Component	N	Mean Pre-test	Mean Post-test	Mean Gain	SD of Gain Scores	t value	df	p value	Decision
Elaboration	48	19.40	27.50	8.10	1.08	52.15	47	<0.001	Rejected

The table shows that all the four components of creative thinking recorded substantial improvement from pre-test to post-test. The obtained t values for Fluency (72.56), Flexibility (66.27), Originality (93.91), and Elaboration (52.15) are all significant at the 0.01 level. Therefore, the null hypothesis H_{02}, stating that there is no significant difference between the mean pre-test and post-test scores of Fluency, Flexibility, Originality, and Elaboration, is rejected in all the four cases. These results show that STEAM-Based Learning was effective in enhancing each component of creative thinking among secondary school students. Among the four components, the highest t value is obtained for Originality, indicating particularly strong improvement in that dimension.

Subin's E Effect Size

In addition to testing the statistical significance of the difference between the pre-test and post-test scores, the magnitude of the treatment effect was also estimated using Subin's E. Subin's E is a heterogeneity-adjusted bounded gain effect size specifically proposed for repeated-assessments research. It is suitable for paired pre-test–post-test designs because it takes into account the mean gain, the reference spread of the two assessments, the small-sample correction, and the heterogeneity in individual gain scores. The value of Subin's E ranges between -1 and +1. For practical interpretation, absolute values from 0.00 to 0.49 indicate limited effect, 0.50 to 0.64 indicate modest effect, 0.65 to 0.79 indicate substantial effect, 0.80 to 0.89 indicate strong effect, and 0.90 to 1.00 indicate very strong effect (Subin, 2024).

Table 4

Subin's E Effect Size for Total Creative Thinking and Its Components

Variable	Subin's E	Magnitude of Effect
Fluency	0.8998	Strong
Flexibility	0.8861	Strong
Originality	0.9157	Very strong
Elaboration	0.8750	Strong
Total Creative Thinking	0.9012	Very strong

The table shows that the effect sizes obtained through Subin's E are high for total creative thinking as well as for all the components. The effect size for total creative thinking is 0.9012, which indicates a very strong effect. Among the components, Originality shows the highest effect size (0.9157), indicating a very strong effect. Fluency (0.8998), Flexibility (0.8861), and Elaboration (0.8750) also show strong effects. These values indicate that the improvement observed after the STEAM-Based Learning intervention is not only statistically significant but also educationally meaningful. Thus, the intervention produced a strong to very strong impact on the creative thinking of secondary school students.

VIII Discussion of the Results

The results of the study showed that STEAM-Based Learning was effective in enhancing the creative thinking of secondary school students. The comparison of pre-test and post-test scores revealed a marked improvement in the total creative thinking score after the intervention. The paired-samples t test showed that the increase was statistically significant, and the effect size also indicated that the magnitude of change was very strong. This suggested that the learning experiences provided through STEAM-Based Learning created favourable conditions for the development of creative thinking among the students. Since STEAM-Based Learning integrated science, technology, engineering, art, and mathematics in an activity-oriented and problem-centred manner, it appeared to have supported active involvement, imagination, idea generation, and meaningful engagement in learning tasks.

The improvement in Fluency indicated that the students became better able to generate a larger number of relevant ideas after the intervention. Before the treatment, the students showed a comparatively lower level of idea production, whereas after undergoing STEAM-Based Learning, their responses reflected greater ease and richness in producing multiple ideas. This may be attributed to the nature of STEAM activities, which generally encourage brainstorming, exploration, and free expression of thoughts. When students were exposed to tasks that demanded open-ended responses, project work, and creative problem solving, they were likely to become more confident in producing a variety of responses without fear of error. The strong effect size obtained for Fluency further confirmed that the gain was not only statistically significant but also substantial in practical terms.

The results relating to Flexibility also showed significant improvement. Flexibility refers to the ability to think from different perspectives and to shift from one category of ideas to another. The higher post-test scores suggested that the students became more capable of approaching a problem in varied ways after experiencing STEAM-Based Learning. This may be because STEAM-based tasks usually do not restrict learners to a single method or one fixed answer. Instead, they promote the exploration of alternatives across different domains and encourage students to connect concepts in diverse ways. Such learning experiences may have broadened the students' thinking patterns and enabled them to move beyond routine or conventional responses. The strong effect size obtained for Flexibility supported the view that the intervention had a meaningful impact on this component.

A notable result of the study was the very high improvement in Originality. Among the four components, Originality showed the highest t value and the highest effect size. This suggested that STEAM-Based Learning was particularly effective in helping students produce novel, uncommon, and meaningful ideas. The interdisciplinary and creative nature of STEAM activities may have played an important role in this improvement. When students were encouraged to design, invent, imagine, and express ideas through integrated tasks, they were given opportunities to go beyond memorised learning and to construct responses in unique ways. The inclusion of artistic expression along with scientific and mathematical thinking may also have contributed to the emergence of original responses. Therefore, the results indicated that STEAM-Based Learning had strong potential for promoting originality in thinking among secondary school students.

The post-test improvement in Elaboration showed that the students became more capable of developing ideas in detail after the intervention. Elaboration involves expanding an idea through explanation, steps, examples, and meaningful detail. The improvement in this component suggested that the students were better able to organise and extend their thoughts in a more complete manner. This may be associated with the practical and project-based nature of STEAM-Based Learning, in which students often needed to explain processes, describe designs, justify their ideas, and present completed work in a structured form. Such experiences may have strengthened their ability to enrich and refine their responses. Although the gain in Elaboration was comparatively lower than that of some other components, it was still statistically significant and supported by a strong effect size, showing that the intervention had a meaningful influence on this aspect also.

Taken together, the findings of the study indicated that STEAM-Based Learning contributed to the enhancement of creative thinking in a broad and comprehensive manner. The improvement was not limited to one isolated dimension but extended to all the major components, namely Fluency, Flexibility, Originality, and Elaboration. This showed that the intervention worked both in increasing the quantity of ideas and in improving the quality, variety, novelty, and detail of student responses. The consistency of statistically significant gains across all components, along with strong to very strong effect sizes, strengthened the conclusion that STEAM-Based Learning served as an effective pedagogic approach for fostering creative thinking among secondary school students.

IX Implications of the Study

The findings of the study carry important implications for classroom teaching at the secondary school level. Since STEAM-Based Learning was found effective in enhancing the creative thinking of students, it suggests that creative abilities can be improved through well-planned instructional interventions rather than being treated as fixed personal traits. This points to the need for classroom practices that deliberately encourage idea generation, exploration, experimentation, and the integration of knowledge across disciplines. Schools may therefore give greater importance to instructional approaches that provide scope for divergent thinking and meaningful student participation.

The study has strong implications for curriculum transaction. The improvement obtained in overall creative thinking and in its components shows that students benefit when learning experiences move beyond routine textbook-centred instruction. This suggests that secondary school teaching may be strengthened by integrating science, technology, engineering, art, and mathematics in an interconnected manner. Lessons designed through STEAM-Based Learning can help students understand concepts more meaningfully while also promoting imagination, innovation, and practical problem solving.

The study also has implications for the teaching of specific components of creative thinking. Since Fluency, Flexibility, Originality, and Elaboration all showed significant improvement, teachers may consciously design learning tasks that address each of these dimensions. Activities such as brainstorming, design challenges, open-ended questioning, model construction, collaborative projects, and creative presentation tasks can be used to promote these components in a systematic way. This means that creative thinking need not be developed incidentally alone, but may be fostered through purposeful pedagogic planning.

The findings suggest important implications for teachers. The effectiveness of STEAM-Based Learning indicates that the teacher's role should increasingly move from mere transmission of information to facilitation of inquiry, design, and creative expression. Teachers may provide opportunities for students to explore multiple solutions, connect ideas from different subject areas, and present responses in original and elaborated forms. This also implies that teachers need adequate orientation and professional preparation in STEAM-based pedagogy so that they can organise learning environments that support creativity and active engagement.

The results also have implications for assessment practices in schools. The Creative Thinking Test used in the study, with its open-ended items and rubric-based scoring, shows the usefulness of assessing student thinking through responses that allow originality, variety, and elaboration. This suggests that school assessment may not rely exclusively on objective or memory-based testing if the aim is to identify and promote creative abilities. Greater use of open-ended tasks, performance-based activities, and rubric-supported evaluation may help teachers capture broader aspects of student learning.

Finally, the study has implications for future research in education. The effectiveness observed in the present study suggests that further studies may be undertaken with larger samples, different school settings, other class levels, and additional learner variables. Similar studies may also examine the long-term retention of creative gains or compare STEAM-Based Learning with other innovative teaching approaches.

X Conclusion

The study concluded that STEAM-Based Learning was effective in enhancing the creative thinking of secondary school students. The analysis of the pre-test and post-test scores showed significant improvement in overall creative thinking as well as in its four components, namely Fluency, Flexibility, Originality, and Elaboration. The effect size analysis using Subin's E further confirmed that the magnitude

of improvement ranged from strong to very strong, indicating that the intervention produced not only statistically significant but also educationally meaningful gains. The findings thus established that when students were provided with integrated, activity-based, and creative learning experiences through STEAM-Based Learning, their ability to generate ideas, think in varied ways, produce original responses, and elaborate their thoughts improved substantially. Therefore, the study affirmed the educational value of STEAM-Based Learning as an effective pedagogic approach for fostering creative thinking among secondary school students.

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