Research Article

Impact of Extracurricular and Cocurricular Science Activities on Students' Scientific Creativity: A Quasi-Experimental Study

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Abstract

This quasi-experimental study aims to assess effectiveness of structured extracurricular and cocurricular activity program on the scientific creativity of Grade IX students in Nepal. In this study, 136 participants were selected from two secondary schools in Kathmandu Valley who were divided into experimental (n = 70; boys = 30, girls = 40), and control (n = 66; boys = 42, girls = 24) groups. The experimental group took part in an 8-month intervention using ECA/CCA programs. To assess the scientific creativity, Scientific Creativity Test (SCT) developed by Hu and Adey (2002) was used. The data was analyzed through descriptive statistics, independent samples t-tests, and Cohen's d effect size. The results demonstrated that students in the experimental group showed statistically significant progress in scientific creativity in comparison to the control group [t(134) = 4.32, p < .001, Cohen's d = 0.74] which produced a medium-to-large effect size. Similarly, there is no gender-based differences visible between pre- and post-intervention during the study as the p-values of the t-tests were found above 0.05. The study demonstrates that ECA/CCA programs which educational institutions design to meet their particular needs functions as effective educational methods for developing scientific creativity in Nepal's resource-limited educational settings which extends to all areas of curriculum development and teacher education and inclusive science education policy creation.

Keywords: cocurricular activities, extracurricular activities, gender equity, quasi-experimental design, scientific creativity

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Introduction

The primary objective of science education is fosterig creativity to deal with the global challenges posed by by rapid scientific advancements (Beghetto, 2016; Sidek et al., 2020). Scientific creativity (SC) requires the combination of domain-specific knowledge together with scientific process skills and innovative thinking to create new ideas (Aktamis & Ergin, 2008; Hu & Adey, 2002; Sak & Ayas, 2013). Scientists need to develop specific abilities to solve research problems through experimental design creation and scientific hypothesis development because these abilities lead to scientific advancements. Thus, the process of scientific creativity development requires more than imagination enhancement because it needs specific thought patterns which scientists use to create new scientific ideas and scientific discoveries.

In Nepal, as in other developing nations, traditional science education practices give priority to completing the curriculum and preparing students for exams instead of using inquiry-based methods and creative student activities (Acharya et al. 2018). Teachers at schools mainly use lecture-based teaching methods which rely upon students listening and note taking the teachers' lectures often delimit students from conducting independent research and developing creative solutions and applying their knowledge in new situations

(McMillan et al., 2018). The teaching environment develops through memorization practices which lead to restricted learning pathways that restrict students from developing advanced scientific creative thinking skills. Students learn scientific knowledge through direct instruction but they fail to develop their ability to use this knowledge in original creative ways across various real-world situations (Haim & Aschauer, 2022).

Science extracurricular and cocurricular activities (ECA/CCA) which include science clubs and exhibitions and project-based learning and field trips provide students with an effective way to develop their creative abilities. Theoretical frameworks which include Dewey's (1938) experiential learning framework and Vygotsky's (1978) sociocultural theory enable ECA/CCA to provide students with real-world situations which require them to use their theoretical knowledge. The activities which students perform in science clubs and field investigations match Dewey's belief that people learn through direct experience and solving real-world problems. Theoretical foundations show that ECA/CCA function as essential learning environments which go beyond their role as supplementary elements to formal teaching (Gottfried & Williams, 2013; Sahin, 2013).

Development of scientific creativity in educational environments of the countries like Nepal manifest a lack of direct research evidence which claims that effective ECA/CCA methods create positive outcomes. The research from Lauer et al. (2006) shows some international studies those disclose a positive relationship between these activities and overall student academic participation. However, the existing literature provides limited evidence to show how ECA/CCA interacts with boys and girls to develop their scientific creativity skills because research shows different gender patterns (Baer & Kaufman 2008; Torrance 1983). As mandated in the policy documents, the current educational environment in Nepal requires both gender equity and incorporation of 21st-century competencies along with the subject related content. Thus, curriculum reform needs to address this agenda.

Theis study investigates how structured ECA/CCA programs affect scientific creativity of Grade IX students in Kathmandu Valley, Nepal to fill existing research gaps. The study establishes three research questions according to the Scientific Creativity Structure Model (SCSM) developed by Hu and Adey (2002).

1. Does participation in a structured ECA/CCA program lead to a significant improvement in students' scientific creativity?
2. Are there gender-based differences in scientific creativity among participants after the intervention?

Methods

Research Design and Participants

This study was conducted using a quasi-experimental research design which included a non-equivalent control group method that utilized pre-test and post-test measurements (Shadish et al., 2002). This design was selected because random assignment of students to conditions was not feasible within the naturalistic school setting. Threfore, intact classes were used. The study population included all Grade IX students who were enrolled in secondary schools throughout Kathmandu Valley during a whole academic session. The researcher selected two schools from this population through purposeful selection because both schools had matching socioeconomic status and institutional resources and teacher qualifications which enabled them to control external factors that could affect creativity results. The researcher established one school as the experimental site while they established the other school as the control site.

A total of 136 Grade IX students (aged 14–15 years) participated: the experimental group comprised 70 students (30 boys, 40 girls) from School B, and the control group comprised 66 students (42 boys, 24 girls) from School A. The researcher established group equivalence on the SCT through pre-testing before starting the intervention. The schools' unequal gender distribution results from natural enrollment patterns which schools did not control. The researcher monitored teacher qualification along with curriculum coverage and co-instructional time to maintain study groups conditions throughout the research period.

Intervention

The experimental group took part in a structured ECA/CCA program for eight months of the academic year (September to April)as an intervention which used authentic science related activities to develop scientific creativity. The intervention used experiential learning and constructivist principles as its theoretical framework and operated as an organized educational program which complemented the existing science curriculum. Table 1 presents the intervention activities with their respective frequency and duration and specific creativity dimensions which they aimed to develop.

Table 1 *Intervention Activities, Timeline, and Targeted Creativity Dimensions*

Activity	Duration/Frequency	Timing	Targeted Creativity Dimension
Weekly Science Club Meetings (inquiry projects)	90 min/week	Months 1–8	Problem solving, scientific purpose, scientific imagination
School-Wide Science Exhibition (design & present)	1 event (2 days)	Month 4	Technical product design, product innovation
Guided Field Trips (museum & environmental sites)	3 trips (1 day each)	Months 2, 5, 7	Scientific phenomena, scientific imagination, sensitivity to problems
Open-Ended Practical Activities (extended labs)	2 hrs/fortnight	Months 1–8	All seven SCT dimensions, emphasis on experimental design

The control group was taught the standard Grade IX science curriculum as prescribed by the CDC (2007) without any additional ECA/CCA involvement beyond routine school activities. The two groups of students received their science instruction from teachers who had equal qualifications and teaching experience to reduce the impact of different teacher effects.

Instrument and Adaptation

The scientific creativity was assessed through the Scientific Creativity Test (SCT) adapted from Hu and Adey (2002). The SCT is based on the Scientific Creativity Structure Model (SCSM), which defines scientific creativity as a specialized skill that develops through the combination of scientific knowledge and creative thinking and scientific methodology (Hu & Adey, 2002). The SCT differs from standard divergent thinking assessments because it requires students to demonstrate creative thinking through scientific problems which they will encounter in actual scientific research. The instrument comprises seven open-ended tasks which assess different scientific creativity aspects according to Table 2.

Table 2 *SCT Task Descriptions and Targeted Creativity Dimensions*

Task	Name	Description	Creativity Dimension Assessed
I	Scientific Purpose	Generate varied and original uses for a scientific object	Fluency, flexibility of thought in technical domain
II	Sensitivity to Problem	Identify and formulate researchable scientific questions	Problem-finding; inquiry initiation
III	Technical Product	Creatively improve a technical tool/product	Technical innovation, design creativity
IV	Scientific Imagination	Generate imaginative scenarios grounded in science	Originality, scientific thinking

V	Problem Solving	Divergent methods for solving a spatial-mathematical problem	Divergent thinking, analytical flexibility
VI	Scientific Phenomena	Design methods to test a scientific phenomenon	Experimental design creativity
VII	Product Design	Design a novel scientific product from a given constraint	Inventive design, product innovation

The responses from the students were scored through fluency (number of relevant ideas), flexibility (diversity of categories), and originality (statistical rarity of responses), dimensions (Torrance 1974) and framework of creative thinking (Wiyanto & Hidayah, 2021). To adapt the research tool (SCT) to use in Nepalese context, the item impacted (e.g., the scientific objects and their use to scientific purpose used in Task I; the problem solving strategies or phenomena and product design in Tasks V, VI and VII) were reviewed and modified by a panel of three senior science educators and two curriculum designers from Tribhuvan University to establish contextual relevance and cultural fairness in the Nepalese environment.

The researcher translated Task instructions into Nepali and then performed back-translation to check for equivalent meaning. The researcher tested the adapted instrument with 30 Grade IX students who did not participate in the main study and found it to have acceptable reliability with a Cronbach's $\alpha = 0.82$. Two trained raters assessed all tasks and their inter-rater reliability achieved satisfactory results with a Cohen's $\kappa = 0.85$.

Data Analysis

The researcher used IBM SPSS 27 for data analysis procedure. For this, descriptive statistics, i.e.; mean and standard deviation were calculated for each SCT task and for total SCT scores for both groups at pre-test and post-test stages. The researcher used independent samples t-tests to compare the post-test total SCT scores of the two groups to determine how the intervention affected their results. The experimental group underwent independent samples t-tests to assess gender differences between boys and girls on all seven SCT tasks at post-test. The researchers assessed practical significance of their results through Cohen's d effect size which they interpreted according to conventional benchmarks: small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$) (Cohen, 1988).

Results and Discussion

The research results are presented in this section which follows the two research questions that guide the study. The first theme assesses how ECA/CCA intervention affects scientific creativity through its complete impact. The second theme investigates how different tasks affect the experimental group through its examination of gender differences. Both themes present a detailed account of how structured ECA/CCA programs affected scientific creativity through their effects on both scientific creativity levels and equity distribution.

Overall Impact of ECA/CCA on Scientific Creativity

The independent samples t-test confirmed that the experimental group and control group showed no significant difference in total SCT pre-test scores before the intervention ($t(134) = 0.31$, $p = .758$). The experimental group showed significantly more improvement in mean SCT scores after the 8-month intervention period when compared to the control group. The independent samples t-test results showed that both groups had different post-test mean SCT scores which reached statistical significance [$t(134) = 4.32$, $p < .001$] and showed a medium-to-large effect size (Cohen's $d = 0.74$) which indicated that the intervention produced educationally important results. The research finding supports the study by Siew and Ambo (2020) which proved that STEM project-based cooperative learning programs increase scientific creativity among students. The research finding supports the

Haim and Aschauer (2022) study which demonstrated that students who experience flexible learning environments will improve their scientific creative thinking abilities.

The results shows that ECA/CCA programs which use organized structures for scientific creativity dimensions create effective instructional strategies that work together with contemporary science teaching. The intervention provided students with repeated, varied opportunities for authentic inquiry, open-ended problem-solving, and creative application of scientific knowledge in real-world contexts. Those activities build through learning and practical experience which both Dewey and Vygotsky describe in their educational theories.

Task-Specific Analysis

The experimental group showed varied improvements in scientific creativity which emerged from the seven SCT tasks with their detailed investigation. The experimental group from School B shows their boys and girls pre-test and post-test results through Table 3 which displays their average SCT task scores together with post-test gender comparison statistics.

Table 3 *Mean SCT Task Scores for Experimental Group (School B) by Gender, Pre-test and Post-test, with Post-test t-test Statistics*

Task	Pre Boys	Pre Girls	Post Boys	Post Girls	t (post)	p (post)	d
I. Scientific Purpose	4.83	4.55	6.63	8.75	-1.24	.221	0.30
II. Sensitivity to Problem	7.07	7.03	9.43	10.20	-0.38	.702	0.09
III. Technical Product	5.00	5.28	7.93	8.55	-0.40	.688	0.10
IV. Scientific Imagination	4.50	4.05	6.73	7.75	-0.69	.491	0.17
V. Problem Solving	3.80	3.50	9.05	8.50	0.46	.644	0.13
VI. Scientific Phenomena	4.30	4.55	4.47	5.13	-0.41	.686	0.10
VII. Product Design	1.83	2.00	2.17	2.65	-0.77	.442	0.19

Note. All p-values are for post-test gender comparisons within the experimental group (two-tailed). d = Cohen's d.

The most significant improvement observed in Task V (Problem Solving) because boys achieved an average score increase from 3.80 to 9.05 and girls increased their average score from 3.50 to 8.50. The ECA/CCA program's hands-on, collaborative and inquiry-based approach developed students' analytical and divergent problem-solving skills. The science club meetings, which centred on inquiry projects requiring students to formulate and test multiple hypotheses, appear to have been especially impactful for this dimension. The students made substantial progress between their initial assessment and final evaluation in Tasks II (Sensitivity to Problem: boys +2.36, girls +3.17), III (Technical Product: boys +2.93, girls +3.27), and I (Scientific Purpose: boys +1.80, girls +4.20). The program helped students improve their skills in researchable scientific question identification and technical product innovation and scientific object creation according to Hu and Adey (2002) concept of scientific creativity.

Conversely, improvements in Task VI (Scientific Phenomena) and Task VII (Product Design) were modest for both groups. For Task VI, post-test means indicated minimal change from baseline, and for Task VII, absolute scores remained low (post-test means of 2.17 for boys and 2.65 for girls). These tasks require abstract reasoning about natural phenomena and complex spatial-mechanical design thinking. Respectively, capacities that may demand more targeted and sustained scaffolding than the current intervention provided (Runco & Acar, 2012). These findings are practically significant for the refinement of future ECA/CCA programs: activities specifically targeting experimental design and product innovation should be allocated more time and structured support within intervention curricula.

Gender Differences in Scientific Creativity

The experimental group post-test showed that independent samples t-tests found no gender differences across all seven SCT tasks (all $p > .05$; see Table 3). The effect size results showed all values from small to negligible which demonstrated that no significant gender differences existed. Girls achieved a higher post-test mean than boys in Task I (Scientific Purpose) (8.75 vs. 6.63), but this difference lacked statistical significance [$t(68) = -1.24$, $p = .221$, $d = 0.30$]. Boys achieved a slightly better score than girls in Task V (Problem Solving) because boys scored 9.05 while girls scored 8.50 but their results remained non-significant [$t(53) = 0.46$, $p = .644$, $d = 0.13$].

The study shows that both boys and girls can develop equal scientific creativity when they receive the same opportunities to experience interactive science learning through the ECA/CCA program. This hypothesis matches Hyde's (2014) gender similarities theory and scientific evidence which shows that most creativity differences between genders come from environmental factors instead of being natural (Baer & Kaufman, 2008). The gender-equitable results of this intervention become especially important because girls in Nepal face systematic obstacles which prevent them from fully participating in science education. The results prove that ECA/CCA programs which design programs should be used to achieve gender equality in science education.

The control group showed no significant changes in SCT performance from pretest to posttest for both male and female participants, which proved that the experimental group achieved their improvements through the study intervention rather than natural development or historical changes.

Conclusion and Implications

The study demonstrates that secondary level students who participate in structured scientific activities scheduled outside their regular class experienced visible improvements in their scientific creativity. The intervention showed a medium-to-large effect on overall scientific creativity (Cohen's $d = 0.74$), which showed the strongest improvement in problem solving and problem sensitivity and technical product design, skills that directly connect to the practical research-based activities of ECA/CCA programs. The program achieved equal success for both boys and girls, which shows that structured ECA/CCA activities can help create gender balance in science creative activities.

The results from this study provide crucial information that affects all parties involved in the educational system of Nepal. The results present a strong argument which requires educators and school leaders to implement science-focused ECA/CCA as required programs instead of optional activities. Core educational methods for developing scientific creativity include science clubs, student-led exhibitions, and guided field investigations as essential teaching methods. Science teachers need professional development training which teaches them how to conduct open-ended ECA/CCA activities that explore all aspects of scientific creativity development. The current intervention demonstrates its ability to function effectively in resource-limited government-affiliated school environments which confirms its suitability for various resource-constrained situations.

The research results show that national science curricula need to define learning outcomes for scientific creativity while offering organized areas and support for ECA/CCA activities. Assessment frameworks should move beyond content knowledge to recognise and reward creative project work experimental design and innovative product development. The minor improvements seen in Tasks VI (Scientific Phenomena) and VII (Product Design) demonstrate the need for programs to provide specific scaffolding resources which should include prolonged support for both experimental design and spatial-mechanical reasoning activities.

Researchers require longitudinal studies to determine whether ECA/CCA interventions lead to long-term creativity improvements which affect students' STEM educational and career decisions. Future research should study how different ECA/CCA activities lead to creativity development while investigating how teacher support quality and student relationship patterns affect the success of these activities. The implementation of mixed-methods designs which include student and teacher perspectives will enable researchers to acquire detailed information about ECA/CCA effectiveness in promoting scientific creativity.

The research includes certain limitations which limit its overall results. The study used intact classes as its research method which restricted its ability to establish causal links between variables because random assignment was not used. The sample was drawn from two schools in Kathmandu Valley which may not represent rural educational settings or schools in resource-deprived areas of Nepal. The groups show an uneven distribution of genders because of normal enrollment trends which researchers need to consider when interpreting results. The evidence base would become stronger through future research that uses larger samples from different geographic areas and includes random assignment whenever it is possible to implement that method.

In conclusion, this study shows that investing in structured extracurricular and cocurricular science activities help to develop scientific creativity in students that is required. Nepal needs to address the challenges of sustainable development and technological innovation for which creative scientific intuition is required. Further, the study discards gender-related discussions in education, which often portray a achievement gap between boys and girls and explores that in scientific creativity gender differences do not play significant roles. Hence, this study proposes the inclusion of structured ECA/CCA in school curriculum to enhance the quality of STEAM education in Nepal.

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