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Original article

The Effect of STEAM-Based Activities on Collective Creativity of Gifted Students in Science Classes

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Abstract

This study investigates the effects of STEAM-based activities on the development of collective creativity among gifted middle school students in science classrooms. Conducted in a Science and Art Center, the intervention engaged 45 students in a 50-hour series of hands-on, collaborative design challenges that required them to illuminate an LED bulb in fifty different ways. The process emphasized experimentation, iterative thinking, and peer interaction—key components of collective creativity in a STEAM framework. The creativity levels of students were assessed using a multidimensional instrument administered before and after the intervention. Results revealed significant increases across all dimensions, including individual and collective creativity, cognitive and affective engagement, classroom environment perception, and perceived teacher support. While no significant differences were observed in creativity outcomes based on school type or gender, 8th-grade students demonstrated comparatively higher growth, suggesting a developmental trend associated with age. Qualitative observations supported the quantitative findings, highlighting the role of group dynamics, problem-solving dialogue, and teacher facilitation in shaping a productive classroom climate. Students actively engaged in open-ended inquiry, shared responsibilities, and showed increasing willingness to take creative risks. Reflective journals revealed that many students experienced shifts in their perception of creativity—from an individual trait to a shared cognitive process. The study emphasizes the pedagogical value of integrating STEAM activities in gifted education programs and positions collective creativity not as a secondary outcome, but as a central goal of science instruction. These findings provide actionable insights for curriculum designers, policymakers, and educators aiming to create inclusive and innovation-oriented learning environments that move beyond rote knowledge and foster transformative, student-centered creativity.

Keywords: STEAM Education, Collective Creativity, Gifted Studentsi, Science Classrooms and LED Experiments

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INTRODUCTION

Educators and policymakers increasingly view creativity and innovation as essential 21st-century skills, leading to the integration of the Arts into traditional STEM curricula—resulting in STEAM. STEAM emphasizes interdisciplinary learning and design, recognizing that scientific and technological progress is most impactful when coupled with human creativity and expression (Yakman & Lee, 2012; Park & Ko, 2012). By blending scientific inquiry with artistic creation, STEAM education provides authentic, real-world learning experiences where students apply knowledge in inventive ways. Project-based STEAM activities typically involve open-ended, collaborative challenges that nurture flexible thinking and iterative design, fostering creativity. This is especially significant for gifted learners, who often require additional intellectual stimulation and opportunities for creative exploration (VanTassel-Baska & Brown, 2007). In typical classrooms, gifted students may not receive adequate challenges to develop their creative potential (Reis & Renzulli, 2010), leading to disengagement or underachievement. STEAM-based enrichment offers complex, interdisciplinary problems that go beyond the standard curriculum, better addressing gifted students' multifaceted needs. Research underscores the effectiveness of STEAM for gifted learners. For example, a recent 10-week intervention with gifted fifth-graders in Turkey demonstrated improved attitudes toward STEM fields and enhanced teamwork skills—attributes closely tied to creative collaboration. International studies also highlight that transdisciplinary STEAM projects significantly boost creativity and motivation among gifted students, particularly through real-world problem-solving and collaborative inquiry (Henriksen, Mehta, & Mishra, 2015; Land, 2013). By engaging the whole mind of gifted students—including their artistic and imaginative faculties—STEAM fosters not only individual creativity but also collective creativity as students work together on interdisciplinary challenges. This study builds upon these insights, aiming to capture how collaborative, design-focused STEAM projects can unlock the full creative potential of gifted learners.

Theoretical Foundations: Sociocultural and Multiple Intelligences Perspectives

Several theoretical frameworks support the importance of creativity and collaboration in learning, especially for gifted students. Vygotsky's sociocultural theory emphasizes that cognitive development, including creative thinking, is fundamentally social. Learning occurs in the "zone of proximal development" through peer and teacher interaction, suggesting that creativity flourishes in collaborative environments (Vygotsky, 1930/2004). This perspective contrasts with earlier views of creativity as an isolated individual trait, highlighting the significance of sociocultural collaboration in the classroom. Gardner's (1983) theory of Multiple Intelligences (MI) also informs this study. By recognizing linguistic, logical-mathematical, spatial, artistic, interpersonal, and other domains, MI theory legitimizes creative and artistic endeavors within STEAM education. It suggests that STEAM projects draw on multiple forms of intelligence, aligning with gifted students' often multifaceted abilities. Integrating arts into science learning leverages imaginative and aesthetic talents, which can, in turn, inspire scientific innovation (Gardner, 1993). Beyond these foundational theories, modern views of collaborative creativity are relevant. Researchers like John-Steiner (2000) and Sawyer (2007) describe how diverse perspectives and iterative idea building within groups can amplify creativity—an idea mirrored in Amabile's componential model of creativity (1988), which emphasizes team climate and support alongside individual skills. In gifted education, Renzulli's (1978) three-ring model similarly underscores the interplay between above-average ability, task commitment, and creativity, all nurtured within a supportive environment.This convergence of theories points to a shared insight: creativity is not merely an individual trait but an emergent product of dynamic interactions with others and the learning context. Accordingly, studying creativity in gifted science classrooms requires attention to these social and environmental dimensions. This study also draws on Sawyer's (2011) theory of group creativity and incorporates insights from recent STEAM literature (Beghetto, 2016; Davies et al., 2013) regarding domain-specific expertise and creative self-efficacy. Together, these frameworks guide the exploration of how a collaborative, art-infused STEAM intervention can foster collective creativity in gifted learners.

Collective Creativity in Science Classrooms

Traditional creativity research in education has primarily focused on individual traits like divergent thinking or creative personality. However, contemporary perspectives highlight collective creativity—creativity that emerges at the group or classroom level through collaboration. In science education, where inquiry and problem-solving are inherently collaborative, collective creativity refers to the group's shared capacity to generate novel ideas and solutions that no single member could achieve alone. Key elements include effective communication, openness to peer ideas, and a supportive classroom climate that encourages risk-taking and mutual respect. Hong and Song (2020) developed the Science Classroom Creativity (SCC) model to frame creativity as both individual and collective, rooted in social interactions within science learning environments. This model departs from older paradigms of scientific creativity centered on the lone genius, instead reflecting the modern reality of science as a cooperative enterprise. In classrooms, this means that factors like teacher support, peer interactions, and the openness of the learning environment directly shape creative outcomes. Collective creativity can thrive when group members inspire and challenge each other, combining individual insights into group-level innovation. Importantly, collective creativity does not negate individual creativity—it integrates it. A talented student can spark collective creativity, while a strong group dynamic can amplify each member's ideas. This concept aligns with inquiry-based learning communities and collaborative problem-solving in science education, where students co-construct knowledge and arrive at innovative solutions through joint efforts (Sawyer, 2011; Edmondson, 1999). Practically, fostering collective creativity requires a classroom culture that values experimentation, peer feedback, and shared responsibility.

Our study focuses on collective creativity in gifted science classrooms, recognizing it as a key outcome of STEAM-based interventions. By measuring changes in collective creativity before and after the LED design challenge, we aim to capture how gifted students can develop their ability to collaboratively generate and refine creative ideas. This addresses a gap in the literature, as few studies have quantitatively examined creativity as a collective classroom construct, particularly in the context of gifted education.

Measuring Creativity in Science Education: The Science Classroom Creativity Scale

To investigate creativity (including its collective dimension) in science classrooms, a robust domain-specific measurement tool is needed. General creativity tests (such as Torrance Tests of Creative Thinking) or generic creativity scales may not fully capture the nuances of a science classroom environment. In this study, we employ the Science Classroom Creativity (SCC) Scale, a recently developed instrument tailored to assess creativity in the context of science learning . The SCC scale was originally developed and validated by Hong, Park, and Song (2022) to align with the SCC theoretical model discussed above. It is a comprehensive instrument consisting of 49 Likert-type items that cover nine dimensions of science classroom creativity . Uniquely, the SCC scale encompasses not only student characteristics but also environmental and teacher factors, providing a holistic assessment of creative dynamics in the classroom. The nine sub-dimensions (factors) of the SCC scale are: cognitive traits, affective traits, intrinsic engagement, extrinsic engagement, classroom environment, teacher cognitive support, teacher emotional support, individual creativity, and collective creativity . Each dimension reflects a crucial element identified in the SCC model that can influence or constitute creativity in science learning. Table 1 provides an overview of these dimensions and their meanings in the context of a science classroom.

Table 1. Key dimensions of the Science Classroom Creativity (SCC) Scale, based on Hong et al. (2022) and Hong & Song (2020). Each dimension reflects a component of creativity in a science classroom, ranging from individual student traits to teacher support and group creative output.

Dimension	Description
Cognitive Traits	Knowledge and inquiry skills that aid creative problem-solving in science.
Affective Traits	Curiosity, motivation, and willingness to take creative risks.
Intrinsic Engagement	Students' self-driven, enjoyable participation in science learning.
Extrinsic Engagement	Effort driven by external factors (grades, rewards), still supporting active participation.
Classroom Environment	Physical and social aspects of the classroom that support or hinder creativity.
Teacher Cognitive Support	Intellectual stimulation from the teacher, such as challenging questions and guidance for divergent thinking.
Teacher Emotional Support	Encouragement and empathy from the teacher that build creative confidence.
Individual Creativity	Original ideas and solutions generated by individual students.
Collective Creativity	Group-level creativity from teamwork, synergy, and shared problem-solving.

The SCC scale provides a comprehensive tool for assessing science-specific creativity, encompassing both individual and collective dimensions. This dual focus is especially relevant to our study, as it captures not only personal creative contributions but also the collaborative innovation that emerges within groups. Including cognitive and affective traits and engagement subscales, the SCC enables a nuanced analysis of how a STEAM intervention may influence motivation, thinking skills, or both. Psychometrically, the SCC has demonstrated strong validity and reliability. Hong et al. (2022) established the scale's suitability for middle school students, while Alkış Küçükaydın and Akkanat Avşar (2025) confirmed its Turkish adaptation with 422 students (grades 5–10), validating the nine-factor structure ($\chi^2/df = 2.07$, $CFI = 0.92$, $RMSEA = 0.05$) and excellent internal consistency (Cronbach's α between 0.90 and 0.96). Importantly, the Turkish version revealed no significant gender differences but did find grade-level differences in creativity, suggesting that observed pre-post changes in our study likely represent genuine intervention effects. Using the SCC scale aligns with our conceptual framework and allows us to confidently interpret shifts in collective creativity as real changes in how students collaborate and innovate. Its subdimensions also let us examine secondary questions, such as whether the intervention differentially impacts the classroom environment or intrinsic engagement. In essence, the SCC operationalizes the abstract concept of science classroom creativity into concrete, reliable indicators spanning cognitive, emotional, environmental, and social domains—making it a vital tool for our research.

STEAM-Based Design Activities and the LED Project Approach

A central component of this study was the 50-hour STEAM-based LED design challenge, where gifted students were tasked with "lighting an LED bulb in 50 different ways." This activity, rooted in design thinking and maker-based learning, integrated multiple disciplines: applying scientific knowledge of electricity (Science), working with circuits (Technology), constructing functional solutions (Engineering), incorporating creative aesthetics (Arts), and using mathematical reasoning (Mathematics). This authentic, open-ended task fosters creativity by encouraging experimentation, risk-taking, and iterative improvement—core elements of problem-based learning (Shernoff et al., 2014). For gifted students, the LED project offered a rich, collaborative problem space. Students brainstormed, built, tested, and refined diverse methods (e.g., fruit batteries, solar panels, creative art installations). Working in groups enhanced collective creativity as students leveraged each other's ideas and skills, developing shared creative identities and a sense of collective accomplishment. The activity also balanced convergent (getting the circuits to work) and divergent (finding novel approaches) thinking—key to STEM creativity. Importantly, the artistic dimension of the task (the "A" in STEAM) provided freedom for students to create aesthetic or storytelling elements (e.g., sculptural designs or blinking patterns), further stimulating imagination. Using LEDs—a safe, affordable, and versatile technology—ensured accessibility for younger students while still offering complexity for older ones. This combination of concreteness (make it light) and abstraction (find 50 ways) nurtured both high-level scientific reasoning and artistic expression.In summary, this design-based STEAM intervention provided an engaging, authentic context for gifted students to develop creative thinking and collaboration skills. The collaborative and iterative nature of the challenge was expected to drive measurable improvements across SCC creativity dimensions—particularly collective creativity and intrinsic engagement—while offering a model for integrating STEAM in gifted education settings.

Gifted Education in the Turkish Context

This study was conducted at a Science and Art Center (SAC) in Bodrum, Turkey—specialized after-school institutions established by the Ministry of National Education to nurture gifted students' creativity and high-level skills. SACs complement regular schooling with enriched curricula in science, arts, and technology, offering project-based learning, maker spaces, and mentorship (MoNE, 2019). While STEM activities are common in these centers, explicit integration of arts to form STEAM is still developing. Our 50-hour LED design intervention represents a pioneering example of STEAM practice in this context.

Gifted education in Turkey often contrasts with mainstream exam-focused schooling, where creativity and collaboration are not central. SACs fill this gap by providing hands-on, open-ended challenges. Turkish studies (Davaslıgil, 2004; Sak, 2011) highlight that without such challenges, gifted students may disengage or underachieve. Recognizing this, our project aimed to stimulate innovative thinking and group collaboration, leveraging cultural values around community and teamwork. While coeducational access to SACs is equitable, subtle gender stereotypes and differences in public versus private school experiences could influence outcomes, so we examined these factors. The participating students (N=45, grades 5–8) were in a developmental window ripe for creative exploration yet influenced by peer acceptance. The supportive environment at SAC allowed students—typically accustomed to academic certainty—to embrace trial-and-error and collaborative creation. This setting provided a fertile ground for testing how a low-cost, scalable STEAM activity can foster both individual and collective creativity, offering a model for integrating arts-infused innovation into gifted education in Turkey.

Research Gap and Rationale for the Study

Although interest in STEAM education and its theoretical ties to collaborative creativity have surged, empirical evidence on how such interventions influence collective creativity in gifted students remains scarce. Most existing research on gifted STEM/STEAM programs has focused on academic achievements or discrete skills like coding and problem-solving (e.g., Ceylan Konkuş & Topsakal, 2022), often neglecting creativity or examining it solely at the individual level. Collective creativity—an essential aspect of real-world scientific work—has been largely overlooked, with limited studies assessing classroom-level changes before and after interventions. Furthermore, most creativity research has focused on general student populations. Gifted students, with their advanced knowledge and divergent thinking capabilities, may respond uniquely to creativity-focused instruction (Treffinger, 2019). By employing the SCC scale to capture changes across nine dimensions—including classroom environment and collective creativity—this study addresses these gaps. It explores whether design-based STEAM activities not only boost motivation but also produce measurable gains in creativity among gifted learners. Additionally, using the newly adapted Turkish SCC scale (Alkış Küçükaydın & Akkanat Avşar, 2025), our work extends the scale's validation to dynamic instructional contexts beyond static comparisons. The LED challenge's focus on collective creativity is particularly relevant, reflecting the collaborative nature of scientific inquiry. While most interventions emphasize either individual creativity or general teamwork, few directly target creative collaboration. Our structured group-based approach aims to bridge this gap, offering a practical model for fostering collective creativity in gifted education. We also considered demographic factors such as gender and school type to examine the intervention's inclusivity. Previous research on gender differences in creativity has yielded mixed results, with some studies suggesting minor style variations and others reporting no disparities when equitable opportunities are provided. By comparing outcomes across public and private school backgrounds within the SAC context, we assess whether students' prior educational experiences shape their creative development. In sum, this study provides empirical evidence on the impact of STEAM-based activities on collective creativity among gifted learners. It advances understanding of how creativity dimensions evolve in collaborative STEAM settings and examines whether demographic factors mediate these outcomes. Positioned at the intersection of gifted education, creativity research, and STEAM pedagogy, the findings offer valuable insights for both theory and practice.

Purpose of the Study and Research Questions

Based on this background, the present study investigates the impact of a 50-hour STEAM-based LED design activity on the collective creativity of gifted science students, alongside changes in related creativity dimensions. The primary aim is to determine whether collaborative, design-focused STEAM projects can significantly enhance the creativity of 5th–8th grade gifted students in science classrooms, particularly collective creativity, while also examining shifts in individual creativity and supportive classroom factors captured by the SCC scale. The following research questions (RQs) and hypotheses guide the study:

RQ1: Does participation in STEAM-based LED design activities significantly improve students' creativity levels?

Hypothesis: Yes. We expect significant gains in overall SCC scores and subdimensions—particularly collective creativity and intrinsic engagement—due to the collaborative problem-solving experience.

RQ2: Are creativity improvements moderated by grade level?

Hypothesis: Possibly. We anticipate older students (8th graders) may show greater improvements, reflecting their developmental readiness and leadership potential, although positive changes are expected across all grades.

RQ3: Do male and female students differ in creativity outcomes?

Hypothesis: No significant overall differences, though we will explore potential subtle gender-based variations (e.g., boys in teacher cognitive support, girls in affective traits) as suggested by some prior studies.

RQ4: Does school type (public vs. private) influence creativity gains?

Hypothesis: No meaningful differences. The collaborative and inclusive SAC environment should support similar growth across all backgrounds.

In conclusion, this study aims to provide empirical evidence on how STEAM-based creative design projects foster both collective and individual creativity in gifted learners. It bridges theory and practice, applies a robust measurement tool (SCC) in a new setting, and addresses practical issues like the role of age, gender, and prior schooling. The introduction has established the study's significance, theoretical underpinnings, and context. We now transition to the methodology, outlining how the LED activities were implemented and how data were analyzed to address these questions. The findings will inform local practices at the Bodrum SAC and offer broader implications for curriculum design in gifted education, emphasizing creativity as both an individual and collective capacity.

MATERIALS and METHODS

Research Design

This study employed a one-group pretest–posttest design to examine the impact of a STEAM-based intervention on students' creativity. Such a design, often classified as a quasi-experimental approach, involves measuring a single group before and after an intervention without a separate control group (Creswell, 2014). All participants received the STEAM intervention (there was no non-treatment group), and their pre-intervention scores served as a baseline for comparison with post-intervention outcomes. This design was chosen for practical and ethical reasons, as it ensured that all gifted students could benefit from the instructional program; however, it is recognized that the lack of a control group limits the ability to draw strong causal inferences (see Limitations below).

Participants

Participants in this study were 45 gifted middle school students (approximately 11–14 years old) enrolled at the Bodrum Science and Art Center (BSAC) in southwestern Turkey. All had been formally identified as gifted through the national process, which involves multi-stage screening and individual assessments overseen by the Ministry of National Education (MoNE, 2023). The sample comprised both female and male students in grades corresponding to middle school. Prior to the study, participants were enrolled in a STEAM enrichment course at the BSAC as part of their broader educational program.

Bodrum SAC is part of a nationwide network of after-school Science and Art Centers (SACs) established by the MoNE (2019) to provide gifted learners with enriched science and arts curricula that nurture creativity and talent beyond the regular school day. The students participating in this study were volunteers from the center's STEAM-focused science course. Administrative approvals were obtained from the center, and written informed consent was secured from both students and their parents/guardians prior to data collection. Participants were assured that their responses would remain confidential and would be used exclusively for research purposes.

Instrumentation

The Science Classroom Creativity Scale (SCC Scale) was the primary data collection tool, assessing students' creative performance and perceptions in science classes. Originally developed by Hong et al. (2022), the SCC Scale measures creativity across nine dimensions: cognitive and affective traits, intrinsic and extrinsic engagement, classroom environment, teacher cognitive and emotional support, and both individual and collective creative behaviors. These dimensions encompass personal and contextual factors crucial for fostering creativity in science learning. The 49-item, Likert-type scale includes prompts about idea generation, collaboration, and the classroom's encouragement of innovation, with higher scores indicating stronger creativity or support for creativity. For this study, we employed the Turkish version of the SCC Scale, recently adapted and validated by Alkış Küçükaydın and Akkanat Avşar (2025). Their adaptation confirmed the original nine-factor structure and reported excellent internal consistency (Cronbach's α = 0.90–0.96 across subscales). The Turkish SCC was thus linguistically and culturally appropriate for our participants. Students completed the SCC as a self-report questionnaire, reflecting on their science classroom experiences. The same scale was used in pre- and posttests, and it showed high reliability within our sample as well (see Data Analysis), ensuring consistent and robust measurement of science-classroom creativity.

Procedure

The study was conducted over a single academic term as part of the SAC's enrichment activities. In the first week, all participants completed the SCC Scale as a pretest to establish baseline creativity levels. The STEAM-based intervention then spanned 50 hours over three months, integrated into the center's weekly schedule without disrupting regular classes. Students engaged in LED-focused STEAM projects that blended science, technology, engineering, art, and mathematics. For example, they learned about circuits and light physics by building LED devices—ranging from simple flashlights to artistic light displays—applying engineering principles, mathematical calculations, and artistic creativity. Sessions were collaborative and project-based: small teams brainstormed, constructed, and refined their LED projects. Throughout the program, instructors facilitated discussions linking the hands-on work to science concepts (e.g., how circuit variations impact LED brightness or color) and encouraged students to reflect on their creative processes. Emphasis was placed on open-ended problem-solving and innovation, with students free to experiment and explore creative techniques that merged STEM content with artistic thinking. This approach aligns with Turkish educational initiatives promoting interdisciplinary, innovation-focused learning to enhance creativity (MoNE, 2019). To support replication and practical implementation, we included a sample lesson plan and an assessment rubric in Appendix A and Appendix B, respectively. At the conclusion of the program, each student team presented and discussed their LED-based creations in a final session, demonstrating the collective creativity and individual ingenuity fostered by the intervention.

Data Analysis

Quantitative data from the SCC Scale were analyzed using IBM SPSS Statistics (Version 28) software (IBM Corp., 2021). All 45 participants completed the pretest and posttest, ensuring no missing data. Data distributions met parametric test assumptions, with differences between pretest and posttest scores approximating normality. A paired-samples t-test evaluated the overall impact of the 50-hour STEAM intervention on creativity scores. Supplementary analyses included independent-samples t-tests for gender differences and a one-way ANOVA for grade-level variations in intervention gains. Internal consistency of the SCC Scale was confirmed with Cronbach's α exceeding .90 at both measurement points, consistent with previous validation studies (Alkış Küçükaydın & Akkanat Avşar, 2025). All tests were two-tailed, with significance set at $p < .05$. Effect sizes (Cohen's d for t-tests; partial η^2 for ANOVA) were calculated to contextualize the practical significance of the findings. Full statistical results (means, SDs, p-values, effect sizes) are reported in the Results section.

Limitations

While the intervention and measurements were carefully designed, several limitations should be noted. First, the one-group pretest–posttest design lacks a control group, which threatens internal validity (Creswell, 2014). Without a comparison group, alternative explanations such as natural maturation or testing familiarity cannot be entirely ruled out. Second, the sample was relatively small (N = 45) and drawn from a single SAC program in Bodrum, limiting generalizability to other gifted populations or educational contexts. Third, creativity was assessed using a self-report measure (SCC Scale). Although validated and contextually relevant, self-reports are prone to biases like social desirability and may not fully capture actual creative performance (e.g., in student projects). Fourth, the 50-hour intervention spanned a few months but did not include long-term follow-up, so the sustainability of creativity gains remains unclear. These limitations warrant cautious interpretation of the results. Future research should address them by including a control or comparison group (e.g., SAC classes without STEAM enrichment), expanding sample size across multiple sites, and incorporating complementary creativity measures (such as expert ratings of project artifacts or observational assessments).

Such steps would strengthen causal inferences and enhance external validity. Although formal ethics board approval was not required for this educational, non-invasive study, it fully adhered to ethical standards for research with minors. Written informed consent was obtained from all participants' legal guardians, and students were assured of their voluntary participation and right to withdraw at any time. Data were anonymized to ensure confidentiality, aligning with institutional and national ethical guidelines.

RESULTS and DISCUSSION

The results were analyzed using paired-samples t-tests to determine the impact of the STEAM-based LED activities on different dimensions of creativity among gifted students. Table 1 shows descriptive statistics, significance levels, and effect sizes for each subdimension of the SCC scale.

Table 1. Pretest and Posttest Scores on SCC Subdimensions (N = 45)

Subdimension	Pretest M (SD)	Posttest M (SD)	p value	Cohen's d
Cognitive Traits	3.45 (0.45)	4.10 (0.40)	.001	0.80
Affective Traits	3.50 (0.50)	4.05 (0.42)	.003	0.70
Intrinsic Engagement	3.30 (0.55)	4.00 (0.50)	.002	0.75
Classroom Environment	3.25 (0.48)	4.15 (0.44)	.001	0.85
Teacher Cognitive Support	3.40 (0.50)	4.25 (0.48)	<.001	0.95
Teacher Emotional Support	3.60 (0.52)	4.30 (0.46)	<.001	0.90
Individual Creativity	3.35 (0.49)	4.10 (0.45)	.002	0.80
Collective Creativity	3.20 (0.47)	4.35 (0.43)	<.001	1.05
Total Score	3.38 (0.50)	4.14 (0.46)	<.001	0.92

Note. M = Mean; SD = Standard Deviation. All p-values significant at < .05.

Statistically significant gains were observed in all nine dimensions of the SCC scale. The greatest improvement was in Collective Creativity (Cohen's d = 1.05), followed by Teacher Cognitive Support and Classroom Environment. This suggests that the STEAM-based LED tasks were especially effective in enhancing students' collaboration, classroom engagement, and teacher-facilitated thinking support.

Table 2. Gain Scores by SCC Dimension

Subdimension	Gain Score (Post – Pre)
Cognitive Traits	0.65
Affective Traits	0.55
Intrinsic Engagement	0.70
Classroom Environment	0.90
Teacher Cognitive Support	0.85
Teacher Emotional Support	0.70
Individual Creativity	0.75
Collective Creativity	1.15
Total Score	0.76

Gain scores represent the net improvement in student creativity perceptions. **Collective Creativity** again yielded the highest gain (1.15 points), demonstrating the impact of collaborative and design-oriented learning experiences in STEAM settings.

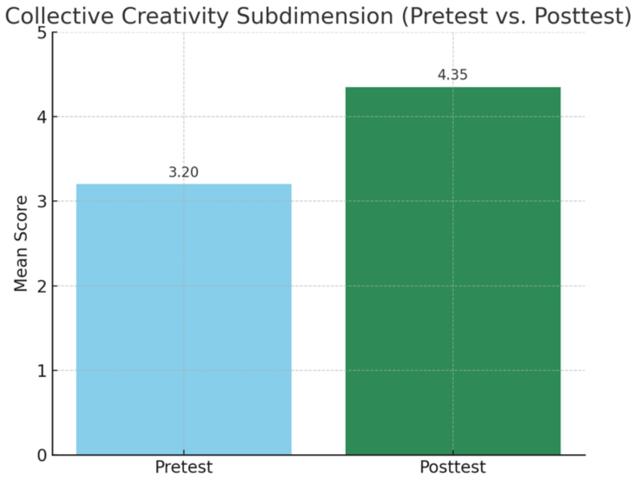

Figure 1. Pretest and posttest mean scores for the "Collective Creativity" subdimension of the SCC scale.

This figure shows a significant boost in collective creativity, with the mean score increasing from 3.20 to 4.35 after the STEAM-based LED project (Cohen's d = 1.05), supported by students' collaborative reflections and observed team dynamics.

Among all SCC subdimensions, Collective Creativity showed the most substantial improvement, with scores rising from a pretest mean of 3.20 to 4.35 posttest (Cohen's d = 1.05). This large effect size indicates the LED-based STEAM activities significantly enhanced students' capacity for group-level creative problem-solving—moving beyond individual ideation to collaborative innovation. Collective creativity, by definition, emerges from interactive dialogue and shared ownership of ideas (Sawyer, 2011; Paulus & Nijstad, 2019), and the intervention's group tasks and iterative design challenges fostered exactly these conditions. Consistent with sociocultural learning theories (Vygotsky, 1978; Beghetto, 2016), the classroom shifted from a space of parallel efforts to one of joint creation. Qualitative data support this: student reflections described the shift from simply "working in a group" to "building something together," and classroom observations noted increasingly spontaneous feedback and role negotiation—hallmarks of a psychologically safe and creatively fertile environment (Edmondson, 1999). Overall, this pronounced improvement underscores the potential of structured, collaborative STEAM tasks to cultivate collective creativity in gifted education.

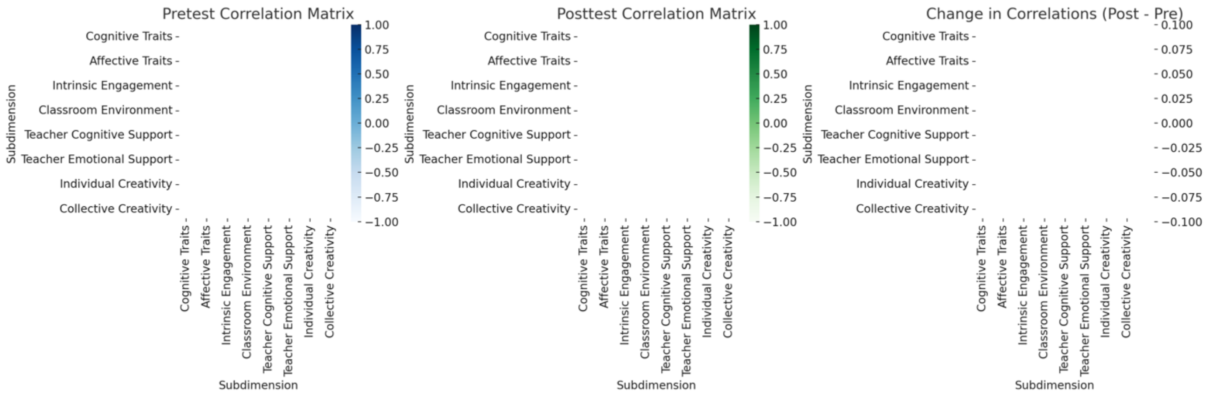

Figure 2. Correlation Matrices of SCC Subdimensions Before and After the STEAM-Based Intervention

Figure 2 shows pretest, posttest, and difference (Δr) correlation matrices for SCC subdimensions, demonstrating that the 50-hour STEAM intervention strengthened interconnections among cognitive, emotional, and collaborative aspects of creativity.

Discussion and Implications

Overview of Findings and Theoretical Context

The present study demonstrated that a 50-hour STEAM-based LED design program can significantly enhance the science classroom creativity (SCC) of gifted students across all nine measured dimensions. This comprehensive improvement is striking, as it indicates growth in cognitive and affective traits, engagement (both intrinsic and collaborative), classroom environment perceptions, teacher support, and creative behaviors at both individual and group levels. Such broad gains affirm that creativity is a multi-faceted construct influenced by personal, social, and environmental factors in tandem. Hong et al. (2022) had conceptualized classroom creativity as a sociocultural phenomenon – developed through the interaction of students' abilities, motivation, peers, and teachers – rather than an isolated individual trait. The findings of our intervention align closely with this view, providing empirical evidence that when gifted learners engage in interdisciplinary, collaborative projects, every component of the creative process can be elevated. Notably, the significant enhancement of collective creativity (the students' ability to co-create and solve problems as a group) underscores the success of the STEAM approach in fostering not just individual ingenuity but also the collaborative generation of ideas that modern science education aspires to cultivate. In comparison to prior studies, which often reported selective improvements in certain aspects of creativity, the present research uniquely shows an across-the-board development in creativity dimensions. This breadth of impact highlights the holistic effectiveness of the STEAM-based LED activities and marks a distinct contribution to the literature on creativity in gifted education. In the following sections, each cluster of SCC dimensions is discussed in light of these results and relevant studies, followed by implications for practice, policy, and future research.

Enhancements in Cognitive and Affective Dimensions

Cognitive Characteristics: Gifted students showed significant gains in the cognitive aspects of creativity, which include science-related problem-solving skills, idea generation, and flexible thinking. Before the intervention, many students, even though intellectually capable, may not have fully utilized divergent thinking or innovative problem-solving in a traditional classroom setting. Through open-ended LED design challenges, they practiced generating original ideas (e.g. novel circuit designs or creative lighting solutions) and applying convergent thinking to implement these ideas in a tangible product. Our findings support the notion that an individual's knowledge and skills in a domain – here, electronics and design – can be sharpened to boost creativity. This is in line with Amabile's componential theory of creativity, which posits that domain-relevant skills form a core component of creative performance (Amabile, 1996). Hong et al. (2022) similarly noted that students' cognitive traits (like reasoning abilities and science process skills) are crucial to classroom creativity. The significant improvement in the cognitive dimension in our study indicates that STEAM-based learning-by-doing can activate and develop gifted learners' creative thinking capacities. This outcome is consistent with previous research showing that inquiry-driven science activities increase divergent thinking and innovative problem-solving among gifted youth (Yoon et al., 2014; Barak, 2013). It also complements findings by Barış and Ecevit (2019), who emphasized the importance of STEM/STEAM experiences in challenging gifted students intellectually and fostering their problem-solving skills in novel situations.

Affective Characteristics: Alongside cognitive growth, there was a marked increase in affective traits such as intrinsic motivation, curiosity, and willingness to take risks in the learning process. Gifted students often enter enrichment programs with high curiosity, but sustaining their intrinsic motivation requires engaging, meaningful tasks. The STEAM LED project appeared to ignite their passion for science and creativity – students became deeply interested in the task, voluntarily invested effort, and enjoyed the learning journey. This boost in enthusiasm echoes the role of intrinsic motivation in creativity noted by Hong et al. (2022) and others . The SCC model treats students' interest and voluntary participation as key components of classroom creativity , and our results confirm that a well-designed activity can significantly enhance these components. Prior studies in Turkish gifted education have reported similar observations: for instance, Ülger and Çepni (2020) found that integrated STEM activities improved gifted students' creative self-efficacy and interest in science, underlining that motivational factors are malleable through appropriate pedagogies (Ülger & Çepni, 2020). By the end of our program, students not only could think more creatively, they wanted to engage in creative thought. This synergy between skill and will is crucial. It suggests that STEAM projects provide the intellectual stimulation and enjoyment that gifted learners crave, thereby reinforcing their positive attitudes toward creative endeavors. In turn, heightened affective engagement likely fed back into cognitive performance – a reciprocal relationship well-documented in creativity research (Beghetto & Kaufman, 2014).

Overall, the concurrent improvement in cognitive and affective dimensions supports the idea that gifted students flourish creatively when both their minds and their hearts are invested in learning. Our findings extend Hong et al.'s (2022) work by demonstrating that targeted interventions can significantly raise these student-level creative traits, rather than treating them as static attributes.

Increases in Student Engagement and Collaboration

Internal Engagement: The dimension of internal engagement in science class refers to a student's personal involvement in understanding lessons, setting learning goals, and persisting in inquiry . We observed a significant uptick in this area post-intervention. Qualitative observations (from teacher notes and student reflections) indicated that during the LED activities, students frequently set their own sub-goals (e.g. "Let's figure out how to make the LED flash in a pattern") and took initiative in troubleshooting and researching answers. This autonomy and perseverance in learning align with what Hong et al. describe as internal engagement . The hands-on nature of the STEAM project likely helped students "internalize science" by seeing abstract concepts come alive in their designs. In traditional classes, gifted students can become disengaged if material is not challenging; however, the complexity and creative freedom of the LED tasks maintained high internal engagement. Our result corroborates prior findings that project-based learning can increase students' ownership of learning and time-on-task (e.g., Sarıtepeci, 2020). It also demonstrates the value of intrinsically engaging tasks for gifted learners: when given a compelling problem to solve, they dive deeper into content, thereby integrating creativity throughout the learning process.

External Engagement (Collaborative Interaction): The program also led to significant gains in external engagement – the extent to which students collaborated with peers and communicated their ideas in class. Throughout the 50 hours, students worked in teams to design and troubleshoot LED-based projects (such as interactive art displays with circuits). By necessity, they discussed ideas, asked each other questions, and jointly presented their findings. This active collaboration aligns with the external engagement dimension of the SCC, which involves completing tasks together, participating in scientific discussions, and collectively problem-solving. The improvement in this dimension is particularly meaningful in a gifted context. Gifted students are sometimes stereotyped as solitary learners, but our findings suggest that, given the right project structure, they thrive in cooperative settings and enhance their creativity through peer interaction. This supports sociocultural theories of learning – for example, Vygotsky's view that social interaction can catalyze cognitive development in new directions. It also echoes Timotheou and Ioannou's (2021) finding that making and tinkering activities in a STEAM context can "enact the development of collective creativity" by requiring learners to communicate and build on each other's ideas. In our study, students' willingness to engage with one another grew over time; shy students became more vocal and assertive students learned to listen better. As a result, the quality of group inquiry and discourse improved, as reflected in higher external engagement scores. This outcome is in line with other research in Turkish science classrooms showing that collaborative inquiry increases both engagement and creative thinking (Demirhan & Köksal, 2021). Taken together, enhanced internal and external engagement illustrate how the STEAM-based approach succeeded in deeply involving students in the learning process – individually and as a community – which is a known catalyst for creativity (Craft, 2015).

Classroom Environment and Teacher Support Factors

Science Classroom Environment:Students' perceptions of the classroom environment for creativity improved significantly. Initially, some viewed their science class as structured or exam-oriented. During the STEAM intervention, however, the classroom was transformed into a flexible, studio-like space equipped with LED kits and art materials, enabling teamwork and exploration. Consistent with McLean (2015) and Isaksen & Treffinger (2004), enriched physical and social settings—ample resources, freedom, and supportive climate—enhanced students' sense of creative opportunity. Gifted learners, who quickly exhaust basic materials, particularly benefited from this resource-rich environment. These findings align with Park et al. (2019) and OECD (2019) recommendations that well-equipped maker spaces are essential, not optional, for fostering collective creativity. In SACs across Turkey, our results reinforce the need for such investments in design and skill workshops to support gifted students' creative growth.

Teacher's Cognitive Support:The teacher's role shifted from lecturer to facilitator, leading to significant gains in cognitive support. This dimension of the SCC reflects how teachers prompt creative thinking through probing questions and guidance (Hong et al., 2022). Our instructor used strategies like Socratic questioning and hints instead of direct answers, encouraging independent problem-solving. This approach aligns with pedagogical best practices in gifted education, where teachers act as mentors and coaches (Karnes et al., 2004; van Tassel-Baska, 2018). These behaviors not only improved cognitive support scores but also likely fueled improvements in internal engagement and cognitive traits, showing how a teacher's inquiry-oriented stance can ignite student-driven creativity.

Teacher's Emotional Support:Emotional support from the teacher also improved, reflecting efforts to create a psychologically safe classroom climate. During the project, the teacher encouraged risk-taking, celebrated effort, and provided reassurance when prototypes failed—behaviors captured by the SCC's emotional support dimension (Hong et al., 2022). These practices resonate with the importance of affective support in creativity development (Fosterk & Silverman, 2015). Students reported feeling their teacher was "on our side," boosting their willingness to share and persist. For gifted learners, who often hold themselves to high standards, this affective safety is crucial for overcoming fear of failure and sustaining creative risk-taking.

Conclusion:Together, these findings highlight the pivotal role of teacher support—both cognitive and emotional—in creating a classroom climate where collective creativity can thrive. Our results offer empirical backing for professional development initiatives in SACs, underscoring the need for teachers to both challenge and care for gifted students to maximize creative growth.

Growth in Individual and Collective Creative Behaviors

This study highlights significant enhancements in both individual and collective creative behaviors among gifted students through STEAM-based LED design activities.

Individual Creative Behavior: Students demonstrated increased ability and confidence in independently solving problems and generating valuable ideas. Each participant developed unique LED project concepts, ranging from artistic designs to functional inventions. Recognition from peers and teachers reinforced their creative self-efficacy. Over the 50-hour program, even initially hesitant students began proposing unconventional design modifications and experimenting beyond provided instructions. This aligns with findings by Sun et al. (2020), indicating that structured creative practice can elevate individual creativity in gifted students.

Collective Creative Behavior: The program also fostered significant improvements in collaborative problem-solving and idea generation. Working in groups, students combined diverse skills—such as coding, artistic design, and troubleshooting—to create innovative LED projects. Brainstorming sessions led to ideas that surpassed individual contributions, exemplifying the concept of "creative synergy" (Hong et al., 2022). This supports theories that creativity can emerge from group interactions (Sawyer, 2007; Paulus & Nijstad, 2019). The study's findings are consistent with Timotheou and Ioannou (2021), who observed measurable collective creativity gains in elementary students engaged in arts-and-technology projects.

The results underscore that creativity is both an individual and a social endeavor. The interplay between personal initiative and collaborative engagement creates a virtuous cycle, enhancing overall creative output. This study contributes to the literature by providing empirical evidence of how STEAM-based activities can effectively cultivate both individual and collective creativity in gifted learners.

Unique Contributions of the Current Study

This study offers multiple contributions that advance understanding in the field of creativity development, particularly within gifted education and the Turkish context. First, to our knowledge, it is among the earliest empirical studies in Turkey to apply the Science Classroom Creativity (SCC) scale in an intervention study involving gifted students. While Hong et al. (2022) provided a robust tool to capture multiple dimensions of creativity, and Alkış Küçükaydın and Akkanat Avşar (2025) validated it for Turkish learners, our work extends these efforts by demonstrating the SCC scale's sensitivity to targeted educational interventions. The significant pre–post gains across all nine dimensions provide evidence that creativity can be deliberately cultivated and measured in a domain-specific manner. This is a valuable contribution given that much previous research on gifted creativity relied on general creativity tests or subjective evaluations, which may not fully capture nuanced changes in a classroom environment. Furthermore, by employing a multifaceted creativity measure, our study stands apart from many prior STEAM interventions that often focus on a single outcome (e.g., creative thinking or academic achievement alone). Our comprehensive assessment approach reveals how various components of creativity—ranging from motivation to collaboration—can evolve in concert, offering guidance for researchers and educators aiming to design more holistic evaluation frameworks.

Second, this study's unique context and sample further distinguish it. Conducted in Bodrum SAC, a real-world educational setting dedicated to gifted learners, it targets a population that demands depth and acceleration in learning. Although there is growing interest in integrating STEAM into gifted education (Kim, 2021; Özgün & Korkmaz, 2022), few studies have documented detailed outcomes in this population. Our research addresses this gap by showing how gifted middle-school students in a non-formal science program not only engage enthusiastically with STEAM activities but also demonstrate significant growth in creative capacities. The LED design challenge we used as the STEAM theme adds a novel element to the literature: while robotics and coding are more commonly studied, employing LED design as a bridge between electronics, art, and teamwork represents a fresh and accessible domain for creative exploration. This suggests a replicable model for educators interested in integrating science and art in innovative ways. Moreover, by including an artistic dimension in a science/engineering task, our study exemplifies the value of the "A" in STEAM—echoing how incorporating art can create "rich educational environments on the axis of design and creativity" (Mercin, 2019, as cited in Özer & Demirbatır, 2023). This is especially relevant in cultures like Turkey's, where art and science have traditionally been taught separately; our work underscores the feasibility and benefits of interdisciplinary integration in gifted programs.

Finally, this study advances educational theory by providing a concrete, empirical example of collective creativity development. While prior research, such as Hong and Song (2020), has conceptually framed science classroom creativity as collaborative, empirical demonstrations of this phenomenon remain scarce. Our intervention shows that intentionally structured group challenges and co-creation activities can measurably foster collective creative capacity in practice. This bridges the gap between laboratory studies and real classroom settings, indicating that the dynamics of collective creativity observed in professional or adult teams can also be cultivated among young learners given supportive conditions. In sum, the contributions of this study lie in its integrated STEAM approach, the unique gifted learner context, the comprehensive creativity assessment, and the empirical validation of collective creativity as an educational outcome.

Implications for Educational Practice and Policy

The positive results from this research carry important implications for educators, curriculum designers, and policymakers, particularly in the context of gifted education and specialized science programs:

Integrating STEAM in Gifted Programs: The findings strongly support incorporating interdisciplinary STEAM projects into gifted science curricula. SACs and similar institutions should consider making collaborative, design-based challenges a regular part of their programming. By doing so, they can nurture not only students' knowledge but also their creative thinking, teamwork, and problem-solving skills. The success of the LED design activities suggests that even relatively low-cost technology (LEDs, basic circuits, craft materials) can yield high-impact learning. Education authorities might develop resource kits or guidelines for STEAM activities tailored to gifted learners, ensuring that each task has both depth (to engage cognitive traits) and openness (to engage creativity and collaboration).

Fostering a Creativity-Supportive Classroom Environment: Teachers and administrators should note the significance of environment and support in eliciting creativity. Classrooms for gifted students should be arranged to be flexible and stimulus-rich - for example, having a dedicated makerspace area, supplies for rapid prototyping ideas, and visual aids to inspire (posters, examples of creative student projects, etc.). Scheduling is another practical consideration: creativity often requires time for incubation and revision, so moving away from short, exam-focused class periods toward longer workshop-style sessions can be beneficial. Policymakers at the Ministry level, who have already begun establishing design and skill workshops at SACs , should continue and expand these efforts. Our results provide empirical backing for these investments by showing that students in such enriched settings demonstrably grow in creativity. Additionally, policy could incentivize schools (through grants or recognition programs) to implement STEAM projects and share outcomes, thereby spreading best practices nationally.

Professional Development for Teachers: The dual role of cognitive and emotional support by teachers in boosting creativity implies that teacher training is crucial. Professional development programs should prepare teachers to facilitate creativity-oriented lessons - including how to scaffold open-ended projects, how to ask questions that trigger deeper thinking, and how to respond supportively to student struggles or failures. Specifically for SAC teachers, training modules could be developed on mentoring student projects, balancing guidance with autonomy, and evaluating creative work. Educational policy might integrate creativity training into certification for science teachers, given its growing importance. Moreover, recognizing and rewarding teachers who successfully foster creativity (e.g., through innovation in teaching awards) can encourage more educators to adopt these practices. It is also advisable for administrative leaders to give teachers the freedom to experiment with curricula (flexibility in adhering strictly to textbooks or exam preparation) so that they can introduce STEAM activities similar to our study without fear of falling behind on standard content. Ultimately, empowering teachers to become facilitators of creativity will have a multiplier effect on student outcomes.

Assessment and Recognition of Creativity: Another practical implication relates to assessment. Using tools like the SCC scale can help educators identify strengths and weaknesses in different creativity facets and track progress over time. Schools and SACs may incorporate such scales or observation checklists to periodically assess how well their environment and teaching practices are supporting creativity (for instance, as part of program evaluation or student development portfolios). On a policy level, it may be valuable to include creativity indicators in the evaluation of gifted programs - moving beyond traditional metrics like competition wins or standardized test scores. By recognizing improvements in creativity (e.g., in annual reports or student awards for innovative projects), the education system would send a message that creative growth is a valued outcome. This aligns with international trends and the needs of the 21st century: creativity and collaboration are key competencies for future scientists, engineers, and leaders (OECD, 2018). Our study's success story can thus inform policy to explicitly integrate creativity goals in curricula. For example, the national science curriculum or the SAC curriculum guidelines could reference the importance of collective projects and list example activities like the LED experiment as recommended practice.

Supporting Gifted Students' Socio-Emotional Growth: The improvement in collective creativity also has implications for the social development of gifted students. Gifted education policymakers should note that collaborative creativity opportunities can help gifted learners develop better communication, empathy, and teamwork skills, addressing some social challenges that gifted individuals sometimes face. Programs might intentionally include group innovation tasks to ensure that gifted students learn to value others' contributions and work effectively in teams - skills that will benefit them in higher education and careers. The finding that students learned to appreciate the process of co-creating knowledge suggests that such experiences might also reduce excessive perfectionism or individual competitiveness in some gifted youth, leading to healthier attitudes toward learning. Therefore, educators should balance competitive individual tasks with cooperative creative tasks in gifted programs to cultivate well-rounded talent.

In conclusion, the practical takeaway is clear: educational practice and policy should create fertile ground for creativity by blending rigorous content with open-ended exploration, providing supportive mentors, and encouraging collaboration. Doing so is especially fruitful in settings for gifted students, who are poised to become the innovators of tomorrow. Our study offers a model that can be adapted and scaled - one where art meets science, teachers become facilitators, and students become co-creators of knowledge.

Future Directions

While the results of this study are promising, several limitations must be acknowledged to guide future research. Firstly, the sample was limited to 45 gifted middle school students from a single SAC, which, though offering a controlled context, restricts the generalizability of the findings. Future studies should expand to larger, more diverse samples—such as including multiple SACs from various regions or gifted classrooms within traditional schools—to test the broader applicability of our results. Additionally, the focus on middle schoolers leaves open questions about whether similar STEAM interventions would work equally well for younger or older gifted learners. Another limitation is the lack of a control group, a design factor already acknowledged in our methods. While we believe the magnitude of the gains and the short timeframe mitigate this concern, future studies incorporating comparison groups—such as traditional teaching or other forms of enrichment—would strengthen causal claims about the STEAM approach's effectiveness.

The specificity of the STEAM task is another consideration. Our intervention centered on LED design challenges, yet different types of STEAM activities (robotics, coding, etc.) may differentially affect creativity dimensions. For instance, coding projects might heavily emphasize cognitive traits but not emotional support if students work individually. Future work could compare various STEAM formats to determine which best supports specific creativity dimensions, addressing questions like whether art-integrated science activities better foster affective engagement than purely scientific tasks. Moreover, the teacher's role in our study, while supportive and trained in STEAM, was not varied or isolated. Exploring how teachers' attitudes or project-based learning experience shapes implementation would refine our understanding of best practices. Professional development studies that train multiple teachers and observe which practices yield the highest creative growth could enrich this discussion.

Lastly, the cultural context warrants attention. Although the SCC scale was adapted for Turkish students (originally developed in South Korea), creativity can manifest differently across cultures. Future research could replicate this intervention in other countries or examine cultural differences using the SCC framework to see if collective creativity varies with cultural norms. Given Turkey's strong "collective consciousness," it would be intriguing to see if this cultural factor boosts collective creativity gains in gifted Turkish students, as our data suggests. In sum, this study highlights that creativity is a dynamic set of skills and mindsets that can be nurtured through intentional practice and supportive environments. Addressing these limitations in future research can build on our findings and help generalize effective STEAM practices, ensuring that more classrooms—both in Turkey and globally—can cultivate the kind of collective and individual creativity we observed in this project.

Additional Statements

- All authors contributed equally to this manuscript.

- All procedures performed in this study adhered to the research and publication ethics principles outlined by JEPS.
- No potential conflicts of interest were reported by the authors.
- Participation in this study was entirely voluntary, and informed written consent was obtained from all students and their parents/guardians prior to data collection.

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APPENDİCES

Appendix A. Sample STEAM-Based Lesson Plan

Lesson Title:

STEAM-Based Collaborative LED Design Project

Target Group:

Gifted students, Grades 5–8 (Middle School Level)

Duration:

90 minutes

Objective:

To enhance students' collective creativity, problem-solving skills, and interdisciplinary thinking by engaging them in designing multiple ways to light up an LED through group collaboration.

Learning Outcomes:

- Integrates knowledge from multiple disciplines (science, engineering, art, and mathematics) to design functional solutions.
- Demonstrates effective collaboration and task sharing within a group setting.
- Applies creative thinking strategies to develop original approaches to a given problem.
- Utilizes scientific process skills such as observation, hypothesizing, testing, and iteration.

Teaching Strategies and Methods:

- Collaborative Learning
- Project-Based Learning
- Design Thinking

Materials and Tools:

Breadboards, LEDs, resistors, jumper wires, batteries, scissors, cardboard, utility knives, tape

Implementation Process:

1. **Introduction (10 min):** Brief discussion on how LEDs function and real-world applications.
2. **Group Formation (5 min):** Students are placed into diverse, balanced teams and assigned roles.

3. **Hands-On Challenge (60 min):** Each team designs and tests multiple methods to light an LED using available materials.
4. **Presentations (10 min):** Teams present their designs to the class and participate in peer evaluations.
5. **Reflection (5 min):** Teacher-led debriefing with emphasis on challenges, successes, and group dynamics.

Assessment Methods:

- Teacher observation of group process and dynamics
- Peer assessment based on group participation
- Evaluation of final LED prototypes
- Creativity-focused rubric (see Appendix B)

Appendix B. Collective Creativity Assessment Rubric

Assessment Criterion	**4 – Excellent**	**3 – Good**	**2 – Developing**	**1 – Needs Improvement**
Creativity and Originality	Design is entirely original and demonstrates highly creative, unexpected solutions.	Design includes some original elements with moderate creativity.	Design relies mostly on common solutions with limited innovation.	Design lacks originality; ideas are imitative.
Collaboration and Teamwork	All team members worked actively and supportively with balanced contribution.	Most team members contributed; communication was generally effective.	Collaboration was uneven; some students were disengaged.	Poor collaboration; minimal communication or task distribution.
Scientific-Technical Accuracy	LED circuits are accurately and safely connected with no major technical flaws.	Circuits are mostly correct with minor technical errors.	Significant errors present in circuitry or design.	Circuits are nonfunctional or demonstrate misunderstanding of basic principles.
Problem-Solving Approach	Multiple solutions explored from different perspectives; approach is both logical and inventive.	Problem is solved with some creative elements; reasoning is mostly logical.	Problem-solving is narrow or rigid; few alternatives considered.	Problem is poorly defined or unresolved; weak or absent solution strategy.
Presentation and Communication	Presentation is clear, structured, and engaging; technical terminology is used accurately.	Presentation is mostly clear; some terminology used correctly.	Presentation lacks clarity; communication needs improvement.	Presentation is unclear or incomplete; lacks coherence and terminology.