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Gender Group Differences in STEAM Learning: How Balloon-Powered Car Enhance Science Process Skills and Creative Thinking Skills in Elementary Students?

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Abstract: This study aims to determine the science process skills (SPS) and creative thinking skills (CTS) of elementary school students during STEAM based balloon-powered car project. A quasi-experimental with 29 sixth-grade students assigned to three group types: all-boys, all-girls, and mixed-gender. Students participated in a four-session STEAM learninng sequence, and their SPS and CTS were assessed through rubric-based observations and interviews. Kruskal-Wallis analysis showed no statistically differences among three groups for either SPS (H = 2.061, p = 0.357) or CTS (H = 3.157, p = 0.206), with very small effect sizes. Although minor descriptive tendencies appeared, in SPS, the boys group showed slightly higher performance in the classifying and prediction indicators, while the girls group excelled in the communication indicator. In CTS, the girls group excelled in the fluency, flexibility, and elaboration indicators, while the boys group excelled in the originality indicator. Overall, all groups achieved moderately high SPS and CTS scores, indicating that the STEAM project effectively facilitated scientific inquiry and creative thinking irrespective of gender composition. These findings confirm that well-designed STEAM-based projects can provide equal opportunities for all students to develop their SPS dan CTS simultaneously.

Keywords: Creative Thinking Skills, Gender Group; Science Process Skills; STEAM Learning

Introduction

In a changing and complex world, the ability to navigate effectively is essential. This urgent has led to a strong emphasis on providing students with 21st-century competencies (van Laar et al., 2020), by placing the development of scientific process skills (SPS) and creative thinking skills (CTS) as a priority. According to the OECD (2018), both skills are crucial foundations for fostering scientific literacy. The effectiveness of this educational orientation depends on the specific contributions of each skill. SPS provides methodological tools for systematic problem-solving (Haerani et al., 2023), while creative thinking encourages the innovation necessary to confront new challenges (Siregar, 2023).In response, projects with an interdisciplinary to Science, Technology, Engineering, Art, and Mathematics (STEAM) have emerged as a promising pedagogical framework.

STEAM learning implementation has become one of the research trends that has gained popularity in recent decades, particularly at the elementary education level (Supriyadi et al., 2023; Wahyuningsih et al., 2020). Unlike the STEM approach, the integration of the discipline of "art" in STEAM encourages various efforts and innovations in the development of SPS and CTS that combines analytical and humanistic sciences (Perignat & Katz-Buonincontro, 2019). The findings of Ihsan & Suwasono (2025) highlight that STEAM has strong potential to develop 21st – century skills in science

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learning – including SPS and CTS – at various levels of education. However, a meta analysis by Asrizal et al. (2023) confirms that the STEAM approach has a more significant impact on the science learning outcomes of primary and secondary school students than on higher education.

Although promising, the implementation of STEAM often ignores gender dynamics in collaborative groups. According to Howe et al. (2019), social-interactive factors such as group composition are significant mediators of student cognition in collaborative learning such as STEAM. Most previous studies involving gender in STEAM/STEM have been dominated by comparative approaches that analyzed differences in individual achievement and interest between boys and girls students as separate groups (Makarova et al., 2019; Verdugo-Castro et al., 2022; Wang & Degol, 2017). Furthermore, intervention studies involving the grouping of students - such as homogeneous groups based on gender – generally only measure learning outcomes within those groups without directly comparing them with mixed groups (Sullivan & Bers, 2019).

The lack of attention to student grouping factors, particularly gender composition, has resulted in a scarcity of empirical studies investigating social interactions within groups of varying gender compositions – specifically, homogeneous (all boys or all girls) versus mixed. More precisely, there is a limited amount of research examining the specific influence of this aspect on enhancement of SPS and CTS among elementary school students, thereby constituting a significant gap in the literature. To address this gap, this study aims to implement STEAM learning through a simple balloon-powered car project by comparing three types of gender groups, which are homogeneous boys, homogeneous girls, and heterogeneous (mixed). Although simple project-based learning with balloon-powered cars has been widely implemented and proven to have an effect on students' creative thinking (Astuti et al., 2022). However, exploration linking it to gender group analysis in STEAM and SPS is still very limited. Therefore, this study aims to answer the following question: Do same-gender (all-boys or all-girls) and mixed-gender groups show significant differences in science process skills and creative thinking of elementary students after the balloon-powered car project?

Methods

Research Design

This study employed a quasi-experimental posttest-only non-equivalent group design to examine whether group gender composition (mixed-gender, all-girls, and all-boys) influenced STS and CTS after following a STEAM-based learning activity with the balloon-powered car project. The groups were naturally formed based on gender rather than random assignment, while all received the same intervention. The intervention was implemented through a STEAM-based learning sequence consisting of four sessions over two weeks. Learning activities centered on the balloon-powered car project, which integrated scientific inquiry (see Table 1).

Table 1. The STEAM learning activities on the balloon-powered car project

Discipline	Learning activity
Science	Understanding force, motion, and energy concepts
Technology	Using simple materials and tools to build the car
Engineering	Designing and modifying the car structure for optimal movement
Arts	Creatively shaping and decorating the model
Mathematics	Measuring distance, speed, time, and interpreting numerical results

Participants and Sampling

The participants were 29 sixth-grade students (aged 11–12 years) from SDN 4 Banjar Agung, a public elementary school in Banten, Indonesia during the 2025/2026 academic year. A purposive sampling technique was applied to ensure similar academic backgrounds and balanced gender ratio. The researcher assigned students to the three gender-composition condition: mixed-gender groups (n = 9), all-girls groups (n = 10), and all-boys groups (n = 10). These larger groups were subdivided into smaller collaborative teams, resulting in a total of six teams for the hands-on project. School permission and parental consent were obtained before the study was conducted.

Instruments and Data Collection

Students' science process skills (SPS) and creative thinking skills (CTS) were assessed through direct observation and structured interviews conducted during the project implementation. The interview questions were designed according to SPS and CTS indicators on coding protocols listed in Appendix A. Each student's responses and behavior during the project were evaluated using a rubric-based scoring system. Points were assigned to each indicator according to performance quality, and the total score for each participant was converted to a scale of 0 – 100. This approach allowed for authentic and process-oriented assessment consistent with the STEAM framework.

Data Analysis

The differences in SPS and CTS across same-gender (all-boys or all-girls) and mixed-gender groups were analyzed with the Kruskal-Wallis H test. For significant results, post-hoc pairwise comparisons were performed using Mann-Whitney U tests with Bonferroni adjustment. All statistical analyses were conducted in IBM SPSS Statistics, version 26. However, effect sizes were reported as epsilon squared (ε^2), which were calculated using the formula by Tomczak & Tomczak (2014):

$$\varepsilon^2 = \frac{H-k+1}{n-k} \quad (1)$$

where H is the value obtained from the Kruskal-Wallis test, k is the number of groups, and n is the total number of sample.

Result and Discussion

Descriptive statistical analysis revealed that students achieved a moderately high level in both SPS and CTS performance. The mean SPS score was 78.86 (SD = 15.42), with a range from 40 to 100, while the mean CTS score was 72.34 (SD = 21.31), with a range from 25 to 100. These results suggest that elementary school students were generally capable to demonstrate inquiry, experimentation, and creative design processes during the STEAM learning sequence. It is noteworthy that the mean SPS score was somewhat higher than the mean CTS score, although the difference was not substantial.

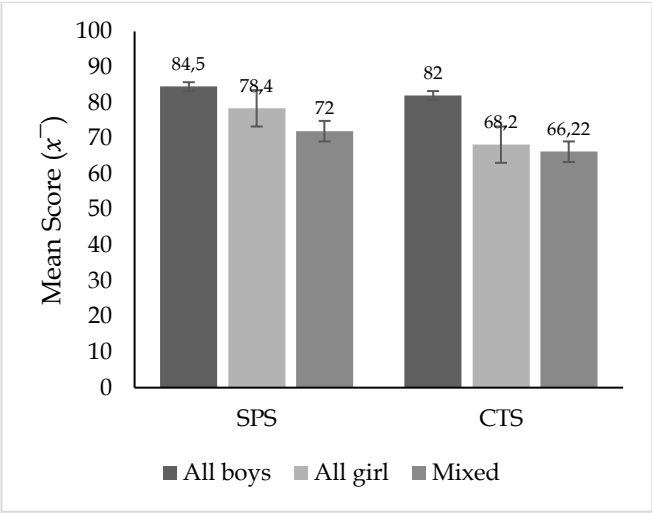

Figure 1. Descriptive analysis based on gender groups

More detailed descriptive comparison across gender-based groups showed varying performance patterns (see Figure 1). The all-boys groups consistently achieved the highest mean scores in both science process skills (SPS: $\bar{x}$ = 84.50, *SD* = 8.30) and creative thinking skills (CTS: $\bar{x}$ = 82.00, *SD* = 17.27), demonstrating relatively homogeneous performance. The all-girls groups had average mean scores on both variables (SPS: $\bar{x}$ = 78.40, *SD* = 14.95; CTS: $\bar{x}$ = 68.20, *SD* = 20.76), while mixed-gender groups obtained the lowest mean scores (SPS: $\bar{x}$ = 72.00, *SD* = 20.24; CTS: $\bar{x}$ = 66.22, *SD* = 24.28) with significant variability within the group. These descriptive trends, however, should be interpreted cautiously, as they do not indicate inferentially meaningful differences.

The Kruskal-Wallis test examined whether students' SPS and CTS differed across same-gender (all-boys or all-girls) and mixed-gender (see Table 2). The results confirm that there are no statistically significant differences between the three groups in terms of SPS (H = 2.061, p = 0.357) dan CTS (H = 3.157, p = 0.206), indicating that gender composition did not substantially influence students' performance after the balloon-powered car project. However, the mean rank pattern suggested that all-boys groups tended to achieve higher ranks on both measures. For SPS, the mean rank were 12.06 (mixed-gender), 15.05 (all-girls), and 17.60 (all-boys). For CTS, the mean ranks were 12.44 (mixed-gender), 13.50 (all-girls), and 18.80 (all-boys). These pattern reinforce the trends observed in the initial descriptive analysis, but these differences were not statistically meaningful. In addition, effect size analysis using epsilon squared (ε^2) showed a very small effect for SPS (ε^2 = 0.002) and small effect for CTS (ε^2 = 0.045). This suggest that group gender composition had little practical influence on either scientific or creative learning outcomes. Because both Kruskal-Wallis tests were non-significant (p > 0.05), no post hoc pairwise comparison were performed.

Table 2. Kruskal-Wallis H test and Effect Size Results

Variable	H	p	ε^2
SPS	2.061	0.357	0.002
CTS	3.157	0.206	0.045

Further analysis of each aspect of SPS and CTS revealed interesting findings. In SPS, which consists of five measurable indicator (classifying, prediction, measuring, observation, and communication), student performance was analyzed by categorizing it into three levels: (1) Low; (2) Medium; and (3) High. The percentage distribution of students in each aspect of SPS based on gender groups is presented in Table 3.

Table 3. Percentage of Students in Each Aspect of SPS

Indicator	Category	Group (%)		
		Mixed	Boys	Girls
Classifying	Low	11	0	10
	Medium	44	10	50
	High	44	90	40
Prediction	Low	22	10	0
	Medium	22	0	30
	High	56	90	70
Measuring	Low	33	10	0
	Medium	22	30	40
	High	44	60	60
Observation	Low	22	0	20
	Medium	67	50	60
	High	11	50	20
Communication	Low	11	20	10
	Medium	67	60	50
	High	22	20	40

On the classifying indicator, the boys' group showed the highest results, with 90% of students in the high category. This means that almost all male students are able to use tools and materials according to their functions without assistance. Most of the girls' group (50%) and mixed group (44%) are still in the medium category, meaning that they are able to use the tools but still need guidance. Only a few students in these two groups still have difficulties.

On the prediction indicator, 90% of students in the boys group were in the high category, while the girls group also showed good results with 70% at the same level. This shows that both groups are able to make predictions and provide logical reasons. The mixed group showed mixed results, with 56% able to predict well, but 22% in the medium category and 22% in the low category, meaning that some students are still unsure about predicting the results of the experiment.

On the measuring indicator, 60% of students in both the boys' group and girls' group were in the high category. These results show that both groups were able to measure and read the measuring instruments correctly. A total of 44% of students in the mixed group were in the high category, but 33% were still unable to use the measuring instruments properly, indicating that the abilities of the group members were not yet evenly distributed.

On the observation indicator, 50% of students in the boys group were in the high category, meaning that half of them were able to observe independently. The girls group and mixed group were mostly at the medium level. These results show that both groups were able to observe but still needed guidance. As many as 22% of students in the mixed group still had difficulty observing independently.

In terms of communication, the girls' group was the most dominant, with 40% of students in the high category, meaning they were better able to write down their observations clearly and independently. The mixed group and boys' group were mostly in the medium category, at 67% and 60% respectively. This means that they were able to write down their observations, but still needed help in compiling their reports.

Research by Budiarti et al (2022) revealed differences in results between male and female groups. Men were found to excel in the observation and prediction indicators, while women excelled in the communication indicator. These results are in line with the SPS formed through the collaboration of girls' groups and boys' groups in STEAM learning. These results differ from the study by Yuliskurniawati et al (2019), which proved that female students had higher average SPS scores than males because they were considered more thorough, careful, and had positive responses. The girls' group in this study dominated the High category in the communication indicator and was equal to the boys' group in the measuring indicator.

The performance of students in the four indicator of CTS (fluency, flexibility, originality, and elaboration) was also analyzed and classified into four levels: (1) Not Enough; (2) Enough; (3) Good; and (4) Very Good. The percentage distribution of students in each indicator of CTS based on gender groups is presented in Table 4.

Table 4. Percentage of Students in Each CTS Indicator

Categories	Fluency (%)			Flexibility (%)			Originality (%)			Elaboration (%)		
	Mixed	Boys	Girls	Mixed	Boys	Girls	Mixed	Boys	Girls	Mixed	Boys	Girls
Not Enough	22	50	30	11	40	0	22	10	0	11	10	0
Enough	22	10	0	33	10	20	33	0	30	44	10	0
Good	11	30	40	22	40	10	22	40	0	22	10	50
Very Good	44	10	30	33	10	70	22	50	70	22	70	50

Based on the results of the CTS analysis after learning, it was found that the girls group dominated the good and very good levels on the indicators of fluency, flexibility, and elaboration. The good and very good levels on the originality indicator were dominated by the boys group. The boys group dominated the not enough level on the indicators of fluency and flexibility, while

the mixed group dominated the indicators of originality and elaboration.

In terms of fluency, or the ability to generate ideas, the girls' group stood out the most. Most of the female students were able to quickly convey many ideas that were relevant to the problems given. In contrast, the boys' group tended to fall more into the "not enough" category, indicating that they still needed more time or encouragement to express their ideas fluently. The mixed group showed mixed results, with some students demonstrating good abilities and others still limited.

On the elaboration indicator, which is the ability to elaborate and develop ideas in detail, the girls' group again dominated the good and very good levels. Female students were generally able to explain designs and work processes in a coherent, logical, and detail-oriented manner. In contrast, most students in the boys' group and mixed group still dominated the enough or not enough levels, indicating that their skills in elaborating ideas still need to be trained.

The difference is shown through the description of the originality indicator, which is the originality of ideas. In this indicator, the boys' group actually dominates the good and very good levels. Many male students produce unique ideas and designs, different from the examples given by teachers or other groups. Meanwhile, the girls' group also shows creativity, but with a tendency toward more conventional ideas. The mixed group shows a wide variety of results, but some still depend on examples.

Overall, this study proves that STEAM learning based on collaboration among elementary school students can reduce gender gaps. The multidisciplinary and contextual characteristics of STEAM encourage each student to contribute to their strengths. The findings that students achieved good and high average SPS and CTS scores in each aspect overall prove the effectiveness of the applied STEAM learning. A meta-analysis by Asrizal et al. (2023) confirms that STEAM learning has a positive impact on student learning outcomes in science. Research by Suryanti et al. (2021) also shows that STEAM-Project-based learning acts as a catalyst for improving the science literacy skills of elementary school students. In the context of multidisciplinary project-based learning, the balloon-powered car project in this study can serve as a foundation for developing students' process skills and creativity, in line with the PjBL-STEM analysis by Kwon & Lee (2025); Retno et al. (2025).

Furthermore, the results of the analysis show that the gender composition of the groups did not show statistically significant differences in SPS and CTS, in line with the research by Ma et al. (2022), which emphasizes the role of the STEAM learning context in creating an equitable learning environment. However, the complexity of gender group dynamics became more apparent when the descriptive patterns were supported by analysis of each aspect of SPS and CTS. In this case, it appears that all-boys groups tend to excel. These results are similar to the research conducted by Lin et al. (2020) in the context of computer science problem solving, where it was found that male groups demonstrated superior knowledge performance and a direct, solution-focused style of collaboration. In contrast, research by Zhan et al. (2015) shows that all-girls groups and mixed-gender groups actually achieved the best performance in creative digital design tasks. The contrast between these two findings indicates that the specific nature of the learning task is one of the factors that influence how gender dynamics can be more visible.

The slightly higher SPS scores among all-boys groups, particularly in more technical indicator such as measuring and prediction, may be related to their involvement and confidence during the project. This is because balloon-powered car projects, which are more technical in nature, tend to be closer and more relevant to the collaborative style of all-boys groups (Lin et al., 2020; Retno et al., 2025). Other studies also show that male students often show a stronger tendency toward direct manipulation and experimentation, while female students may emphasize collaboration and aesthetic expression (Ma et al., 2022), so that the influence is not fully apparent in structured SPS assessments.

However, this tendency is not a biological determinant. Research by Sullivan & Bers (2019) shows that with the right intervention and learning design in his research he used robotics – girls' interest and skills in technical subjects can be significantly improved. The balloon-powered car project emphasizes technical and experimental aspects that align with the collaborative preferences of male students, but its design also provides equal creative exploration opportunities for all genders.

For CTS, the small effect size confirms that creativity largely does not depend on the gender composition of the group. Research by Filipe et al. (2024) shows that creative thinking depends more on open-ended tasks and a supportive learning climate, such as integrated STEAM education, than on gender structure. These results are in line with research by Astawan et al. (2023), which shows the significant impact of STEM/STEAM-based learning on critical and creative thinking skills. The integration of arts and sciences within the STEAM framework likely provides balanced opportunities for male and female students to explore every aspect of CTS in generating ideas ide (Ma et al., 2022; Retno et al., 2025; Yudha et al., 2023). In addition, collaboration in STEAM learning encourages students to

exchange ideas, thereby strengthening the creativity of the group as a whole and making gender composition less prominent (Ellianawati et al., 2025). This means that gender differences may be more apparent in the collaboration process and participation style (Lin et al., 2020; Zhan et al., 2015) than in cognitive learning outcomes, especially in integrative STEAM learning (Perignat & Katz-Buonincontro, 2019).

These findings underscore the importance of designing STEAM activities that integrate both technical and creative components to engage all students. In line with the research by Soto et al. (2024), teachers can further support equitable participation by assigning rotating roles that balance technical, analytical, and creative responsibilities within groups. This can be achieved by utilizing gender dynamics to create inclusive tasks that attract the interest and abilities of all students. The balloon-powered car project demonstrates how hands-on, contextual, and collaborative learning can provide meaningful opportunities for students—regardless of gender—to develop essential scientific and creative competencies.

Conclusion

This study concludes that there are no statistically significant differences in science process skills (SPS) and creative thinking skills (CTS) among the three gender-group compositions - all-boys, all-girls and mixed-gender – after participating in the baloon-powered cas STEAM project. While minor descriptive trends were observed, such as slightly higher technical SPS and originality among boys and stronger fluency and elaboration among girls, these patterns were not statistically meaningful. Overall, students across all groups achieved comparable learning outcomes, highlight that well-designed STEAM-based projects can provide equitable opportunities for all students to enhance both scientific and creative competencies. Future research should expand the sample size, explore longitudinal effects, and examine interaction patterns during collaboration to better understand how gender dynamics influence learning in STEAM contexts.

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Author Contributions
Conceptualization, methodology, validation, A.P.P., K.S., and N.K.R.; data analysis using SPSS and Microsoft Excel, formal analysis, resources, data curation, writing—original draft preparation, writing—review and editing, A.P.P.; investigation, supervision, K.S. and N.K.R.; All authors have read and approved the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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