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CultuSTEM: A Culture-Based Pedagogical Model for Fostering Creativity in Secondary STEM Classrooms

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ABSTRACT

Background. Culture-based teaching may help students build creativity in STEM, but few interventions have examined its effects on creative thinking.

Objective. This study examined whether CultuSTEM, a pedagogical model that links local culinary heritage to STEM teaching, fosters creative thinking skills, STEM achievement, and cultural appreciation in secondary school students.

Methods. A quasi-experimental pretest–posttest control group design was used with 136 Grade 10 students (68 experimental, 68 control) from two public secondary schools in Palembang, Indonesia. For 10 weeks, the experimental group followed five thematic modules: fermentation science, thermal dynamics in traditional cooking, spice preservation chemistry, recipe scaling mathematics, and cooking tool engineering. Every lesson ran through a four-phase cycle of Cultural Immersion, Scientific Inquiry, Creative Challenge, and Reflective Synthesis. The main outcome was the Creative Thinking Skills Test (CTST), adapted from the Torrance Tests of Creative Thinking. Data were analyzed with MANOVA and Bonferroni-corrected ANCOVA.

Results. MANOVA showed a significant multivariate effect (Pillai's V = 0.412, $F(3,132) = 30.84$, $p < 0.001$). The experimental group outperformed the control group on creative thinking ($F(1,133) = 142.68$, $p < 0.001$, partial $\eta^2 = 0.518$), STEM achievement ($F(1,133) = 78.42$, $p < 0.001$, partial $\eta^2 = 0.371$), and cultural appreciation ($F(1,133) = 45.86$, $p < 0.001$, partial $\eta^2 = 0.256$). Hedges' g ranged from 1.32 to 2.15.

Conclusion. Culturally grounded STEM teaching may raise creative thinking considerably. It also appears to improve academic performance and cultural engagement. Because intact classes were assigned to conditions, the findings need confirmation in larger studies.

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1. Introduction

Bringing cultural knowledge into science, technology, engineering, and mathematics (STEM) education is a promising way to raise student engagement and learning outcomes.[1] Creativity matters in STEM. Yet analyses of United States TTCT norming data have been read as showing a decline in creative thinking among students,[2] although a later re-analysis found no evidence of a generational decline.[3] Whatever the trend, creativity is widely seen as essential for scientific innovation and technological advancement.[4] Current STEM frameworks call for interdisciplinary approaches. These approaches cross disciplinary boundaries and tie abstract scientific concepts to the lived experiences of students.[5]

Culturally responsive pedagogy offers a theoretical basis for linking academic content to the cultural backgrounds of students, so that learning becomes more meaningful and more equitable.[6,7] The overlap between culturally responsive teaching and STEM creativity is still underexplored. Southeast Asia is a telling case. Rich culinary traditions there offer plentiful chances for authentic scientific inquiry. Local culinary heritage is a largely untapped pedagogical resource, and it carries complex scientific principles (fermentation biochemistry, thermal dynamics, chemical preservation, mathematical proportionality, and engineering design) inside contexts that students already know. Ethnographic work on a traditional Indonesian food, for example, has documented biological, chemical and physical knowledge in its preparation that maps onto the junior high school science curriculum.[8]

Creativity is the ability to produce ideas or products that are both novel and appropriate.[9–11] It has several cognitive dimensions: originality, fluency, flexibility, and elaboration.[10,12] Environment matters too. The social psychology of creativity adds that factors such as cultural context can support or constrain creative expression.[13] Recent scholarship has widened the concept to include "mini-c" creativity, meaning the personally meaningful interpretive processes that accompany learning.[14] It has also asked for closer attention to creativity in educational settings.[15]

Creativity has long been treated as a core component of scientific thinking and innovation.[9] Guilford's Structure of Intellect model named divergent thinking as a key cognitive operation behind creative production, covering fluency, flexibility, originality, and elaboration.[9] Torrance then built comprehensive measures of creative thinking. Educational research has widely adopted them.[10]

Individual cognitive processes and environmental conditions act on each other, as the social psychology of creativity describes.[12,13] Amabile's componential model says creativity arises when three things meet: domain-relevant skills, creativity-relevant processes, and intrinsic task motivation.[13] Pedagogical approaches and cultural context can strongly shape each component. Beghetto and Kaufman's Four C Model separates "mini-c" (personally meaningful), "little-c" (everyday), "Pro-C" (professional), and "Big-C" (eminent) creativity. The model offers a finer framework for understanding creative development in educational settings.[14,16]

Creativity is acknowledged as important. Educational psychologists have nonetheless observed that it gets too little attention in educational research and practice.[15] Kim analyzed Torrance Tests of Creative Thinking data and found a significant decline in the creative thinking scores of American students, which she called the "creativity crisis."[2] Research on testing conditions suggests that time limits and rigid instructional formats can suppress creative expression.[17] Such trends show why we need pedagogical approaches that nurture creative thinking.

Gay conceptualized culturally responsive teaching as the use of the cultural knowledge, prior experiences, and performance styles of diverse students to make learning more appropriate and effective.[6] Ladson-Billings added a theory of culturally relevant pedagogy with three dimensions: academic achievement, cultural competence, and critical consciousness.[7] STEM education has increasingly applied these frameworks. The aims are to close persistent equity gaps and to engage culturally diverse learners.[1] Survey data from 343 STEM teachers in Nigeria show that culturally responsive teaching predicts teachers' knowledge of their students' cultures and the integration of those cultures into STEM classes.[18]

Vygotsky's sociocultural theory lends support from another angle. It holds that learning is social by nature and mediated by culture.[19] Situated learning theory adds that knowledge is acquired inside authentic activity, context, and culture.[20] Indigenous education scholars have argued for years that traditional ecological knowledge and cultural practices belong in science curricula.[21,22] Their work shows that indigenous and Western knowledge systems can enrich each other instead of clashing.

Cross-cultural science education research shows that students from non-Western backgrounds often go through cultural border crossings between the culture of home and the culture of school science.[1] These crossings can create cognitive and affective barriers to learning. Pedagogical models that connect cultural knowledge with scientific content may ease the transition and deepen understanding.[23] Culinary heritage looks like an especially promising bridge. Food science spans several scientific disciplines, and it carries deep cultural meaning in societies everywhere.[24]

Researchers have studied the link between creativity and cultural context from several angles. Barron and Harrington's comprehensive review concluded that creative achievement depends on a complex mix of cognitive abilities, personality traits, and environmental factors.[25] Sawyer's synthesis stressed that social and cultural contexts fundamentally shape creative processes.[26] International comparisons of STEM education reveal large cross-national differences in pedagogical approaches and learning outcomes.[27] Cultural context, then, seems to matter for STEM learning.

Cropley argued that creativity in schools needs pedagogical environments that encourage risk-taking, value diverse perspectives, and leave room for open-ended exploration.[28] CultuSTEM builds on these ideas. It places creative challenges inside culturally meaningful contexts and uses cultural familiarity to lower inhibition and encourage creative risk-taking. The model ties STEM concepts to culinary traditions that students recognize and value, and in doing so it aims to activate domain knowledge and intrinsic motivation. Both are essential components of Amabile's componential model of creativity.[13]

Project-based learning has been shown to deepen understanding and build transferable skills in STEM contexts.[29] Recent meta-analyses report positive effects of project-based and STEM project-based learning on students' creativity.[30,31] Few interventions, though, have systematically examined how culture-based pedagogical models shape the multidimensional nature of creative thinking in STEM classrooms. Recent quasi-experiments in secondary schools point in a promising direction: Ethno-STEM project work improved fluency, flexibility, and originality in Nigeria,[32] and STEM activities raised creative thinking scores in Indonesia.[33] The present study addresses this gap. We developed CultuSTEM and evaluated it as a pedagogical model that joins local culinary heritage with STEM education through a structured four-phase instructional cycle, intended to foster creativity.

One primary research question guided the work. To what extent does the CultuSTEM pedagogical model enhance creative thinking skills, STEM achievement, and cultural appreciation among Grade 10 students, compared with conventional STEM instruction? Drawing on culturally responsive pedagogy[6,7] and the componential model of creativity,[13] we hypothesized that students taught with CultuSTEM would show significantly greater gains than their counterparts in conventional classes. The hypothesis covered creative thinking skills, STEM achievement, and cultural appreciation.

2. Methods

2.1 Participants

A total of 136 Grade 10 students from two public secondary schools in Palembang, Indonesia, took part. Intact classroom assignment placed them in the experimental group (n = 68) or the control group (n = 68). Table 1 summarizes their demographics. The two groups did not differ significantly in gender distribution ($\chi^2 = 0.12$, p = 0.726), mean age (t(134) = 0.41, p = 0.684), or school distribution ($\chi^2 = 0.03$, p = 0.861). Baseline equivalence was thus confirmed.

Table 1. Demographic characteristics of participants.

Characteristic	Experimental (*n* = 68)	Control (*n* = 68)	Total (*N* = 136)	*p*
Gender: male	32 (47.1%)	34 (50.0%)	66 (48.5%)	0.726
Gender: female	36 (52.9%)	34 (50.0%)	70 (51.5%)	
Age, *M* ± *SD*	15.4 ± 0.6	15.3 ± 0.5	15.4 ± 0.6	0.684
School A	35 (51.5%)	36 (52.9%)	71 (52.2%)	0.861
School B	33 (48.5%)	32 (47.1%)	65 (47.8%)	

Note. Values are *n* (%) unless otherwise stated. Gender and school: χ^2 test; age: independent-samples *t*-test.

2.2 Research design

The study used a quasi-experimental pretest–posttest control group design.[34,35] The experimental group received the CultuSTEM intervention for 10 weeks. The control group received conventional STEM instruction on the same curricular content. Both groups completed identical pretest and posttest

measures of creative thinking skills, STEM achievement, and cultural appreciation, and pretest scores entered the analysis as covariates, so the design controlled for preexisting differences. Random assignment of individual students was not feasible within the school context. Intact classes were assigned to conditions instead. The unit of allocation was the intact class, whereas the analyses were conducted at the student level.

2.3 The CultuSTEM pedagogical model

CultuSTEM was developed to integrate local culinary heritage with STEM education through a structured four-phase instructional cycle. Five thematic modules made up the intervention. Fermentation science (1) explored the biochemistry of traditional fermented foods, and thermal dynamics in traditional cooking (2) examined heat transfer and energy transformation. Spice preservation chemistry (3) investigated chemical reactions in food preservation. Recipe scaling mathematics (4) applied proportional reasoning and algebraic thinking, while cooking tool engineering (5) engaged students in design thinking and materials science.

Each 90-minute lesson followed the same four-phase cycle. Cultural Immersion came first (15 minutes), and students met authentic cultural artifacts, stories, and demonstrations tied to the culinary tradition. Scientific Inquiry (30 minutes) followed, in which students investigated the underlying scientific principles through guided and open-ended inquiry. In Creative Challenge (30 minutes), they applied their understanding to generate novel solutions, designs, or explanations. Reflective Synthesis (15 minutes) closed the lesson. Students described the connections among cultural knowledge, scientific understanding, and creative processes.

2.4 Instruments

Three instruments were used to measure the dependent variables:

Creative Thinking Skills Test (CTST). The CTST was adapted from the Torrance Tests of Creative Thinking[10] and assesses four dimensions of creative thinking: originality, fluency, flexibility, and elaboration. The adapted instrument has figural and verbal tasks set within STEM scenarios. Internal consistency was established with a Cronbach's alpha of 0.84, and inter-rater reliability, expressed as the intraclass correlation coefficient (ICC), was 0.89, indicating good to excellent agreement.[36] Two trained raters scored all responses independently. They resolved discrepancies of more than two points through discussion.

STEM Achievement Test. This 40-item multiple-choice test was developed to assess content knowledge across the five thematic modules. Its items were aligned with national curriculum standards and reviewed by three subject-matter experts. The Kuder-Richardson 20 (KR-20) reliability coefficient was 0.86, which indicates good internal consistency.[37]

Cultural Appreciation Scale (CAS). This 25-item Likert-type scale was developed to measure how much students appreciate local culinary heritage and its links to STEM disciplines. Internal consistency was acceptable (Cronbach's $\alpha = 0.82$). Two cultural anthropologists and two STEM educators reviewed the scale to establish content validity.

2.5 Procedures

The intervention ran for 10 consecutive weeks within regularly scheduled science classes. Before implementation, teachers in the experimental group received 16 hours of professional development on CultuSTEM, and weekly classroom observations with a structured protocol monitored fidelity; the overall fidelity rating was 94.2%. Control group teachers delivered conventional STEM instruction on the same curricular content, without cultural integration or the four-phase cycle. Pretests took place during the week before the intervention, and posttests followed within one week of its conclusion. The Enigma Institute Research Ethics Committee granted ethical approval (approval number 2024/008, dated 12 January 2024). Written informed consent was obtained from the parents or guardians of all participating students. Every student participant gave written assent before data collection.

2.6 Data analysis

Data were analyzed with multivariate and univariate statistical techniques.[38,39] A one-way multivariate analysis of variance (MANOVA) tested the overall effect of the intervention across the three dependent variables. Assumptions of multivariate normality, homogeneity of variance-covariance matrices, and absence of multicollinearity were assessed and met. Follow-up analyses of covariance (ANCOVA) came next. They were run for each dependent variable separately, with pretest scores as covariates, and a Bonferroni correction controlled the familywise error rate ($\alpha = 0.05/3 = 0.017$). Hedges' g was computed from the posttest means and SDs of the two groups (pooled SD, small-sample correction), with 95% confidence intervals from the standard error of g. For ANCOVA results, partial η^2 was reported with noncentral-F confidence intervals.[38] Magnitudes followed Cohen's conventions: small ($g = 0.20$), medium ($g = 0.50$), and large ($g = 0.80$).[38]

3. Results

3.1 Descriptive statistics

Descriptive statistics for all outcome measures appear in Table 2. At pretest, the experimental and control groups performed comparably on every measure, with no statistically significant differences (all $p > 0.05$). At posttest, the experimental group scored well above the control group on all outcome variables.

On the CTST Total score, the experimental group rose from a mean of 98.4 (SD = 14.2) to 142.6 (SD = 12.8), a gain of 44.2 points. The control group moved from 97.8 (SD = 14.8) to 114.2 (SD = 15.6), a gain of 16.4 points. Hedges' g for the total score was 1.98. Elaboration showed the largest standardized effect among the CTST subscales (Hedges' $g = 2.15$), followed by originality ($g = 1.83$), fluency ($g = 1.56$), and flexibility ($g = 1.43$). Every effect size passed Cohen's threshold for a large effect.[38] In STEM achievement, the experimental group went from 62.4 (SD = 8.6) to 81.2 (SD = 7.4) and the control group from 61.8 (SD = 9.1) to 70.4 (SD = 8.8), giving a Hedges' g of 1.32. Cultural appreciation scores increased from 68.2 (SD = 9.4) to 86.4 (SD = 8.1) in the experimental group, and from 67.6 (SD = 9.8) to 74.2 (SD = 10.2) in the control group. Hedges' g was 1.32.

Table 2. Descriptive statistics for outcome measures by group and time.

Measure	Experimental, pretest	Experimental, posttest	Control, pre-test	Control, post-test	Hedges' *g*	95% CI
CTST total	98.4 (14.2)	142.6 (12.8)	97.8 (14.8)	114.2 (15.6)	1.98	[1.57, 2.39]
Originality	24.6 (4.8)	38.2 (4.2)	24.2 (5.1)	29.4 (5.3)	1.83	[1.43, 2.23]
Fluency	28.2 (4.1)	39.8 (3.8)	27.8 (4.4)	33.2 (4.6)	1.56	[1.17, 1.94]
Flexibility	23.4 (3.6)	33.2 (3.4)	23.1 (3.8)	27.8 (4.1)	1.43	[1.05, 1.80]
Elaboration	22.2 (3.4)	31.4 (3.2)	22.7 (3.5)	23.8 (3.8)	2.15	[1.73, 2.57]
STEM achievement	62.4 (8.6)	81.2 (7.4)	61.8 (9.1)	70.4 (8.8)	1.32	[0.95, 1.69]
Cultural appreciation	68.2 (9.4)	86.4 (8.1)	67.6 (9.8)	74.2 (10.2)	1.32	[0.95, 1.69]

Note. Values are *M* (*SD*); *n* = 68 per group. Hedges' *g* is computed from the posttest means and SDs (pooled SD, small-sample correction), with 95% CI from the standard error of *g*. CTST total is the sum of the four subscales. CTST = Creative Thinking Skills Test.

As Figure 1 shows, the experimental group made larger pre-to-post gains than the control group on every measured variable. The gap was widest for creative thinking skills, where experimental posttest scores clearly exceeded those of the control group.

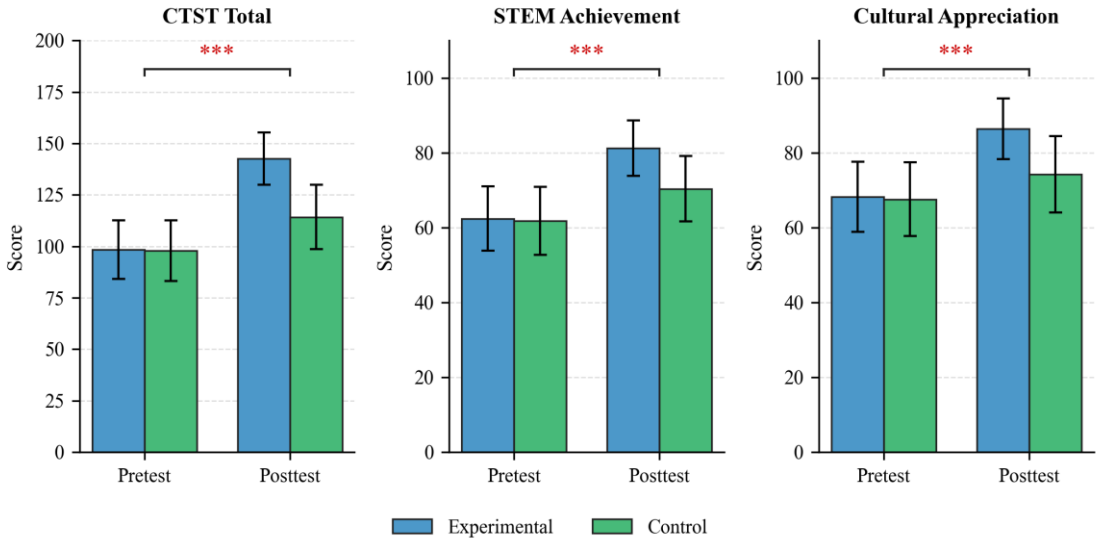


Figure 1. Pretest and posttest scores by group for the CTST total, STEM achievement, and cultural appreciation. Bars show means and error bars show ±1 SD (Table 2); *** $p < 0.001$ (ANCOVA, Bonferroni-adjusted).

3.2 Multivariate and univariate analyses

The MANOVA showed a statistically significant multivariate effect of group on the combined dependent variables, Pillai's V = 0.412, F(3,132) = 30.84, p < 0.001. The CultuSTEM intervention thus produced significant differences across the set of outcome measures when they were considered together.

Follow-up ANCOVAs used pretest scores as covariates and a Bonferroni-adjusted significance level (α = 0.017). They confirmed significant group differences on each dependent variable. For creative thinking skills, F(1,133) = 142.68, p < 0.001, partial η^2 = 0.518. Group membership therefore accounted for 51.8% of the variance in posttest CTST scores after controlling for pretest performance. For STEM achievement, F(1,133) = 78.42, p < 0.001, partial η^2 = 0.371, so group membership explained 37.1% of posttest variance. For cultural appreciation, F(1,133) = 45.86, p < 0.001, partial η^2 = 0.256, and group membership accounted for 25.6% of posttest variance. Table 3 gives the detailed results, and Figure 2 visualizes them.

Table 3. MANOVA and ANCOVA results for group comparisons.

Analysis	Test statistic	df	*p*	Effect size	95% CI
MANOVA (overall)	Pillai's V = 0.412	3, 132	< 0.001	—	—
ANCOVA: CTST total	*F* = 142.68	1, 133	< 0.001	partial η^2 = 0.518	[0.40, 0.60]
ANCOVA: STEM achievement	*F* = 78.42	1, 133	< 0.001	partial η^2 = 0.371	[0.24, 0.48]
ANCOVA: cultural appreciation	*F* = 45.86	1, 133	< 0.001	partial η^2 = 0.256	[0.14, 0.37]

Note. V = Pillai's trace; partial η^2 = partial eta-squared; CI = noncentral-F confidence interval of partial η^2.

The forest plot in Figure 2 shows the Hedges' g effect sizes with 95% confidence intervals for all outcome measures. No confidence interval included zero. This indicates statistically significant effects, and their sizes are large by conventional benchmarks.

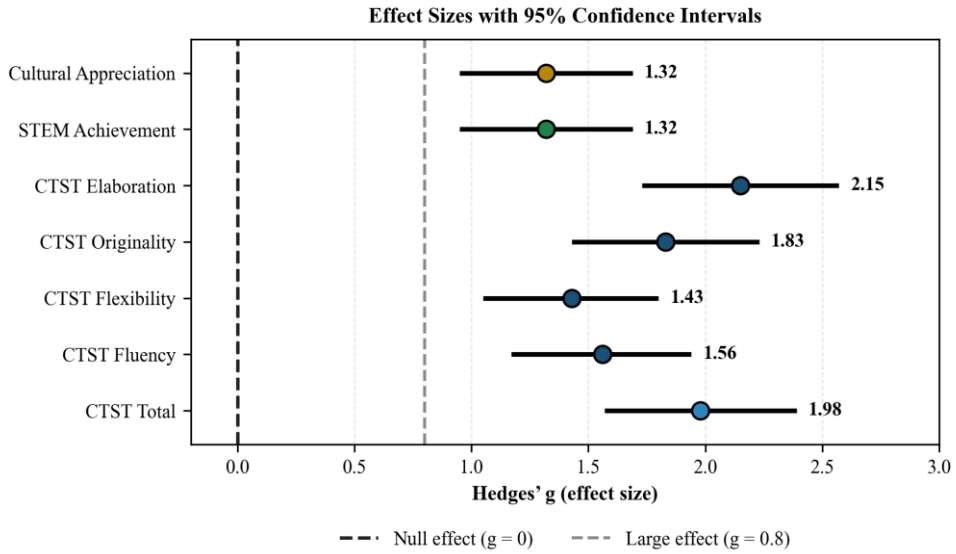


Figure 2. Forest plot of Hedges' g effect sizes with 95% confidence intervals for all outcome measures. The dashed line at g = 0.8 marks the conventional threshold for a large effect.

3.3 Creative thinking skills profile

The radar plot in Figure 3 shows the posttest creative thinking skills profile of both groups across the four CTST dimensions. The experimental group had a more balanced and expanded profile. Originality showed the largest between-group difference (experimental: M = 38.2, SD = 4.2; control: M = 29.4, SD = 5.3; Hedges' g = 1.83), which suggests that CultuSTEM was especially effective in promoting novel idea generation. Fluency (experimental: M = 39.8, SD = 3.8; control: M = 33.2, SD = 4.6; g = 1.56) and flexibility (experimental: M = 33.2, SD = 3.4; control: M = 27.8, SD = 4.1; g = 1.43) also showed large effects. Elaboration showed a very large effect (experimental: M = 31.4, SD = 3.2; control: M = 23.8, SD = 3.8; g = 2.15). Elaboration had the largest standardized difference, because the control group hardly changed on this dimension (22.7 to 23.8) and its posttest SD was small. In raw points, the smallest between-group difference was for flexibility (5.4 points).

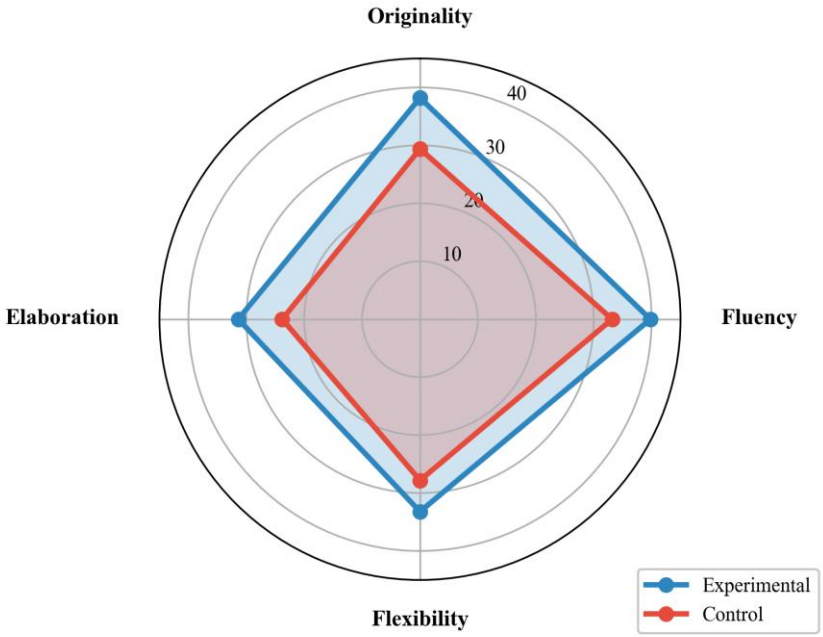


Figure 3. Radar plot of posttest CTST subscale means by group (raw subscale scores from Table 2).

4. Discussion

This study provides empirical evidence that Grade 10 students taught with the CultuSTEM pedagogical model reached significantly higher creative thinking skills, STEM achievement, and cultural appreciation than students in conventional classes. Effect sizes were large on every outcome variable (Hedges' g from 1.32 to 2.15), which is large relative to benchmarks for education interventions,[40] and combining cultural culinary heritage with STEM education therefore looks like a promising instructional approach. Recent meta-analyses of STEM project-based learning and of scientific problem-solving approaches likewise report large positive effects on creativity.[30,41]

The strong effect on originality (g = 1.83) deserves attention. Two phases of the CultuSTEM cycle, Cultural Immersion and Creative Challenge, may have given students rich contextual resources for generating novel ideas, and, in line with Amabile's componential model,[13] culturally familiar contexts may have strengthened both domain knowledge and intrinsic motivation. Creative outcomes improved. The finding matches Sawyer's observation that social and cultural contexts fundamentally shape creativity.[26] It also extends that observation, because deliberately structured cultural integration can amplify creative development in formal educational settings. Fluency, flexibility, and originality also rose after Ethno-STEM project work in Nigerian secondary schools.[32]

The effects differed across creativity dimensions, and this has theoretical implications. In raw posttest points, originality and fluency improved more than flexibility, so CultuSTEM may be especially good at promoting divergent ideation, the capacity to generate many novel ideas. Guilford's framework fits this pattern, since it named divergent production as a primary cognitive operation,[9] and so do meta-analytic findings that project-based learning and STEM contexts raise scientific creativity.[41] Elaboration showed the largest standardized difference, mainly because the control group hardly changed on this dimension. That result needs careful reading. In a meta-analysis of educational technology interventions, elaboration was the one TTCT subscale that did not respond,[42] and developing and refining ideas places greater cognitive demands on students. A replication with a longer intervention and independent scoring of elaboration would show whether the present effect is stable.

STEM achievement improved significantly (g = 1.32). CultuSTEM thus does not trade academic learning for creativity. It strengthens both at once. This twofold benefit fits the proposition that culturally responsive pedagogy can improve academic outcomes by linking content to the knowledge frameworks students already hold,[6,7] and situated learning theory points the same way.[20] That theory holds that knowledge gained in authentic, contextually rich environments is understood more deeply and transfers more readily than knowledge gained through decontextualized instruction.

Cultural appreciation also improved (g = 1.32). This further supports the multidimensional benefits of CultuSTEM. Students in the experimental group may have come to understand the scientific principles embedded in their own culinary traditions more deeply, and that understanding may in turn have raised their appreciation of both the cultural practices and the scientific knowledge. The reciprocal enrichment echoes Cajete's argument that indigenous knowledge systems and Western science can reinforce each other.[21] It also echoes Snively and Corsiglia's demonstration that indigenous science has major implications for formal science education.[22] The molecular gastronomy perspective of This adds to the case for culinary science as a vehicle for STEM learning.[24]

A sociocultural reading can explain why CultuSTEM worked, using Vygotsky's concept of the zone of proximal development.[19] Anchoring STEM concepts in familiar culinary practices may have widened students' zones of proximal development, so that they could tackle more complex scientific ideas and creative challenges than they otherwise would have attempted. The four-phase cycle moves from Cultural Immersion through Scientific Inquiry to Creative Challenge and Reflective Synthesis. That progression gave structured scaffolding. It helped students connect cultural knowledge with scientific understanding.

High implementation fidelity (94.2%) increases confidence in the internal validity of the findings. Several limitations still need attention. First, the quasi-experimental design with intact classroom assignment limits causal inference compared with randomized controlled trials.[34] Second, the study took place in one cultural context (Palembang, Indonesia), so generalizability to other cultural settings needs further investigation. Third, 10 weeks was long enough to show significant effects but says nothing about the long-term sustainability of the gains. Fourth, the CTST had adequate psychometric properties, yet it assessed creativity under structured conditions that may not fully capture the creative behavior of students in naturalistic settings.[10] Fifth, students were nested in classes, which the analyses did not model. Sixth, the instruments were developed or adapted by the authors, and only the teachers of the experimental group received training in the model. Seventh, the standardized effects are larger than the average effect of creativity training in a large meta-analysis (0.53 SD, with strong signs of publication bias),[43] so they should be replicated before they are generalized. Future work should use longitudinal designs with follow-up assessments, add process-oriented measures of creativity, and test the model across diverse cultural and educational contexts.[27,28]

5. Conclusion

This study suggests that CultuSTEM may enhance creative thinking skills, STEM achievement, and cultural appreciation among Grade 10 students. The model integrates local culinary heritage with STEM education through a structured four-phase instructional cycle. Effects were large on every outcome. They were strongest for elaboration (g = 2.15) and originality (g = 1.83). Culturally grounded STEM instruction may therefore foster creative thinking while improving academic performance, and the findings support the view that culturally responsive pedagogy and creativity education can work together rather than compete as goals. CultuSTEM offers educators a practical framework, supported by these findings, for developing the creative capacities of students in culturally meaningful STEM contexts. Future studies should do three things. They should examine how well the model transfers across diverse cultural settings. They should look at long-term effects on creative development. And they should test the mediating mechanisms through which cultural integration enhances creative thinking in STEM education.

Declaration

Artificial Intelligence Use Statement

No generative artificial intelligence tool was used to write or revise the text, analyze the data, create images, or generate any other scholarly content of this manuscript.

Author Contribution Statement

Conceptualization, I.S.; methodology, I.S. and E.W.; investigation, I.S.; formal analysis, F.D.; data curation, I.S.; writing – original draft, I.S.; writing – review and editing, E.W. and F.D.; supervision, F.D.; project administration, I.S. All authors approved the final version of manuscript.

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Conflict of Interest / Competing Interests

The authors declare that they have no competing financial or non-financial interests related to this work.

Ethics Approval and Consent to Participate

The study was approved by the Ethical Committee of Social Research, Enigma Institute, Indonesia(approval number 2024/008). Written informed consent was obtained from the parents or guardians of all participating students, and written assent was obtained from all student participants before data collection

Consent for Publication

Not applicable. The manuscript reports aggregate data only.

Data Availability Statement

The datasets generated and analyzed during this study can be obtained from the corresponding author on reasonable request.

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None.

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