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Chemistry–Entrepreneurship Co-Curricular Projects in the Merdeka Curriculum: Design, Validation, and Trial

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A B S T R A C T

Secondary chemistry in Indonesia is still taught mostly through teacher-centred delivery, and few validated models link chemistry with entrepreneurship inside the co-curricular space of the Merdeka Curriculum. This study designed, validated, and tried out such a model. A design and development approach following the ADDIE stages was applied in Jambi Province. Needs were surveyed among 12 chemistry teachers; four experts rated the model with a 38-item questionnaire; and 68 Grade XI students from three senior high schools joined a ten-week trial built around green chemistry products. Critical thinking and entrepreneurial self-efficacy were measured before and after the trial, creativity was scored from design portfolios, and observations and interviews were analysed thematically. Experts judged the model highly valid (mean CVR = 0.87; 35 of 38 item met the retention criterion of CVR 0.50). Critical thinking rose from 52.3 to 74.6 (dz = 2.23; day = 2.81) and entrepreneurial self-efficacy from 61.4 to 78.9 (dz = 1.66; day = 2.23); portfolio creativity averaged 11.8 of 16. Local materials such as citrus peel and cassava starch sustained engagement, whereas unresolved group conflict and teachers' limited business knowledge slowed some work. Without a control group, the gains remain preliminary. The model offers schools a structured starting point for chemistry-based entrepreneurial projects and underlines the need for teacher training.

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1. Introduction

Chemistry sits behind food processing, materials, medicines, and environmental management, yet many students still regard the subject as detached from anything they will do after school (Cooper & Stowe, 2018; Demelash et al., 2024; Stuckey et al., 2013). Indonesian classrooms are no exception. Lessons tend to move from definition to formula to exercise, leaving little room for the cross-subject thinking that real problems demand (Asyhar et al., 2025). The Merdeka Curriculum, regulated through Ministerial Regulation No. 12 of 2024, tries to loosen this pattern. It treats co-curricular work, above all the Pancasila Student Profile Strengthening Project (P5), as a deliberate part of learning, and it asks schools to build locally grounded projects around six competencies: critical thinking, creativity, collaboration, communication, citizenship, and character (Hunaepi & Suharta, 2024; Mulyasa, 2023; Pasongli et al., 2024). These competencies overlap strongly with entrepreneurial capacities such as recognising a need, solving problems creatively, and acting under uncertainty (Bacigalupo et al., 2016; Nabi et al., 2017; Thornhill-Miller et al., 2023), and chemistry supplies concrete products through which they can be practised.

Indonesian work that joins the two fields is usually labelled chemo-entrepreneurship. Umah and Kamaludin (2024) produced YouTube practical videos on functional groups that experts rated between 87% and 96% and that 97% of students reviewed favourably, which speaks to feasibility more than to learning gains. Sudarmin et al. (2023)built an ethno-STEM project course on secondary metabolites and reported stronger conservation and

entrepreneurial character among chemistry education students, and Asyhar et al. (2025) explored team-based project design for environmental chemistry and entrepreneurship learning. In parallel, green chemistry has become a favoured theme for project work. Jusniar et al. (2025) found, in a quasi-experiment, that project-based learning infused with green chemistry principles raised Grade XI students' critical thinking and environmental sensitivity. Tian et al. (2022), Mitarlis et al. (2023), Koulougliotis et al. (2021), and Purwanto et al. (2024) examined micro-projects, sustainability-oriented content, context-based projects, and socio-critical environmental issues in the same spirit, while Chen et al. (2020) place such work within sustainability education and Aubrecht et al. (2019) and Mahaffy et al. (2019) stress systems thinking. More broadly, project-based learning tends to benefit engagement and higher-order thinking (Almulla & Al-Rahmi, 2023; C.-H. Chen & Yang, 2019; Kokotsaki et al., 2016), including critical thinking in project settings (Amin et al., 2020; Cortázar et al., 2021; Rahayu & Karima, 2024; Suradika et al., 2023).

Taken together, these studies leave three issues open. First, most chemo-entrepreneurship work develops a single product, such as a video, module, or worksheet, and judges it through expert ratings and student opinion rather than through a design that spans a whole project cycle. Second, entrepreneurship is largely absent from green chemistry project studies, so students are seldom asked who a product is for or what it would cost to make. Third, teachers carry much of the burden. In a survey of 132 chemistry teachers, Stašević et al. (2026)found positive attitudes toward entrepreneurial competencies but little classroom practice and limited preparation, and green chemistry teaching likewise depends on teachers' pedagogical content knowledge (Nahlik et al., 2022). In Indonesia these gaps meet a curriculum that gives schools wide freedom over co-curricular design but little validated guidance, which invites uneven, ad hoc projects. Work on integrated STEM education likewise treats integration as something to be designed deliberately (Kelley & Knowles, 2016; Margot & Kettler, 2019). To our knowledge, no validated design yet treats entrepreneurship as a co-equal discipline that shapes the project brief, the assessment, and the competency pathway of a P5-aligned chemistry project, or has been tried in schools with different resource levels.

This study therefore pursued two aims: (1) to design an interdisciplinary framework that integrates chemistry and entrepreneurship through contextual co-curricular projects aligned with the Merdeka Curriculum, and (2) to examine its expert-rated validity and its preliminary effects on students' critical thinking, creativity, and entrepreneurial self-efficacy. The study contributes a validated and adaptable project structure for chemistry teachers, an argument for treating entrepreneurship as a structuring discipline rather than an add-on, and evidence from three schools of unequal resources, including one semi-rural school with limited laboratory infrastructure.

2. Methods

2.1. Research Design

The study used design and development research, which aims both to produce a usable educational product and to learn which design principles make it work. The ADDIE sequence of analysis, design, development, implementation, and evaluation (Branch, 2009) organised the work into two phases (Figure 1). Phase 1 covered analysis and design and produced the conceptual framework and project architecture. Phase 2 covered development,

implementation, and evaluation: a co-curricular module was built, validated by experts, tried out in a limited implementation, and evaluated. Findings from each stage fed back into earlier ones.

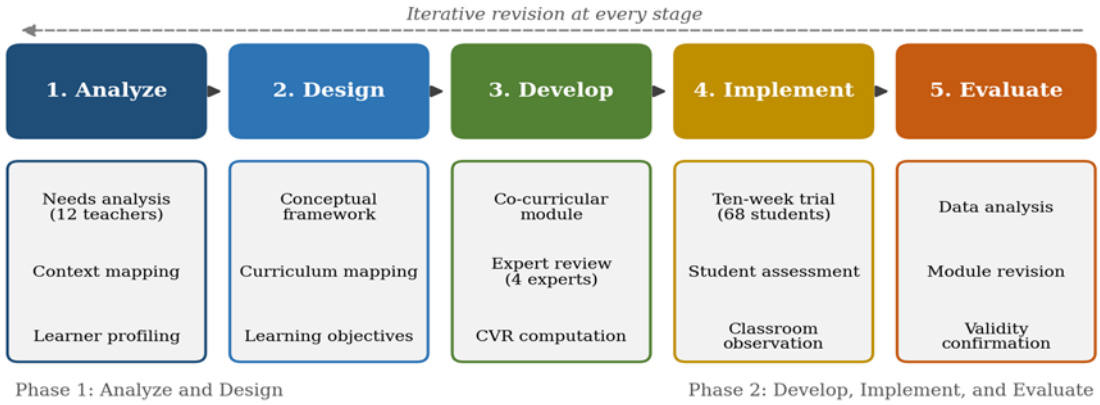


Figure 1. ADDIE-based design and development framework for chemistry–entrepreneurship co-curricular learning

2.2. *Research Setting, Participants, and Sampling*

The research was carried out in Jambi Province, Indonesia. Participants were recruited through purposive sampling so that every stakeholder group was represented (Table 1). The 68 Grade XI science students came from three senior high schools chosen to differ in resources: a high-resource urban school (n = 24), a mid-resource urban school (n = 23), and a semi-rural school with limited laboratory infrastructure (n = 21).

Table 1. Participants by group and role

Group	n	Affiliation	Role in the study	Gender (M/F)
Chemistry teachers	12	3 senior high schools	Needs analysis; facilitation; interviews	4 / 8
Content experts	2	Universitas Jambi	Module validity assessment	2 / 0
Curriculum experts	2	Ministry of Education / university	Framework alignment review	1 / 1
Grade XI students	68	3 senior high schools	Implementation trial	29 / 39
Total	84			

Note. M = male; F = female.

2.3. *The Interdisciplinary Framework*

Four principles guided the framework. Contextual authenticity meant that tasks mirror chemical production processes students can reach in Jambi Province. Bidirectional integration meant that entrepreneurial thinking frames the project brief while chemistry supplies the technical content. Competency coherence meant that objectives, activities, and assessments line up with the six competencies. Curriculum alignment meant that the framework maps onto the thematic and structural requirements of P5. Table 2 shows how the five project phases combine these elements. In the trial, student teams were asked to develop eco-friendly cleaning products from materials abundant locally, namely citrus peel extract and cassava starch.

Table 2. Chemistry content, entrepreneurship themes, and competencies across the five project phases

Phase (weeks)	Chemistry content	Entrepreneurship theme	Main competencies	Assessment
1. Contextual inquiry (1–2)	Twelve principles of green chemistry; atom economy	Market problem identification; consumer needs mapping	Critical thinking; communication	Inquiry journal; group presentation
2. Product design (3–4)	Functional groups; reaction mechanisms; material properties	Product concept; value proposition; material costing	Creativity; collaboration	Design portfolio; peer rubric
3. Prototype development (5–7)	Applied organic chemistry; environmental safety; green synthesis	Prototype fabrication; safety compliance; iterative testing	Collaboration; character	Lab observation checklist; reflective log
4. Market simulation (8–9)	Product quality analysis; safety labelling; environmental impact	Pricing; packaging; sales pitch	Creativity; citizenship	Business plan; self and peer evaluation
5. Reflection and presentation (10)	Cross-cutting principles; sustainability links	Entrepreneurial reflection; scalability analysis	Communication; citizenship; character	Public presentation; holistic rubric

Note. Competencies refer to critical thinking, creativity, collaboration, communication, citizenship, and character.

2.4. Research Instruments

Five instruments were used. A Needs Analysis Questionnaire (24 items, 1–5 scale; Cronbach's α = .87) captured teachers' practices, perceived barriers, and attitudes toward entrepreneurship-linked teaching. A Content Validity Questionnaire (38 items in four domains: content relevance, curricular alignment, pedagogical appropriateness, and assessment quality) was completed by the four experts, who rated each item on Lawshe's three-point scale (1 = essential, 2 = useful but not essential, 3 = not necessary). A Critical Thinking Assessment Rubric adapted from Facione (1990)was used as pre-test and post-test and covered interpretation, analysis, evaluation, inference, explanation, and self-regulation (inter-rater agreement κ = .82). A Creativity Indicator Checklist scored the originality, elaboration, flexibility, and fluency of product designs on a 16-point rubric. An Entrepreneurial Self-Efficacy Scale of 18 items, adapted from McGee et al. (2009) and translated into Indonesian, assessed confidence in opportunity recognition, resource mobilisation, and venture execution.

2.5. Data Collection Procedures

Data collection followed the ADDIE order. The needs analysis came first, then expert validation of the module, then a ten-week implementation in the three schools that followed the five phases in Table 2. Pre-test and post-test data on critical thinking and entrepreneurial self-efficacy were collected at the start and end of the cycle, and creativity was scored from design portfolios at Phase 4. Classroom observations were recorded with a checklist throughout, and teachers were interviewed after the implementation.

2.6. Data Analysis and Trustworthiness

Quantitative data were analysed in SPSS version 26. Means, standard deviations, and frequencies described all scores; paired-samples t-tests assessed pre-test to post-test change in critical thinking and entrepreneurial self-efficacy. Two effect sizes based on Cohen's (1988) d are reported for the paired data because both are used in the literature (Lakens, 2013): $d_z = M_{diff} / SD_{diff}$ (equivalent to $t/\sqrt{n}$), with 95% confidence intervals from the noncentral t distribution, and $d_{av} = M_{diff} / [(SD_{pre} + SD_{post})/2]$, which is closer in scale to the between-group effect sizes reported in meta-analyses. Item-level content validity followed Lawshe (1975): $CVR = (n_e - N/2)/(N/2)$, where n_e is the number of experts rating the item essential and N = 4. With four experts, CVR can only equal −1.00, −0.50, 0.00, 0.50, or 1.00. Critical values for testing CVR (Ayre & Scally, 2014; see also Almanasreh et al., 2019) are not tabulated for panels smaller than five, so CVR could not be tested for significance. Items were therefore retained descriptively when at least three of four experts rated them essential (CVR ≥ 0.50) and revised otherwise. Domain and overall indices are mean item CVRs (very valid ≥ 0.80; valid 0.50–0.79; revise < 0.50). Because mean CVR = 2p − 1, where p is the proportion of "essential" judgements, the overall index was also expressed as that percentage and compared with the 75% benchmark common in Indonesian development research (Sugiyono, 2013). Observation and interview data were analysed through inductive thematic analysis in six phases (Braun & Clarke, 2008). To support trustworthiness (Nowell et al., 2017), a second researcher independently verified the themes, and inter-coder agreement was 88%.

2.7. Ethical Considerations

The Research Ethics Committee of Universitas Jambi approved the study. All participants gave written informed consent; students under 18 gave assent and their parents or guardians gave consent.

3. Results

3.1. Needs Analysis

Of the 12 teachers, 11 (91.7%) taught mainly through teacher-centred lectures, and only two (16.7%) had used project-based learning in the previous year. Ten (83.3%) knew the P5 component, but just three (25%) had designed a P5 project with chemistry content. Nine (75%) agreed that chemistry matters for product development, yet ten (83.3%) had never formally brought entrepreneurship themes into their lessons. They named three barriers: no validated interdisciplinary materials (91.7%), too little professional development in entrepreneurship-linked pedagogy (75%), and timetable pressure (66.7%). Table 3 gives the item-level scores.

Table 3. Teachers' perceptions of chemistry–entrepreneurship integration (n = 12)

Survey item	*M*	*SD*	% agree	Category
Chemistry is relevant to entrepreneurial product development	4.2	0.75	75.0	High
I regularly use project-based approaches in chemistry class	2.1	0.90	16.7	Low
I understand the P5 co-curricular component	3.9	0.83	83.3	High
I have designed a P5 project using chemistry content	2.3	1.03	25.0	Low

Survey item	*M*	*SD*	% agree	Category
Validated interdisciplinary materials are needed (currently absent)	4.6	0.52	91.7	Very high
Professional development in entrepreneurship pedagogy is lacking	4.3	0.65	75.0	High
Time constraints hinder co-curricular chemistry projects	4.1	0.79	66.7	High

Note. Scale from 1 (strongly disagree) to 5 (strongly agree); % agree = agree or strongly agree.

3.2. Expert Validation

Four experts, two in chemistry education and two in curriculum design, rated the 38-item questionnaire. Thirty-five items met the retention criterion (CVR ≥ 0.50), 31 of them with unanimous agreement (CVR = 1.00). Three items, one each in curricular alignment, pedagogical appropriateness, and assessment quality, had CVR = 0.00 (two of four experts) and were revised after expert feedback. Mean CVR was 0.87 overall, highest for content relevance and curricular alignment (0.90) and lowest for assessment quality (0.81; Table 4). Overall, 93.4% of the 152 expert judgements (38 items × 4 experts) rated items essential, above the 75% benchmark. Experts praised how the framework maps the six competencies onto project phases and how closely it follows P5 themes. They asked for stronger formative checkpoints in Phase 3, and the final module added weekly reflective lab journals.

Table 4. Expert validation results by domain (4 experts)

Domain	Items	Mean CVR	Min. CVR	Item CVR = 1.00	Items revised	Category
Content relevance	10	0.90	0.50	8	0	Very valid
Curricular alignment (Merdeka)	10	0.90	0.00	9	1	Very valid
Pedagogical appropriateness (project-based learning)	10	0.85	0.00	8	1	Very valid
Assessment quality (six competencies)	8	0.81	0.00	6	1	Very valid
Overall framework	38	0.87	0.00	31	3	Very valid

Note. CVR = content validity ratio = (ne − N/2)/(N/2), N = 4; possible item values are −1.00, −0.50, 0.00, 0.50, and 1.00. Items with CVR < 0.50 were revised. Very valid = mean CVR ≥ 0.80; valid = 0.50–0.79.

3.3. Student Outcomes

Table 5 summarises the pre-test and post-test results for the 68 students. Critical thinking rose by 22.3 points, from 52.3 to 74.6, a large effect ($t(67) = 18.42$, $p < .001$, $dz = 2.23$, 95% CI [1.79, 2.68]; $dav = 2.81$). The pre-test mean sat in the "below basic" band (< 60) of the rubric, so most students started with little experience of structured critical thinking in chemistry. Entrepreneurial self-efficacy also improved significantly (M gain = 17.5, $t(67) = 13.67$, $p < .001$, $dz = 1.66$, 95% CI [1.29, 2.02]; $dav = 2.01$). Portfolio creativity at Phase 4 averaged 11.8 of 16 (SD = 2.4), or 73.8% of the maximum; scores were highest for elaboration and originality and varied more for flexibility, which reflects the different prior knowledge students brought to the project. Figure 2 shows the same pattern in every school. The semi-rural school started and finished lowest, but its gains (critical thinking +23.1; self-efficacy +17.8) were as large as those in the high-resource school (+21.7; +17.2) and the mid-resource school (+22.1; +17.2).

Table 5. Pre-test and post-test results and paired-samples t-tests (n = 68)

Outcome	Pre *M*	Pre *SD*	Post *M*	Post *SD*	Gain	*t*(67)	d_z [95% CI]	d_z
Critical thinking	52.3	8.7	74.6	7.2	+22.3	18.42*	2.23 [1.79, 268]	2.81
Entrepreneurial self-efficacy	61.4	9.3	78.9	8.1	+17.5	13.67*	1.66 [1.29, 2.02]	2.01
Creativity (portfolio checklist, max. 16)	–	–	11.8	2.4	–	–	–	

Note. **p < .001. dz = Mdiff/SDdiff = t/√n; dav = Mdiff/[(SDpre + SDpost)/2] (Lakens, 2013). Creativity was assessed once, at Phase 4.*

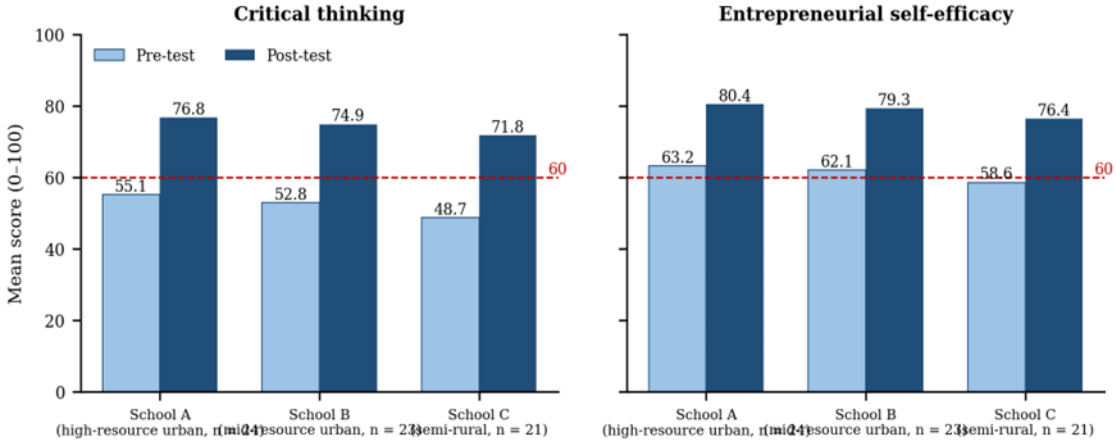


Figure 2. Pre-test and post-test mean scores by school

(dashed line = basic competence threshold of 60)

3.4. Qualitative Findings

Observation notes and teacher interviews yielded four themes. Authentic context as a motivational catalyst. In all three schools, engagement rose when the brief was framed around a local problem, eco-friendly cleaning products from citrus peel and cassava starch. Students began looking up prices, competing products, and labelling rules without being asked; as one teacher at School B put it, "Students were researching ingredient suppliers online before I even asked them to." Bidirectional enrichment. When students found their first surfactant formulation less stable than commercial products, they went looking for explanations in micelle formation and hydrophilic–lipophilic balance, content that was not in the brief. In the other direction, saponification chemistry gave them a principled basis for estimating costs and shelf life. Collaboration under productive tension. Disagreements over product direction and division of labour often led to better design decisions, but two groups, one each in Schools A and C, got stuck in conflict that stalled Phase 3. Uneven teacher confidence. All 12 teachers said the structured framework reduced their uncertainty, yet the seven with lower self-rated entrepreneurship knowledge felt "disciplinary inadequacy" when students' questions moved into business strategy.

4. Discussion

The study set out to design a chemistry–entrepreneurship framework for P5-type projects and to check its validity and early effects. Experts rated the framework as highly valid, and students' critical thinking and entrepreneurial self-efficacy rose markedly over ten weeks. The needs analysis explains why such a framework was wanted: teachers agreed that

chemistry is relevant to product development, but almost none had ever combined the two, and nine in ten named the lack of validated materials as the main obstacle. The framework answers that gap directly. It also moves beyond single-product chemo-entrepreneurship studies, such as the video and ethno-STEM courses reported by Umah and Kamaludin (2024) and Sudarmin et al. (2023), by organising a complete project cycle with assessment attached to each phase.

The critical thinking gain is the result that most needs careful reading. Gains of this size ($_{dz}$ = 2.23, $_{dav}$ = 2.81) are far larger than the benefits usually found for project-based learning in meta-analytic work (C.-H. Chen & Yang, 2019), whose between-group effect sizes are closest in scale to d_{av}. Jusniar et al. (2025) also found higher critical thinking after green chemistry projects, but with a post-test-only control-group design that, unlike the present trial, allows a comparison with students who were not exposed. Several explanations compete. The starting point was low, so there was room to grow. A single group, tested twice by people who knew the intervention, cannot separate the framework from practice effects, novelty, or ordinary development over ten weeks. At the same time, the design may add something real: when students must weigh a product's chemistry, cost, safety, and market at once, they face the kind of multi-criteria judgement that critical thinking frameworks describe (Ennis, 2018; Peter A. Facione, 1990) and that online and science project courses have been shown to promote (Cortázar et al., 2021; A. M. Wibowo et al., 2024). The weekly reflective journals added after expert review resemble the scaffolding that improved critical thinking in chemical inquiry practicals (Van Brederode et al., 2020), although this study cannot isolate their effect. Similar caution applies to self-efficacy: mastery experiences with a real product plausibly strengthen it (Nabi et al., 2017; Newman et al., 2019), but a self-report scale completed after a rewarding project invites optimistic responses.

The qualitative findings support the design logic more convincingly than the scores do. Local feedstocks worked as a motivational hook, in line with accounts of project-based engagement (Almulla, 2020) and of relevance as the missing ingredient in chemistry teaching (Stuckey et al., 2013). The two-way pull between market questions and chemical explanations, seen when students turned to micelle formation after a failed formulation, is the kind of integration that Lackéus et al. (2015) describe when entrepreneurship is used as a way of teaching rather than as a separate subject, and the cost and shelf-life reasoning echoes the sustainability linkages emphasised in green chemistry education (Aubrecht et al., 2019; Zuin et al., 2021). The stalled groups show that collaboration needs scaffolding: productive disagreement is a social process that has to be mediated (Vygotsky, 1978), and the framework should include explicit conflict-resolution routines. The semi-rural school's gains suggest that the design does not depend on well-equipped laboratories, which matters for a policy that is meant to reach all schools. Finally, the teacher findings mirror those of Stašević et al. (2026), who reported limited preparation in entrepreneurial competencies among chemistry teachers, and they point toward teacher preparation through project-based experiences (Domenici, 2022) and attention to pedagogical content knowledge (Nahlik et al., 2022).

For practice, schools can adopt the five-phase structure as a ready-made P5 pathway, and teacher education programmes should add short modules on market reasoning and costing. For curriculum designers, the results suggest that freedom in co-curricular design is

more productive when a validated skeleton is available. The study has clear limits. It used a single-group pre-test/post-test design without a comparison group, so causal claims are not warranted. The sample came from one province, the trial lasted ten weeks, and creativity was measured only once. In addition, the expert panel was small, and the validity statistics should be read with that in mind. With four experts, CVR takes only five possible values per item and cannot be tested for significance, so content validity is reported descriptively. Future work should use matched or randomised comparison groups, test the framework in other provinces, follow students over a longer period, and evaluate teacher development programmes built around the gaps identified here.

5. Conclusion

This study showed that a chemistry–entrepreneurship framework built for the Merdeka Curriculum's co-curricular space can be designed, judged highly valid by experts, and implemented in schools with different resources. In a ten-week trial with 68 Grade XI students, critical thinking and entrepreneurial self-efficacy increased substantially and creativity scores were adequate to good. Its main contribution is a five-phase structure in which entrepreneurship shapes the brief, the assessment, and the competency pathway while chemistry supplies the technical substance. Teachers can use it as a starting point for P5 projects, and teacher educators can use the confidence gap it revealed to plan training. Because there was no control group, the trial had a short duration, and expert validity rests on four raters, the results are preliminary. Controlled studies in more regions and with longer follow-up are the next step. If chemistry projects begin with a real human need and a locally available material, students may learn more of the chemistry because they care about the product.

Declarations

Author Contribution Statement

Ika Kartikasari conceptualized the study, designed the methodology, conducted the investigation, and wrote the manuscript. Rayandra Asyhar supervised the research and validated the findings. Haryanto supervised the research and reviewed the manuscript. All authors have read and approved the final version of the manuscript.

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Data Availability Statement

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

Declaration of Interests Statement

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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References

Almulla, M. A. (2020). The Effectiveness of the Project-Based Learning (PBL) Approach as a Way to Engage Students in Learning. SAGE Open, 10(3). https://doi.org/10.1177/2158244020938702

Almulla, M. A., & Al-Rahmi, W. M. (2023). Integrated Social Cognitive Theory with Learning Input Factors: The Effects of Problem-Solving Skills and Critical Thinking Skills on Learning Performance Sustainability. Sustainability (Switzerland), 15(5). https://doi.org/10.3390/su15053978

Amin, S., Utaya, S., Bachri, S., Sumarmi, & Susilo, S. (2020). Effect of problem-based learning on critical thinking skills and environmental attitude. Journal for the Education of Gifted Young Scientists, 8(2), 743–755. https://doi.org/10.17478/jegys.650344

Asyhar, R., Effendi-Hasibuan, M. H., & Kartikasari, I. (2025). Team-Based Project Design for Environmental Chemistry and Entrepreneurship Learning. International Journal of Research in STEM Education, 7(2), 77–90. https://doi.org/10.33830/ijrse.v7i2.1811

Aubrecht, K. B., Bourgeois, M., Brush, E. J., Mackellar, J., & Wissinger, J. E. (2019). Integrating Green Chemistry in the Curriculum: Building Student Skills in Systems Thinking, Safety, and Sustainability. Journal of Chemical Education, 96(12), 2872–2880. https://doi.org/10.1021/acs.jchemed.9b00354

Bacigalupo, M., Kampylis, P., Punie, Y., & Brande, G. Van Den. (2016). EntreComp : The Entrepreneurship Competence Framework. https://doi.org/10.2791/593884

Branch, R. M. (2009). Instructional Design: The ADDIE Approach. In Springer New York Dordrecht Heidelberg London. Springer New York Dordrecht Heidelberg London. https://doi.org/10.64898/2026.05.05.722881

Braun, V., & Clarke, V. (2008). Using thematic analysis in psychology. 0887(2006).

Chen, C.-H., & Yang, Y.-C. (2019). Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. Educational Research Review, 26, 71–81. https://doi.org/10.1016/j.edurev.2018.11.001

Chen, M., Jeronen, E., & Wang, A. (2020). What lies behind teaching and learning green chemistry to promote sustainability education? A literature review. International Journal of Environmental Research and Public Health, 17(21), 1–24. https://doi.org/10.3390/ijerph17217876

Cooper, M. M., & Stowe, R. L. (2018). Chemistry Education Research—From Personal Empiricism to Evidence, Theory, and Informed Practice. Chemical Reviews, 118(12), 6053–6087. https://doi.org/10.1021/acs.chemrev.8b00020

Cortázar, C., Nussbaum, M., Harcha, J., Alvares, D., López, F., Goñi, J., & Cabezas, V. (2021). Promoting critical thinking in an online, project-based course. Computers in Human Behavior, 119(February). https://doi.org/10.1016/j.chb.2021.106705

Demelash, M., Andargie, D., & Belachew, W. (2024). Enhancing secondary school students' engagement in chemistry through 7E context-based instructional strategy supported with simulation. Pedagogical Research, 9(2), em0189. https://doi.org/10.29333/pr/14146

Domenici, V. (2022). STEAM Project-Based Learning Activities at the Science Museum as an Effective Training for Future Chemistry Teachers. Education Sciences, 12(1). https://doi.org/10.3390/educsci12010030

Ennis, R. H. (2018). Critical Thinking Across the Curriculum: A Vision. Topoi, 37(1), 165–184. https://doi.org/10.1007/s11245-016-9401-4

Huda, A., Purwosetiyono, F. D., Purwanto, P., & Rahmawati, N. (2024). Analisis Kemampuan Numerasi Peserta Didik pada Materi Fungsi Berdasarkan Hasil Asesmen Diagnostik di SMP Negeri 6 Semarang. Jurnal Pendidikan Dan Pembelajaran Indonesia (JPPI). https://doi.org/10.53299/jppi.v4i2.491

Hunaepi, H., & Suharta, I. G. P. (2024). Transforming Education in Indonesia: The Impact and Challenges of the Merdeka Belajar Curriculum. Path of Science, 10(6), 5026–5039. https://doi.org/10.22178/pos.105-31

Jusniar, J., Auliah, A., Syamsidah, S., & Fadly, D. (2025). Improving students' critical thinking abilities and environmental sensitivity through project-based learning integrated with green chemistry

principles. Ecletica Quimica, 50, 1–7. https://doi.org/10.26850/1678-4618.eq.v50.2025.e1597

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. International Journal of STEM Education. https://doi.org/10.1186/s40594-016-0046-z

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. Improving Schools, 19(3), 267–277. https://doi.org/10.1177/1365480216659733

Koulougliotis, D., Antonoglou, L., & Salta, K. (2021). Probing Greek secondary school students' awareness of green chemistry principles infused in context-based projects related to socio-scientific issues. International Journal of Science Education, 43(2), 298–313. https://doi.org/10.1080/09500693.2020.1867327

Lackeus, M. (2015). Entrepreneurship in Education What Why When How. OECD.

Mahaffy, P. G., Matlin, S. A., Whalen, J. M., & Holme, T. A. (2019). Integrating the Molecular Basis of Sustainability into General Chemistry through Systems Thinking. Journal of Chemical Education, 96(12), 2730–2741. https://doi.org/10.1021/acs.jchemed.9b00390

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. International Journal of STEM Education, 6(1). https://doi.org/10.1186/s40594-018-0151-2

Mcgee, J. E., Peterson, M., Mueller, S. L., & Sequeira, J. M. (2009). Entrepreneurial self-efficacy: Refining the measure. Entrepreneurship: Theory and Practice, 33(4), 965–988. https://doi.org/10.1111/j.1540-6520.2009.00304.x

Mitarlis, Azizah, U., & Yonata, B. (2023). Journal of Technology and Science Education The Integration of Green Chemistry Principles. Chemistry Education Practice, 13(1), 233–254.

Mulyasa, E. (2023). Implementasi Kurikulum Merdeka. https://books.google.co.id/books?id=ec_hEAAAQBAJ&printsec=copyright&hl=id#v=onepage&q&f=false

Nabi, G., LiñáN, F., Fayolle, A., Krueger, N., & Walmsley, A. (2017). The impact of entrepreneurship education in higher education: A systematic review and research agenda. Academy of Management Learning and Education, 16(2), 277–299. https://doi.org/10.5465/amle.2015.0026

Nahlik, P., Kempf, L., Giese, J., Kojak, E., & Daubenmire, P. L. (2022). Developing green chemistry educational principles by exploring the pedagogical content knowledge of secondary and pre-secondary school teachers. Chemistry Education Research and Practice, 24(1), 283–298. https://doi.org/10.1039/d2rp00229a

Newman, A., Obschonka, M., Schwarz, S., Cohen, M., & Nielsen, I. (2019). Entrepreneurial self-efficacy: A systematic review of the literature on its theoretical foundations, measurement, antecedents, and outcomes, and an agenda for future research. Journal of Vocational Behavior, 110(October 2017), 403–419. https://doi.org/10.1016/j.jvb.2018.05.012

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. International Journal of Qualitative Methods, 16(1), 1–13. https://doi.org/10.1177/1609406917733847

Pasongli, H., Tonra, W. S., Wahyudi, D., Aswan, M., & Tonra, W. S. (2024). Literacy and technology program to enhance the potential of the youth of Mira village through community empowerment. Transformasi: Jurnal Pengabdian Masyarakat. https://doi.org/10.20414/transformasi.v20i1.8236

Peter A. Facione. (1990). Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction.

Rahayu, P., & Karima, I. S. (2024). Defining key features of smart-dry model: Bibliometric and expert judgement analysis. In A. Wibowo, N. N. B. N. Ghazali, V. Pestova, A. Zainudin, P. Susongko, & Y. Arfiani (Eds.), AIP Conference Proceedings (Vol. 2952, Issue 1). American Institute of Physics. https://doi.org/10.1063/5.0212010

Stašević, F., Dinčev, E., Maksimović, A., & Durdević Nikolić, J. (2026). Secondary school chemistry teachers' attitudes toward developing entrepreneurial competencies in chemistry education. Chemistry Teacher International, 8(1), 193–206. https://doi.org/10.1515/cti-2025-0093

Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of "relevance" in

science education and its implications for the science curriculum. Studies in Science Education, 49(1), 1–34. https://doi.org/10.1080/03057267.2013.802463

Sudarmin et al. (2023). Journal of Technology and Science Education METABOLITE COURSE WITH ETHNO-STEM APPROACH TO IMPROVE STUDENTS ' CONSERVATION AND ENTREPRENEURIAL CHARACTER. Journal of Technology and Science Education, 13(1), 393–409.

Suradika, A., Dewi, H. I., & Nasution, M. I. (2023). Project-Based Learning and Problem-Based Learning Models in Critical and Creative Students. Jurnal Pendidikan IPA Indonesia, 12(1), 153–167. https://doi.org/10.15294/jpii.v12i1.39713

Thornhill-Miller, B., Camarda, A., Mercier, M., Burkhardt, J. M., Morisseau, T., Bourgeois-Bougrine, S., Vinchon, F., El Hayek, S., Augereau-Landais, M., Mourey, F., Feybesse, C., Sundquist, D., & Lubart, T. (2023). Creativity, Critical Thinking, Communication, and Collaboration: Assessment, Certification, and Promotion of 21st Century Skills for the Future of Work and Education. Journal of Intelligence, 11(3). https://doi.org/10.3390/jintelligence11030054

Umah, N., & Kamaludin, A. (2024). Chemo-Entrepreneurship (CEP) Essentials: Practical Videos on Functional Group Material via YouTube. JTK (Jurnal Tadris Kimiya), 9(1), 35–47. https://doi.org/10.15575/jtk.v9i1.33606

Van Brederode, M. E., Zoon, S. A., & Meeter, M. (2020). Examining the effect of lab instructions on students' critical thinking during a chemical inquiry practical. Chemistry Education Research and Practice, 21(4), 1173–1182. https://doi.org/10.1039/d0rp00020e

Vygotsky. (1978). Mind In Socity:The Develompment of Higher Psychological Processes. 17.

Wibowo, A. M., Utaya, S., Wahjoedi, W., Zubaidah, S., Amin, S., & Prasad, R. R. (2024). Critical Thinking and Collaboration Skills on Environmental Awareness in Project-Based Science Learning. Jurnal Pendidikan IPA Indonesia, 13(1), 103–115. https://doi.org/10.15294/jpii.v13i1.48561

Zang, F., Tian, M., Fan, J., & Sun, Y. (2022). Influences of Online Learning Environment on International Students' Intrinsic Motivation and Engagement in the Chinese Learning. Journal of International Students, 12(Special Issue 1), 61–82. https://doi.org/10.32674/jis.v12iS1.4608

Zuin, V. G., Eilks, I., Elschami, M., & Kümmerer, K. (2021). Education in green chemistry and in sustainable chemistry: perspectives towards sustainability. Green Chemistry, 23(4), 1594–1608. https://doi.org/10.1039/d0gc03313h