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Integration of STEM and Local Wisdom: Development of the Herbal STEMpreneur Model to Enhance 21st-Century Skills among Senior High School Students

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ABSTRACT - This study aims to develop and test the effectiveness of the STEMpreneur Herbal Model as a STEM-based learning innovation integrated with local wisdom through the use of herbal plants to improve students' 21st-century skills. Using a mixed-methods approach with an explanatory sequential design, the study involved 32 Grade XI students from SMA Negeri 1 Karas Magetan through six weeks of project-based learning. Quantitative data were collected through critical thinking tests, creativity questionnaires, collaboration, and entrepreneurial literacy, while qualitative data were obtained from observations and interviews. The results showed a significant increase in critical thinking (Cohen's d = 1.21), creativity (+36.7%), collaboration (+25%), and entrepreneurial literacy (+30%), with the first three variables being the main predictors of entrepreneurial literacy. Qualitatively, students showed high engagement, appreciation for local knowledge, and increased motivation to learn. The Herbal STEMpreneur model proved effective in fostering 21st-century competencies, strengthening the Pancasila Student Profile, and contextualising science in real life. Wider implementation is recommended through interdisciplinary teacher training, adaptation of a curriculum based on regional potential, and collaboration with MSMEs and universities to support the sustainability of relevant and character-building STEM education.

Keywords: STEM, local wisdom, entrepreneurship, project-based learning, herbal plants.

INTRODUCTION

Rapid advances in science and technology in the era of the Fourth Industrial Revolution and digital transformation have changed the structure of global life, requiring education systems to adapt quickly. One of the main challenges facing education today is the gap between workplace competencies and the skills mastered by students. According to the World Economic Forum (2023), critical thinking, creativity, collaboration, and technological literacy are among the top ten essential skills for the next generation(Schwab & Zahidi, 2024). Unfortunately, traditional learning approaches that emphasise memorisation and theoretical knowledge often fail to develop these skills. In the Indonesian context, the results of the 2022 Programme for International Student Assessment (PISA) show that only 15% of students are able to solve complex problems(Education at a Glance: OECD Indicators, 2023), indicating an urgent need for pedagogical innovation that emphasises real-world application.

STEM (Science, Technology, Engineering, and Mathematics) based learning has emerged as a strategic solution to bridge this gap. STEM not only integrates these disciplines holistically but also places students as active agents in solving authentic problems through design, experimentation, and reflection processes (Bybee, 2013; Wahono et al., 2020). Research by Hasni et al., (2016) shows that STEM implementation increases students' critical thinking skills by 32% compared to traditional methods, while Margot & Kettler, (2019) emphasise that STEM integration encourages creativity through the exploration of multidimensional solutions. Other studies highlight the importance of contextual STEM learning in increasing student engagement and scientific literacy (Vossen et al., 2018).

However, the effectiveness of STEM greatly depends on its suitability to the local context in order to make abstract concepts concrete and meaningful. Indonesia, as the country with the second largest biodiversity in the world, has great potential in utilising herbal plants as a source of contextual learning. According to Indonesian data (Tri Eko Wahjono et al., 2021), more than 30,000 species of medicinal plants grow throughout the country, such as *Curcuma xanthorrhiza* (temulawak), Zingiber officinale (red ginger), and Andrographis paniculata (sambiloto), which are traditionally used in local medicine. Unfortunately, the younger generation shows limited interest in these local assets due to a lack of curriculum integration and the dominance of a narrative of 'modernisation' that ignores traditional knowledge (Listiyani et al., 2025). However, processing herbal plants into ready-to-consume products such as instant herbal powder offers multidimensional educational opportunities, ranging from understanding phytochemical content (biology), extraction and drying processes (chemistry), to sustainable packaging design (engineering and design).

In this context, local wisdom serves not only as a source of teaching materials but also as a vehicle for preserving the cultural values inherent in community herbal practices. The tradition of herbal medicine, for example, represents a philosophy of balance between the body and nature, which has been passed down from generation to generation through practices of mutual cooperation, natural consumption ethics, and respect for the ecosystem (Andajani et al., 2023; Elfahmi et al., 2014). These values reflect the worldview of Indonesia's agrarian communities, which place health, harmony, and sustainability as integral parts of character education. Thus, the integration of local wisdom into STEM learning not only enriches cognitive aspects but also fosters ecological awareness, social ethics, and cultural identity among students (Zahrawati, 2023). Furthermore, processing herbal plants into ready-to-consume products such as instant herbal powder or functional drinks can represent the synergy between modern science and local traditions. Through this activity, students not only learn about chemical reactions, drying processes, and data analysis, but

Listiyani et al., (2025) found that such projects not only improve scientific literacy but also broaden students' entrepreneurial perspectives. The export market for Indonesian herbal products is estimated to reach USD 2.3 billion by 2025 (Aditama Putra Maulana, 2024). SMA Negeri 1 Karas Magetan, located in an agricultural area with access to herbal farming centres such as the 'Jamu Gendong' tourist village, serves as a strategic location for developing a locally-rooted STEM model. The school has a medicinal plant garden with 15 herbal species and collaborates with local herbal MSMEs, although these resources are currently not being optimally utilised in formal education.

Through the Herbal STEMpreneur project, students are involved in the complete product development cycle: identifying plants based on market needs (mathematics: consumer data analysis), extracting active compounds (chemistry: spectrophotometry), optimising drying techniques using simple solar dryers (engineering: thermodynamics), and designing packaging that complies with halal and BPOM standards (engineering: ergonomic design). This model reflects the principles of context-based learning (Khusyairin et al., 2024) while strengthening students' local identity as guardians of Indonesia's natural wealth.

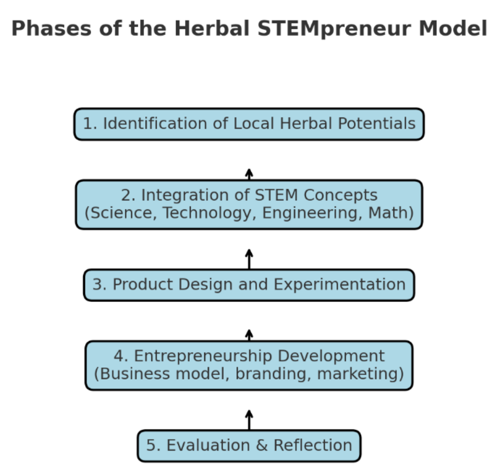

FIGURE 1. Phases of herbal STEMprenuer model.

The integration of STEM and local wisdom is also a concrete implementation of the Merdeka Curriculum, which emphasises: (1) differentiated learning based on student speed, (2) project-based learning to strengthen the Pancasila Student Profile (e.g., critical thinking through analysis of herbal product health claims, creativity in innovation design), and (3) multidimensional literacy (scientific, digital, financial). (Laila et al., 2022) emphasise that this curriculum allows schools to design learning outcomes tailored to regional needs, such as developing herbal products that support the ‘Healthy Village’ programme in Magetan.

The Herbal STEMpreneur model is positioned differently from existing STEM integration because its implementation does not only focus on mastery of science, technology, engineering, and mathematics as in traditional STEM, but is also enriched with local wisdom in the form of utilising herbs as the main object of learning. Unlike STEM-A, which emphasises the arts to foster aesthetic creativity, creativity in Herbal STEMpreneur is directed towards exploring cultural values and developing herbal-based products. Meanwhile, unlike STEM -Entrepreneurship, which is oriented towards creating modern business opportunities, Herbal STEMpreneur is distinguished by the dimensions of cultural preservation and local economic empowerment so that entrepreneurship is not merely understood as a commercial activity, but as a means to connect knowledge, tradition, and product innovation that is contextually valuable for students.

TABLE 1. Existed STEM model differentiation.

Model	Main Focus	Limitations	Distinctive Value of Herbal STEMpreneur
Traditional STEM	Emphasizes problem-solving in science, technology, engineering, and mathematics.	Often abstract and classroom-based, with limited cultural or real-life relevance.	Connects STEM learning to local herbal practices, making it authentic and contextual.
STEM-A (STEM + Arts)	Integrates creativity and design thinking into STEM.	Creative but sometimes detached from students’ socio-cultural environment.	Embeds creativity within local wisdom and cultural heritage (herbal knowledge).
STEM-Entrepreneurship	Focuses on business innovation and market readiness.	Risk of overemphasis on profit, less attention to sustainability or cultural aspects.	Promotes entrepreneurial skills grounded in ecological sustainability and cultural continuity.
Herbal STEMpreneur	Integrates STEM, entrepreneurship, and local wisdom through herbal-based learning.		Creates a balanced model that fosters STEM skills, entrepreneurial readiness, environmental responsibility, and cultural identity.

METHOD

Research Design

This study utilised a mixed-methods approach with an explanatory sequential design, combining quantitative and qualitative data to obtain a comprehensive understanding of the effectiveness of the Herbal STEMpreneur instructional model (Creswell & Plano Clark, 2018). This study was conducted in two main phases: Quantitative Phase: A quasi-experimental design with a single-group pretest-posttest format was used to measure changes in students' critical thinking, creativity, collaboration, and entrepreneurial literacy skills before and after the intervention. Qualitative Phase: An embedded case study was conducted to explore the implementation process, challenges encountered, and classroom dynamics through participatory observation and semi-structured interviews. This design allowed researchers to not only measure the impact of the model empirically but also interpret students' experiences within the framework of the Merdeka Curriculum (Guetterman et al., 2015).

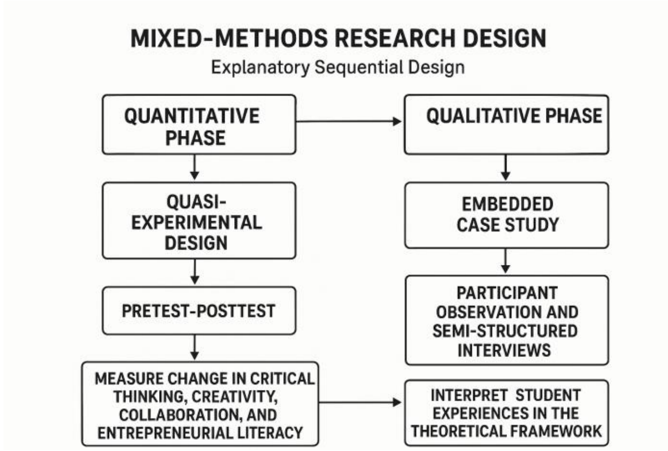

FIGURE 2. Mixed-method research design.

Research Participants

Participants in this study included: Students: 32 Year 11 students at Karas Magetan State Senior High School, selected through purposive sampling based on academic readiness and willingness to participate in the six-week project. Experts: Two food technology lecturers and three culinary education lecturers were involved in instrument validation and student product evaluation. Teachers: Four subject teachers (Biology, Chemistry, Physics, and Mathematics) collaborated in designing and facilitating project-based learning.

TABLE 2. Consider separating participants (teachers, students, experts).

Participant Group	Number	Roles in the Study
Students	32 (11th grade, SMA N 1 Karas)	Carried out the Herbal STEMpreneur project for 6 weeks: experimentation, formulation, packaging design, and marketing.
Teachers	4 (Biology, Chemistry, Physics, Mathematics)	Designed the curriculum, facilitated PBL, and guided cross-disciplinary experiments.
Experts	5 (2 Food Technology, 3 Culinary Education)	Validated research instruments and assessed the quality and innovation of student products.

Data Collection Instruments

Quantitative Instrument: Critical Thinking Test: Adapted from the Watson-Glaser Critical Thinking Appraisal (WGCTA) and tailored to the case of local herbal plants (Facione, 2015). This instrument consists of 20 case-based items with a Cronbach's Alpha reliability of 0.87. Creativity and Collaboration Questionnaire: A 5-point Likert scale developed from the Torrance Tests of Creative Thinking (TTCT) and the Collaborative Learning Rubric (Johnson & Johnson, 2009), with an Aiken's V content validity index ≥ 0.85. Entrepreneurship Literacy Assessment: Developed based on Gujrati & Uygun, (2019) Entrepreneurial Competency Instrument (ECI), in line with the competencies of the Merdeka Curriculum (Ministry of Education, Culture, Research, and Technology Regulation No. 56 on Guidelines for Curriculum Implementation, 2022).

Qualitative Instruments: Observation Sheet: Based on the STEM Integration Rubric to document student activities during the project. Semi-Structured Interview Guide: Designed for students and teachers to explore their perceptions, reflections, and challenges. Product Assessment Rubric: Covers safety (microbial and moisture testing), design innovation, and economic value, validated by SME practitioners and pharmacy lecturers.

The Implementation Phase began with a preliminary test to assess students' baseline knowledge of STEM and entrepreneurial literacy. After that, students participated in project-based learning (PBL) activities conducted in small groups, where they designed and produced instant herbal products. After the intervention is complete, a final test is administered to evaluate changes in students' knowledge and skills. In addition, the final products are evaluated by external experts to assess their quality and innovation. To enrich the qualitative dataset, classroom observations and semi-structured interviews are conducted, providing deeper insights into students' experiences and learning processes.

In the Analysis Phase, quantitative and qualitative data were analysed using established techniques. Quantitative data were analysed using a paired t-test to compare pre-test and post-test scores, and Pearson's correlation coefficient was calculated to explore the relationship between variables. Prior to parametric testing, the normality of data distribution was evaluated using the Shapiro-Wilk test at a significance level of $\alpha = 0.05$. Effect sizes were calculated using Cohen's d to determine the magnitude of observed changes. In addition, multiple regression analysis was used to investigate the extent to which STEM competencies predict entrepreneurial literacy (Field, 2014).

Qualitative data were analysed through thematic analysis (Braun & Clarke, 2006), which involved data reduction, open coding, categorisation, and identification of recurring themes such as 'interdisciplinary integration' and 'student reflections on learning.' To ensure data credibility and reliability, methodological and source triangulation was applied (Patton, 2015). This included cross-verification of findings from interviews, observations, and document analysis.

Validity and reliability were strictly maintained throughout the study. Internal validity was strengthened through data triangulation, integrating diverse data sources, observations, and interviews. Inter-rater reliability for product assessment was calculated using Cohen's Kappa, with a threshold of $\kappa \geq 0.80$ indicating substantial agreement (McHugh, 2012). In addition, member verification was conducted by sharing initial interpretations with participants to ensure the accuracy and authenticity of the findings, thereby increasing confirmability (Lincoln et al., 1985).

RESULTS AND DISCUSSION

This section presents the quantitative and qualitative findings of this study, followed by a discussion interpreting the results in relation to existing literature and educational frameworks. The Herbal STEMpreneur Model was evaluated for its impact on students' 21st-century skills, entrepreneurial literacy, and their engagement in a contextual STEM learning environment.

Quantitative Results

The implementation of the Herbal STEMpreneur Model resulted in significant improvements in various aspects of student competence. Critical thinking skills showed a significant improvement, with the average score rising from 61.3 on the pre-test to 78.6 on the post-test. A paired t-test confirmed the significance of this improvement ($p < 0.05$), and the effect size, calculated using Cohen's d = 1.21, indicated a large practical impact. This substantial improvement supports Margot & Kettler, (2019) argument that STEM-based pedagogy facilitates higher-order thinking through inquiry, problem-solving, and evidence-based reasoning. The structured phases of plant exploration, formulation, and product development required students to analyse data, evaluate alternatives, and justify decisionskey components of critical thinking.

In terms of creativity, students showed a 36.7% increase in creativity-related indicators, including originality, development, and design innovation. The practical nature of herbal product development encouraged students to experiment with formulations, packaging aesthetics, and branding strategies. These findings are in line with Sahin (2007), who emphasises that an integrated STEM environment stimulates creative thinking by allowing learners to explore open-ended problems and build concrete solutions.

Collaboration also increased by 50%, as reflected in peer assessments and observation rubrics. Students engaged in role-sharing, consensus-building, and joint decision-making throughout the project. These results highlight the effectiveness of project-based learning (PBL) in developing teamwork and communication skills. This is in line with Vossen et al., (2018), who found that collaborative STEM tasks not only improve academic performance but also social-emotional competencies essential for real-world collaboration.

This model significantly improved entrepreneurial literacy, including financial planning, market awareness, and product viability by 30%. Regression analysis shows that critical thinking, creativity, and collaboration are significant predictors of entrepreneurial competence, highlighting the synergistic relationship between STEM skills and entrepreneurial mindset. These results are in line with Jiatong et al., (2021), who advocate the integration of creative and collaborative learning approaches in entrepreneurship education to prepare students for an innovation-driven economy.

TABLE 3. Pretest and posttest score.

Competency Domain	Average Pre-Test Score	Average Post-Test Score	Improvement (%)	Effect Description
Critical Thinking	61.3	78.6	+28.2%	Significant ($p < 0.05$), Cohen's d = 1.21 (large effect)
Creativity	56	76.5	+36.7%	Improvement in originality, elaboration, and design innovation
Collaboration	50	75	+50%	Significant (peer assessment & observation rubric)
Entrepreneurial Literacy	60	78	+30%	Significant (predictors: critical thinking, creativity, collaboration)

Qualitative Results

Qualitative data from observations, interviews, and product evaluations provide rich contextual insights into the learning process and outcomes. Participatory observations revealed high levels of student engagement and enthusiasm throughout the six-week intervention. Students were actively involved in every stage, from selecting local medicinal plants to formulating and marketing their products. This sustained engagement reflects the principle of active learning, in which students take responsibility for their learning through authentic tasks (Prince, 2004). The dynamic classroom environment fostered curiosity, perseverance, and intrinsic motivation.

Semi-structured interviews with students, teachers, and external experts highlighted the value of contextualised learning rooted in locality. Participants consistently noted that the use of familiar plants and the fulfilment of community needs made the learning experience more meaningful and relevant. As argued by Brown et al., (1989), learning embedded in real-life contexts enhances understanding and knowledge retention. Students reported a deeper appreciation of local wisdom and traditional knowledge, reinforcing the cultural relevance of science education.

Product assessment by external experts showed that most student groups met basic safety standards, including microbiological limits and water content, demonstrating scientific rigour in product development. Notably, several groups integrated innovative features such as QR codes linked to product information and detailed cost analysis using Estimated Procurement Prices (EPP), reflecting a practical understanding of local entrepreneurship. These features illustrate the core principles of the STEMpreneur model, described by Bybee, (2013) as the integration of STEM practices with entrepreneurial thinking to solve community-based problems.

Discussion

The overall findings indicate that the STEMpreneur Herbal Model effectively promotes various 21st-century competencies through an interdisciplinary and context-sensitive approach.

First, this model significantly improves core 21st-century skills: critical thinking, creativity, collaboration, and entrepreneurial literacy. By integrating scientific inquiry into the product development cycle, students engage in authentic problem-solving that requires systemic thinking, iterative design, and reflective practice. These processes align with Hasni et al., (2016), which emphasises that real-world applications in STEM education deepen conceptual understanding and develop transferable skills.

Second, the success of this locally-based STEM model highlights the importance of cultural and environmental relevance in science education. The use of local herbal resources not only reduces costs and logistical barriers but also strengthens students' connection to their socio-ecological context. This approach supports the statement by Margaret Honey et al., (2014) that contextual STEM learning increases student motivation and promotes interdisciplinary integration between science, technology, and social studies.

Third, the competencies improved through the Herbal STEMpreneur model are strongly aligned with the six dimensions of the Pancasila Student Profile (PPP). First, the ethical and responsible use of herbal plants nurtures faith, devotion to God Almighty, and noble character by fostering ecological stewardship and moral awareness. Second, combining indigenous herbal knowledge with global entrepreneurship perspectives cultivates global diversity appreciation, preparing students for international engagement. Third, the significant gains in collaboration reflect the spirit of gotong royong, as students worked collectively in research, formulation, and product marketing. Fourth, independence is strengthened through entrepreneurial literacy, enabling students to plan finances, manage risks, and exercise self-directed learning. Fifth, the substantial increase in critical reasoning (Cohen's d = 1.21) demonstrates students' capacity to analyse problems and make evidence-based decisions. Finally, the 36.7% improvement in creativity indicators reflects the creative dimension, as students designed innovative, marketable, and culturally rooted herbal products.

To ensure the broader applicability of the Herbal STEMpreneur model, it is essential not only to acknowledge its benefits but also to reflect on the barriers encountered during implementation. Several challenges emerged, ranging from pedagogical to infrastructural constraints. Addressing these issues is critical for sustaining and scaling the model in diverse educational contexts. Table 3 summarises the main challenges identified during the study and proposes possible solutions to support future adoption.

TABLE 4. Challenges and possible solutions in implementing the herbal STEMpreneur model.

Challenge	Description	Possible Solutions
Interdisciplinary teaching	Teachers faced difficulty integrating Biology, Chemistry, Physics, and Mathematics in one coherent project.	Provide targeted professional development, collaborative lesson planning, and co-teaching models.
Herbal preparation complexity	Extraction, drying, and packaging processes required advanced equipment and technical guidance.	Strengthen partnerships with local universities/MSMEs, utilize simplified low-cost technologies, and provide teacher training.
Limited laboratory facilities	Schools lacked tools for microbiological testing and quality assurance.	Collaborate with local labs or vocational schools, and gradually invest in shared lab facilities.
Time management	The six-week period was insufficient to cover all stages of exploration, formulation, and marketing.	Extend project duration or integrate it into multiple subjects/semesters for deeper learning cycles.
Entrepreneurial literacy gaps	Students struggled with financial planning, cost analysis, and market feasibility.	Integrate financial literacy modules, invite practitioners as mentors, and use digital business simulation tools.
Resource disparities between schools	Not all schools have herbal gardens or MSME access like SMA Negeri 1 Karas.	Contextualize projects using locally available resources; encourage cross-school collaboration and community-based partnerships.

CONCLUSION

The STEMpreneur Herbal Model has been proven effective in improving students' 21st-century skillscritical thinking, creativity, collaboration, and entrepreneurial literacy through contextual, interdisciplinary project-based learning rooted in local potential. The integration of herbal plants into STEM learning strengthens cultural relevance, fosters an entrepreneurial spirit, and aligns with the values of the Pancasila Student Profile and the principles of the Merdeka Curriculum.

For wider and more sustainable implementation, it is recommended to: (1) increase teacher capacity through project-based interdisciplinary training, (2) adapt the curriculum to be flexible and based on local potential, (3) strengthen collaboration between schools and universities, MSMEs, and local governments, (4) providing laboratory facilities and contextual learning resources, and (5) replicating and conducting further research in various regions to assess the scalability of the model. Integrating this model into national education policy could be a strategic step towards innovative, character-building, and sustainable STEM education.

REFERENCES

Aditama Putra Maulana. (2024). Meningkatkan Perekonomian Indonesia Melalui Ekspor Obat Herbal Tradisional. *Pemuliaan Keadilan*, *1*(3), 55–67. https://doi.org/10.62383/pk.v1i3.32

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher*, *18*(1), 32–42. https://doi.org/10.3102/0013189X018001032

Bybee, R. W. . (2013). *The case for STEM education : challenges and opportunities*. National Science Teachers Association.

Creswell, J. W. . (2013). *Educational research : planning, conducting, and evaluating quantitative and qualitative research*. PHI Learning Private Limited.

Creswell, J. W. ., & Plano Clark, V. L. . (2018). *Designing and conducting mixed methods research*. SAGE.

Education at a glance : OECD indicators. (2023). Organisation for Economic Co-operation and Development.

Facione, P. (2015). *Critical Thinking: What It Is and Why It Counts*. https://www.researchgate.net/publication/251303244

Field, Andy. (2014). *Discovering statistics using IBM SPSS statistics : and sex and drugs and rock "n" roll*. SAGE.

Guetterman, T. C., Fetters, M. D., & Creswell, J. W. (2015). Integrating Quantitative and Qualitative Results in Health Science Mixed Methods Research Through Joint Displays. *The Annals of Family Medicine*, *13*(6), 554–561. https://doi.org/10.1370/afm.1865

Gujrati, R., & Uygun, H. (2019). Role of Strategic Entrepreneurship to Develop the Enterprises. *SMS Journal of Enterpreneurship & Innovation*, *6*(01), 21–27. https://doi.org/10.21844/smsjei.v6i01.17661

Hasni, A., Bousadra, F., Belletête, V., Benabdallah, A., Nicole, M.-C., & Dumais, N. (2016). Trends in research on project-based science and technology teaching and learning at K–12 levels: a systematic review. *Studies in Science Education*, *52*(2), 199–231. https://doi.org/10.1080/03057267.2016.1226573

Jiatong, W., Murad, M., Bajun, F., Tufail, M. S., Mirza, F., & Rafiq, M. (2021). Impact of Entrepreneurial Education, Mindset, and Creativity on Entrepreneurial Intention: Mediating Role of Entrepreneurial Self-Efficacy. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.724440

Johnson, D. W., & Johnson, R. T. (2009). An Educational Psychology Success Story: Social Interdependence Theory and Cooperative Learning. *Educational Researcher*, *38*(5), 365–379. https://doi.org/10.3102/0013189X09339057

Kepmendikbudristek-No.56-ttg-Pedoman-Penerapan-Kurikulum (2022). https://smatarunagarudabali.com/storage/2024/03/salinan_20220215_093900_Salinan-Kepmendikbudristek-No.56-ttg-Pedoman-Penerapan-Kurikulum.pdf

Khusyairin, K., Sa'ud, U. S., Sururi, S., & Hartini, N. (2024). Integrating local wisdom into learning in school's curriculum: A bibliometric analysis. *Inovasi Kurikulum*, *21*(4), 2155–2172. https://doi.org/10.17509/jik.v21i4.75667

Laila, R. N., Assunniyah, N., Nugroho, N. S. A., Permata Sari, R. G., Suwandi, S., & Setiyoningsih, T. (2022). Implementation of Pancasila Student Profile in the Merdeka Curriculum For High School in Sragen Regency. *Al Hikmah: Journal of Education*, *3*(1), 135–148. https://doi.org/10.54168/ahje.v3i1.111

Lincoln, Y. S., Guba, E. G., & Pilotta, J. J. (1985). Naturalistic inquiry. *International Journal of Intercultural Relations*, *9*(4), 438–439. https://doi.org/10.1016/0147-1767(85)90062-8

Listiyani, L. R., Wilujeng, I., Suyanto, S., & Pratama, D. H. (2025). EthnoSTEM-based Learning Tools: Connecting Cultural Heritage with STEM Education. *Lnternational Electronic Journal of Elementary Education*. https://doi.org/10.26822/iejee.2025.402

Margaret Honey, Greg Pearson, & Heidi Schweingruber. (2014). *STEM Intergration in K-12 education : Status, prosects and an agenda for research*. National Academies Press.

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

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

McHugh, M. L. (2012). Interrater reliability: the kappa statistic. *Biochemia Medica*, 276–282. https://doi.org/10.11613/BM.2012.031

Patton, M. Quinn. (2015). *Qualitative research & evaluation methods : integrating theory and practice*. SAGE Publications, Inc.

Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education*, *93*(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Sahin, A. (2007). *STEM Clubs and Science Fair Competitions: Effects on Post-Secondary Matriculation*.

Schwab, K. , & Zahidi, S. (2024). *Shaping the Future of Learning : The role of AI in Education 4.0 : Insight Report* (K. , Z. S. Schwab, Ed.). https://www3.weforum.org/docs/WEF_Future_of_Jobs_2023.pdf

Tri Eko Wahjono, SP., Ir. Jusniarti, & Dr. Ir. Dono Wahyuno. (2021). *BUKU-SAKU-TANAMAN-OBAT-rev-Red_watermark_compressed*. Pusat Penelitian dan Pengembangan Perkebunan. https://repository.pertanian.go.id/items/f650a6e1-11b7-47c2-80e5-bb405b998832

Vossen, T. E., Henze, I., Rippe, R. C. A., Van Driel, J. H., & De Vries, M. J. (2018). Attitudes of secondary school students towards doing research and design activities. *International Journal of Science Education*, *40*(13), 1629–1652. https://doi.org/10.1080/09500693.2018.1494395
Wahono, B., Lin, P. L., & Chang, C. Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. In *International Journal of STEM Education* (Vol. 7, Issue 1). Springer. https://doi.org/10.1186/s40594-020-00236-1