Development of a regional potential-based teaching factory instructional package integrated with deep learning for basic mechanical engineering in vocational high school

Rizki Samudra As Arif[1,*], Waskito[1], Syahril[1], Gulzhaina K. Kassymova[2,3]

[1] Department of Mechanical Engineering, Faculty of Engineering, Universitas Negeri Padang, **Indonesia**
[2] Abai Kazakh National Pedagogical University, **Kazakhstan**
[3] JSC Institute of Metallurgy and Ore Beneficiation, Satbayev University, **Kazakhstan**

[*]Corresponding author: rizkisamudraasarif@gmail.com
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Abstract: This study developed and evaluated a regional-potential-based Teaching Factory instructional package integrated with Deep Learning principles for Grade X Basic Mechanical Engineering. Using the ADDIE framework, the package comprised a teaching module, student worksheet, and assessment instruments that embedded mindful, meaningful, and joyful learning across orientation, competency preparation, brainstorming, authentic production, and public presentation. Two expert validators rated the package at 89.06%, while three vocational teachers reported a practicality score of 92.22%, both within the very-high category. Classroom implementation with 30 students showed an increase in mean cognitive scores from 69.50 to 87.10, with a statistically significant pre-test–post-test difference and a normalized gain of 0.613, classified as medium. These findings indicate that the developed package is feasible for classroom use and is associated with meaningful within-group improvement in students' cognitive learning outcomes. The study contributes by operationalizing regional-potential-based TEFA and mindful, meaningful, and joyful learning within a structured vocational instructional package. However, because the evaluation involved one intact class without a comparison group, causal claims are not warranted. Future studies should involve multiple schools, comparison groups, longer implementation periods, and broader outcomes, including psychomotor performance, work attitudes, critical thinking, motivation, and work readiness across diverse vocational education settings worldwide.

Keywords: learning approach; mechanical engineering education; regional potential; teaching factory; vocational education

1. Introduction

Vocational education is expected to prepare students for participation in occupational settings by aligning school-based learning with competencies and practices relevant to the world of work (S. Rahmawati et al., 2025; Triyono & Hariyanto, 2024). In manufacturing education, the Teaching Factory (TEFA) paradigm was developed to align teaching and training with modern industrial practice by exposing learners to authentic production environments and industry-relevant processes (Chryssolouris et al., 2016). Studies in Indonesian vocational-school contexts indicate that structured TEFA implementation can support work readiness and contribute to students' knowledge, skills, work attitudes, self-confidence, and occupational preparation (Imran et al., 2024; Rosidah & Sutirman, 2023).

Nevertheless, implementing industry-linked TEFA can be particularly challenging in schools located in low-industrial areas, where opportunities to derive learning activities from nearby industrial production may be limited (Syahril et al., 2024). This problem has encouraged the development of *the Students' Regional Potential-Based Project* (SRPP), in which production tasks are derived from locally available economic, technological, or community potential rather than depending exclusively on external industrial orders. Previous studies developed project-oriented learning materials grounded in regional potential, while the subsequent SRPP-TEFA model extended this idea into a Teaching Factory framework for vocational schools in low-industrial areas (Noptario et al., 2025; Rozan et al., 2024; Syahril et al., 2024). However, that model was still positioned for wider classroom testing rather than being comprehensively evaluated as a complete learning-device package in an authentic vocational classroom.

A second pedagogical development relevant to this challenge is Indonesia's current *Deep Learning* or *Pembelajaran Mendalam* approach. In this study, Deep Learning refers to Indonesia's Pembelajaran Mendalam framework, not machine learning. The framework emphasizes mindful, meaningful, and joyful learning and organizes learning experiences around understanding, application, and reflection (Y. Rahmawati et al., 2025). The national framework emphasizes learning experiences in which students understand concepts, apply them in relevant contexts, and reflect on their learning (Miglani et al., 2026), while the recent theoretical synthesis similarly positions Deep Learning as contextual, learner-centered, and oriented toward deeper understanding rather than content transmission alone (Y. Rahmawati et al., 2025).

The potential compatibility between TEFA and Deep Learning is conceptually strong. TEFA provides authentic production contexts, whereas mindful learning can structure students' attention to safety, quality, and work processes; meaningful learning can connect mechanical-engineering concepts to locally relevant products; and joyful learning can strengthen participation, collaboration, reflection, and product presentation. Recent research has already examined Deep Learning within TEFA at the school level and reported the use of authentic projects, collaboration, reflection, and industry-oriented production. However, that study employed a qualitative design and did not develop or quantitatively evaluate a regional-potential-based instructional package for Basic Mechanical Engineering (Miglani et al., 2026).

Against this literature, the remaining gap is not the integration of TEFA and Deep Learning per se, as such integration has begun to be documented. Rather, limited classroom-based evidence exists on the systematic development and evaluation of a regional-potential-based TEFA instructional package that explicitly operationalizes mindful, meaningful, and joyful learning for Grade X (Basic Mechanical Engineering) Antika et al., 2026; Latifa et al., 2022; Syahril et al., 2024). Accordingly, the novelty of the present study lies in translating this integration into a structured, classroom-ready instructional package for Grade X Basic Mechanical Engineering, extending previous conceptual and qualitative work into a developmental classroom context.

This research gap is particularly relevant to SMK Negeri 1 Batipuh, where a preliminary needs assessment based on classroom observation and teacher consultation indicated continued reliance on printed instructional materials, predominantly concept-oriented instruction, and difficulties in connecting foundational mechanical-engineering concepts with authentic production activities. In response, the present study develops an instructional package comprising a teaching module, a student worksheet (*Lembar Kerja Peserta Didik*; LKPD), and assessment instruments that integrate regional-potential-based TEFA with mindful, meaningful, and joyful learning. Figure 1 illustrates the conceptual relationships among the identified learning problem, the pedagogical foundations, the developed instructional package, and its evaluation.

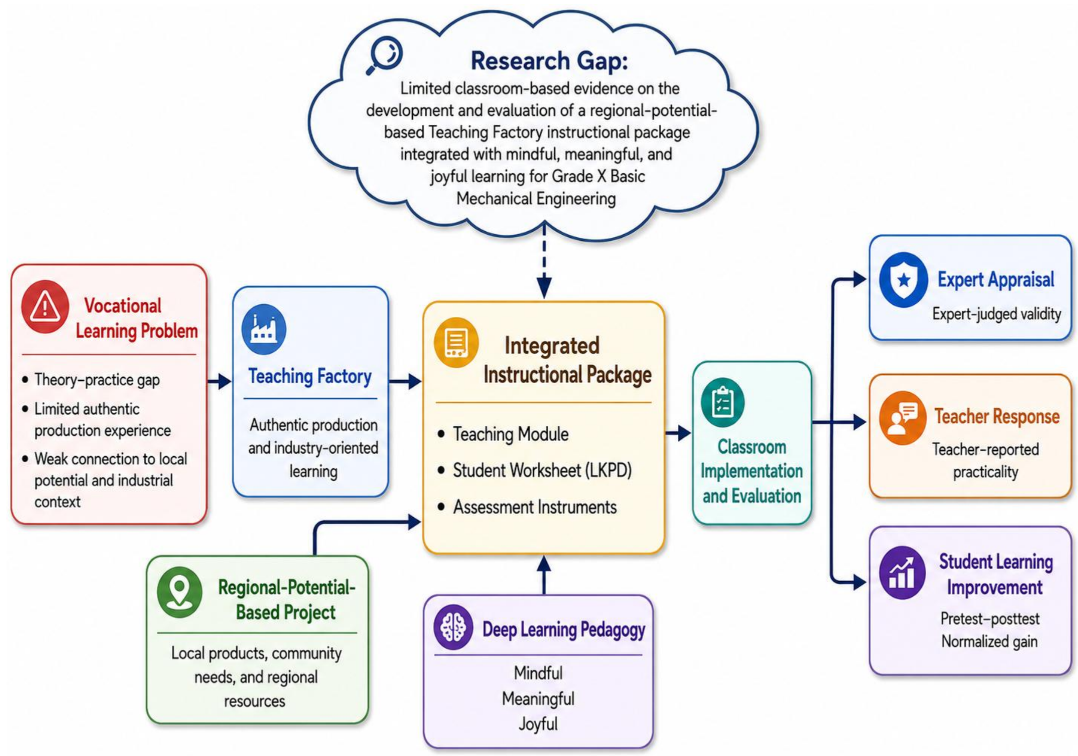

Figure 1. Conceptual framework and research gap

As shown in Figure 1, Teaching Factory provides the authentic production context, regional-potential-based projects connect learning activities to locally relevant products and resources, and Deep Learning provides the pedagogical principles underpinning the instructional process. These components converge in the development of the instructional package, which is subsequently examined through expert appraisal, teacher-reported practicality, and students' learning outcomes. Based on this framework, the study addresses the following research questions:

RQ1. How can regional-potential-based Teaching Factory stages and the principles of mindful, meaningful, and joyful learning be operationalized into an instructional package for Grade X Basic Mechanical Engineering?
RQ2. How do expert validators evaluate the feasibility of the developed instructional package, and how do vocational teachers evaluate its classroom practicality?
RQ3. What changes in students' cognitive learning outcomes are observed after implementation of the developed instructional package, as indicated by pre-test–post-test differences and normalized gain?

The study makes three interconnected contributions. Conceptually, it explicitly maps regional-potential-based TEFA stages onto mindful, meaningful, and joyful learning principles. Methodologically, it shows how this mapping can be translated into an integrated teaching module, student worksheet, and assessment instruments, and evaluated in an authentic vocational-classroom setting. Empirically, it provides pilot evidence regarding expert appraisal, teacher-reported practicality, and within-group changes in students' cognitive learning outcomes. Given the one-group pre-test–post-test design, these findings are interpreted as preliminary evidence of learning improvement rather than as definitive evidence that the instructional package alone caused the observed changes.

2. Methods

2.1 Research design and procedure

This study employed a developmental Research and Development (R&D) design structured by the ADDIE framework, comprising *Analyze, Design, Develop, Implement,* and *Evaluate*. ADDIE provides a systematic instructional-design process in which learning needs are identified, instructional strategies and resources are designed and developed, the resulting product is implemented, and evidence is used to evaluate and refine the instructional solution (Branch, 2009). In this study, a preliminary needs assessment informed the development process, while quantitative evidence from expert ratings, teacher responses, and pre-test–post-test scores was used to evaluate the resulting instructional package.

During the *Analyze* stage, classroom observations and teacher consultation were conducted to identify gaps between existing instruction and the competencies expected from production-oriented learning. The *Design* stage focused on mapping regional-potential-based Teaching Factory activities onto the mindful, meaningful, and joyful principles of Deep Learning and specifying the structure of the teaching module, LKPD, and assessment instruments. During the *Develop* stage, the instructional package was produced, reviewed by expert validators, and revised based on their feedback. The revised package was subsequently implemented in the target classroom during the *Implement* stage. Finally, the *Evaluate* stage examined teacher-reported practicality and students' learning outcomes and informed further refinement of the instructional package. Figure 2 presents the overall development sequence.

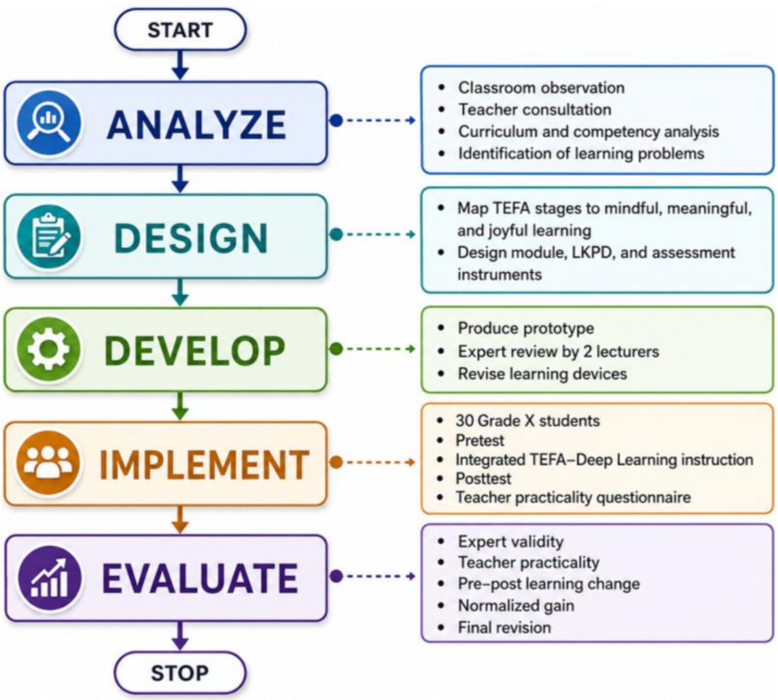

Figure 2. ADDIE-based development and evaluation procedure

2.2 Setting and participants

The study was conducted at SMK Negeri 1 Batipuh, Tanah Datar Regency, West Sumatra, Indonesia, from April to June 2026. The classroom trial involved one intact Grade X.2 class comprising 30 students from the Machining Engineering program who were studying Basic

Mechanical Engineering during the research period. The class served as the implementation group rather than a probability sample; therefore, the findings are interpreted within the study context.

The study also involved two Mechanical Engineering Education lecturers as expert validators and three machining teachers as practitioner respondents. Two Mechanical Engineering Education lecturers served as expert validators, while three machining teachers served as practitioner respondents. Selection was based on their disciplinary and instructional relevance to mechanical-engineering education and the learning content evaluated in this study (Palinkas et al., 2015). The student group was an intact instructional class rather than a probability sample; consequently, the findings should be interpreted as evidence from the study context rather than as statistically representative of all vocational-school students.

Table 1. Study setting and participant profile

Aspect	Description
Location	SMK Negeri 1 Batipuh, Tanah Datar Regency, West Sumatra
Level	Grade X (Phase E), Machining Engineering
Subject	Basic Mechanical Engineering
Learning element	Manufacturing production process (introductory welding)
Student participants	30 students, Grade X.2
Expert validators	2 Mechanical Engineering Education lecturers
Practitioner respondents	3 machining teachers
Classroom design	R&D using ADDIE with one-group pre-test–post-test evaluation

2.3 Development of the instructional package

Three primary instructional packages were developed: (1) a teaching module, (2) an LKPD, and (3) assessment instruments. Their instructional organization combined the stages of regional-potential-based TEFA with the three principles of Deep Learning. The underlying TEFA model was informed by the regional-potential approach developed for vocational schools in areas where industrial partnerships may be limited. The existing SRPP-TEFA literature emphasizes project tasks based on regional resources and authentic production, while the Deep Learning framework emphasizes conscious engagement, contextual meaning, application, and reflection (S. Rahmawati et al., 2025; Syahril et al., 2024). Table 2 summarises the operational integration used in the developed devices.

Table 2. Integration of teaching factory stages and deep learning principles

Teaching factory stage	Deep learning emphasis	Operational learning activity
Orientation	Meaningful	Connecting welding competencies with locally relevant products and community applications
Competency briefing	Mindful	Guided demonstrations with explicit safety, quality, and process checkpoints
Brainstorming	Meaningful	Designing a locally relevant product, preparing sketches, and planning production procedures
Authentic production	Mindful and Joyful	Performing welding tasks, monitoring process quality, and conducting peer/self-checks
Public presentation	Joyful and Reflective	Presenting the finished product, receiving feedback, and reflecting on the production and learning process

2.4 Instruments and data collection

Four sources of evidence were used. First, an expert-validation form evaluated the lea instructional package in terms of content relevance, presentation, language, and graphics (Waskito et al., 2024). The two expert validators independently reviewed the prototype and provided quantitative scores and revision comments. Second, a five-point Likert teacher-response questionnaire was administered to three machining teachers after implementation to evaluate the instructional package's practicality for classroom use (Claveria, 2021). Third, Students completed a cognitive pre-test and post-test developed to represent the intended learning outcomes across the revised cognitive taxonomy. The test specification, number of items, scoring procedure, expert-review process, and evidence of item quality are reported to enable assessment of measurement adequacy (Anderson & Krathwohl, 2001). Subject experts reviewed the test for alignment among items, content, and intended learning outcomes. Fourth, classroom documentation was used to record implementation of the Teaching Factory stages and associated learning activities. Performance rubrics and work-attitude observation sheets formed part of the developed package; however, because the present results focus on cognitive learning outcomes, these measures are not treated as primary effectiveness outcomes in this article. Table 3 aligns each research question with its principal evidence and analysis.

Table 3. Alignment of research questions, evidence, and analysis

Research question	Primary evidence	Analysis
RQ1: Development and operationalization	Needs analysis, curriculum analysis, developed module/LKPD, integration matrix	Descriptive development analysis
RQ2: Validity and practicality	Expert-validation forms; teacher-response questionnaires	Percentage of maximum obtainable score and descriptive interpretation
RQ3: Student learning change	Pre-test and post-test scores from 30 students	Descriptive statistics, Shapiro–Wilk test, paired-samples t-test, normalized gain

2.5 Data analysis

Expert-validation and teacher-practicality ratings were summarized descriptively and converted into percentages of the maximum obtainable score. The percentage score was calculated to determine the level of agreement among experts and practitioners regarding the quality and practicality of the developed product. The calculation procedure is expressed in Equation (1).

$$P = (S_o/S_{max}) \times 100 \qquad (1)$$

where P is the percentage score, S_o is the obtained score, and S_{max} is the maximum possible score. Because these percentages represent descriptive expert and practitioner judgments, they were interpreted as appraisal categories rather than as psychometric estimates of construct validity. For descriptive interpretation, the study applied the following pre-specified categories: 81–100% = very high, 61–80% = high, 41–60% = moderate, 21–40% = low, and 0–20% = very low.

Student learning outcomes were analyzed descriptively using means and standard deviations. To examine changes in individual student performance following the intervention, a paired difference score was calculated for each participant by subtracting the pre-test score from the post-test score. The calculation of the paired difference score is presented in Equation (2).

$$D_i = Post_i - Pre_i \quad (2)$$

Before conducting inferential statistical analysis, the distribution of paired difference scores was examined using the Shapiro–Wilk test and inspection of extreme outliers to assess the assumptions required for parametric testing. Subsequently, a two-tailed paired-samples *t*-test was performed at an alpha level of 0.05 to determine whether the mean difference score significantly differed from zero (Shapiro & Wilk, 1965).

In addition to statistical significance testing, the magnitude of within-group improvement was evaluated using an effect size analysis. Cohen's d^z was calculated to estimate the standardized magnitude of change and was reported together with the mean difference and its 95% confidence interval. The calculation of Cohen's d^z is presented in Equation (3) (Lakens, 2013).

$$d^z = t / \sqrt{n} \quad (3)$$

where t represents the test statistic from the paired-samples *t*-test and n represents the number of participants. The resulting effect size value provides additional information regarding the practical magnitude of the observed improvement beyond statistical significance.

Normalized gain analysis was conducted as a supplementary descriptive measure to estimate the proportion of possible learning improvement achieved by students. Unlike inferential testing, normalized gain was used to describe the magnitude of improvement relative to the maximum possible gain. The calculation procedure applied in this study was based on individual student scores. Individual normalized gain was calculated first and subsequently averaged across participants using Equations (4) and (5).

The individual normalized gain calculation is presented in Equation (4).

$$g_i = \frac{Post_i - Pre_i}{X_{max} - Pre_i} \quad (4)$$

where g_i represents the normalized gain score for each student, $Post_i$ represents the post-test score, and Pre_i represents the pre-test score.

The mean normalized gain was then calculated by averaging individual normalized gain scores across all students, as shown in Equation (5).

$$\bar{g} = \frac{1}{n} \sum_{i-1}^{n} g_i \quad (5)$$

where $\bar{g}$ represents the average normalized gain, $\sum_{i-1}^{n} g_i$ represents the total individual normalized gain scores, and n represents the number of students. This approach was applied to ensure that the analysis reflected individual variations in learning improvement rather than relying solely on aggregated class-level scores.

If normalized gain is instead calculated directly from the class mean pre-test and post-test scores, Hake's class-average normalized gain formulation should be applied as presented in Equation (6) (Hake, 1998).

$$\langle g \rangle = \frac{\overline{Post} - \overline{Pre}}{X_{max} - Pre_i} \quad (6)$$

The normalized gain values were interpreted according to Hake's conventional classification, where values greater than 0.70 indicate high gain, values between 0.30 and 0.70 indicate medium gain, and values below 0.30 indicate low gain. The term "medium gain" was used to describe the magnitude of improvement rather than to indicate causal effectiveness, as normalized gain represents the extent of achieved improvement relative to the possible improvement. The interpretation categories are summarized in Table 4.

Table 4. Interpretation of normalized gain

Normalized gain	Interpretation
$g > 0.70$	High gain
$0.30 \leq g \leq 0.70$	Medium gain
$g < 0.30$	Low gain

Because the classroom evaluation involved one intact class without a comparison group, statistically significant pre-test–post-test differences were interpreted as evidence of within-group change during the instructional period rather than as definitive evidence that the instructional package alone caused the observed improvement. History, maturation, repeated testing, and other uncontrolled factors remain plausible alternative explanations in a one-group pre-test–post-test design (Knapp, 2016).

3. Results and discussion

3.1 Development and operationalization of the instructional package

The preliminary needs assessment indicated a mismatch between the existing delivery of Basic Mechanical Engineering and the production-oriented learning experiences expected in vocational education. Classroom observation and teacher consultation indicated continued reliance on printed instructional materials and predominantly concept-oriented activities, while opportunities for students to connect foundational concepts with authentic production tasks remained limited. These findings informed the development of an instructional package integrating regional-potential-based Teaching Factory activities with the mindful, meaningful, and joyful principles of Deep Learning.

The final instructional package comprised three interconnected components: a teaching module, a student worksheet, and assessment instruments. Rather than treating Deep Learning as an additional activity, the instructional sequence established during the Design stage embedded its principles. The resulting package therefore operationalized the conceptual integration presented previously in Table 2.

The teaching module structured instruction around five stages: orientation, competency briefing, brainstorming, authentic production, and public presentation. Orientation connected introductory welding competencies with products and needs relevant to the local context. Competency briefing provided guided demonstrations and explicit checkpoints for occupational safety, work procedures, and product quality. During brainstorming, students prepared product sketches and production plans. Authentic production required students to perform the planned welding task while monitoring safety and quality, whereas public presentation provided opportunities to present the completed product, receive feedback, and reflect on the learning and production process.

The LKPD served as an operational guide across these stages. It included product-design sheets, planning activities, occupational safety checklists, SMAW procedure sheets, self-evaluation activities, and peer-feedback forms. The assessment component included cognitive pre-test–post-test instruments and supporting performance and work-attitude rubrics. The latter two formed part of the instructional package but were not treated as primary effectiveness outcomes in the present analysis, consistent with the scope specified in the methodology. Table 5 summarises the role of each component.

Table 5. Components and functions of the developed instructional package

Component	Main Content	Function in the integrated learning process
Teaching module	Learning outcomes, instructional sequence, welding content, learning activities, reflection, and assessment guidance	Structures the five regional-potential-based TEFA stages and embeds mindful, meaningful, and joyful learning
Student worksheet (LKPD)	Product sketches, production planning, safety checklist, SMAW procedures, self-evaluation, and peer feedback	Guides students through planning, production, monitoring, and reflection
Assessment instruments	Cognitive pre-test–post-test, performance rubric, and work-attitude observation sheet	Supports assessment of learning outcomes and production-related performance

As shown in Table 5, the developed product was not limited to a teaching module; the three components were designed to function as a single instructional package. This operational structure addresses RQ1 by demonstrating how regional-potential-based TEFA and Deep Learning principles were translated into classroom-ready instructional materials.

3.2 Expert appraisal and teacher-reported practicality

To address RQ2, two Mechanical Engineering Education lecturers first reviewed the developed instructional package. Expert appraisal covered four dimensions: content, presentation, language, and graphical design. Table 6 presents the results.

Table 6. Expert appraisal of the instructional package

Dimension	Validator 1 (%)	Validator 2 (%)	Mean (%)	Interpretation
Content	81.25	93.75	87.5	Very high
Presentation	93.75	100	96.88	Very high
Language	81.25	81.25	81.25	Very high
Graphical design	87.5	93.75	90.63	Very high
Overall	85.94	92.19	89.06	Very high

The overall expert-appraisal score was 89.06%, placing the package in the predefined very-high category. Presentation received the highest mean appraisal (96.88%), followed by graphical design

(90.63%), content (87.50%), and language (81.25%). The language dimension therefore had the lowest rating, although it remained within the predefined very-high category. Expert comments primarily resulted in minor revisions to ensure consistent terminology and clear visual labelling before classroom implementation. After implementation, three machining teachers evaluated the package's classroom practicality. Their overall mean response was 92.22%, also corresponding to the very-high category. In addition to the numerical rating, teacher responses indicated that the module's systematic organization facilitated implementation and that the specified instructional sequence and time allocation were manageable in the classroom. Table 7 provides a concise summary.

Table 7. Summary of teacher-reported practicality

Source	n	Overall Score	Interpretation	Main implementation feedback
Machining teachers	3	92.22%	Very high	Systematic instructional sequence; limited need for additional procedural guidance; manageable time allocation

Taken together, the expert and practitioner findings indicate strong initial feasibility and classroom usability of the developed package. However, these results represent expert and teacher judgments within the present study context rather than psychometric evidence of generalizable validity or usability.

3.3 Changes in students' cognitive learning outcomes

RQ3 examined changes in students' cognitive learning outcomes following classroom implementation. Table 8 presents descriptive statistics for the 30 students.

Table 8. Descriptive pre-test and post-test outcomes

Indicator	Pre-test	Post-test	Change
Number of students	30	30	—
Mean score	69.5	87.1	17.6
Standard deviation	8.65	7.74	−0.91
Minimum score	55	75	20
Maximum score	84	100	16
Students meeting mastery criterion	7 (23.3%)	26 (86.7%)	+63.4 percentage points

As shown in Table 8, the mean score increased from 69.50 at pre-test to 87.10 at post-test, corresponding to an average increase of 17.60 points. The minimum score increased from 55 to 75, while the maximum score increased from 84 to 100. The standard deviation decreased slightly from 8.65 to 7.74. The proportion of students meeting the established mastery criterion also increased substantially. At pre-test, 7 of 30 students (23.3%) met the criterion, whereas at post-test, 26 students (86.7%) achieved mastery. The Shapiro–Wilk analysis indicated that both the pre-test scores ($W = 0.954$, $p = 0.210$) and post-test scores ($W = 0.944$, $p = 0.117$) did not significantly deviate from normality. A paired-samples t-test was subsequently used to examine the difference between pre-test and post-test performance. The results are summarised in Table 9.

Table 9. Paired-samples t-test and normalized-gain results

Statistical indicator	Result
Number of students	30
Mean pre-test score	69.5
Mean post-test score	87.1
Mean difference	17.6
t-value	−27.860
Degrees of freedom	29
Sig. (2-tailed)	< .001
Mean N-Gain	0.613 (61.33%)
N-Gain interpretation	Medium gain

The paired-samples t-test showed a statistically significant difference between students' pre-test and post-test scores, $t\ (29) = -27.860$, $p < .001$. The average normalized gain was 0.613, equivalent to 61.33%, which falls within the medium-gain category according to the interpretation criteria established in the methodology. Taken together, the descriptive statistics, mastery achievement, paired-samples comparison, and normalized-gain results indicate a clear within-group improvement in students' cognitive learning outcomes during the instructional period. These findings address RQ3 by demonstrating measurable changes in cognitive performance following implementation of the developed instructional package.

4. Discussion

4.1 Operationalizing regional potential-based TEFA and deep learning

The developed instructional package demonstrates how regional-potential-based Teaching Factory and Deep Learning can be operationalized as complementary rather than parallel pedagogical components. In this integration, TEFA provides an authentic, production-oriented structure; regional potential supplies locally relevant problems and product contexts; and Deep Learning provides the pedagogical principles through which students engage with these activities. Accordingly, mindful, meaningful, and joyful learning was embedded within planning, competency preparation, production, quality monitoring, presentation, and reflection rather than being introduced as additional activities detached from the Teaching Factory sequence.

This operationalization extends previous developments in vocational learning. The Teaching Factory paradigm was originally intended to narrow the distance between educational environments and contemporary industrial practice through authentic production-related learning. Regional-potential approaches subsequently broadened this logic by allowing projects to be derived from locally available resources and needs, which is particularly relevant for schools with limited access to industrial partners. Previous studies have demonstrated that students' regional potential can be incorporated into project-oriented learning materials and subsequently extended into the SRPP-TEFA model for vocational schools in low-industrial areas, with the latter recommended for broader implementation following model development and validation (Latifa et al., 2022; Syahril et al., 2024).

The present study advances this line of work by translating these principles into a classroom-ready package comprising a teaching module, LKPD, and assessment instruments for Grade X Basic Mechanical Engineering. This contribution should not be interpreted as the first integration of TEFA and Deep Learning, because such integration has already been documented qualitatively. Rather, the present study extends previous work by explicitly embedding mindful, meaningful, and joyful principles within a regional-potential-based TEFA sequence and evaluating the resulting instructional package through developmental and classroom-based evidence. This positioning is consistent with recent research showing that TEFA–Deep Learning integration can involve authentic problem solving, contextual learning, collaboration, reflection, and production aligned with occupational contexts, while the broader Deep Learning framework emphasizes mindful, meaningful, and joyful learning through understanding, application, and reflection (Antika et al., 2026; Y. Rahmawati et al., 2025; Syahril et al., 2024).

4.2 Expert appraisal and teacher-reported practicality

The instructional package received an overall expert-appraisal score of 89.06%, with all four assessed dimensions falling within the predefined very-high category. Presentation received the highest score (96.88%), followed by graphical design (90.63%), content (87.50%), and language (81.25%). The comparatively lower language score is particularly informative because it identifies a specific area in which refinement remained necessary despite the favourable overall appraisal. Consequently, revisions concerning terminology consistency and visual labelling were incorporated before classroom implementation. The expert-appraisal findings therefore served not merely as evidence of product feasibility but also as part of the iterative refinement process characteristic of developmental instructional design.

These findings extend previous SRPP-TEFA development from model-level validation to the appraisal of instructional materials intended for direct classroom use. A similar development process involving needs analysis, model development, expert validation, pilot implementation, and evaluation was used to develop SRPP-TEFA for low-industrial areas (Syahril et al., 2024). More broadly, iterative refinement of instructional resources matters because the educational value of Teaching Factory depends not only on providing production activities but also on how clearly industrial processes, learning responsibilities, and authentic tasks are translated into the instructional environment (Chryssolouris et al., 2016; Syahril et al., 2024).

Teacher responses provide a complementary perspective on classroom usability. The three participating teachers reported an overall practicality score of 92.22% and perceived the instructional sequence as systematic, sufficiently explicit, and manageable within the available instructional time. These responses suggest that integrating regional-potential-based TEFA and Deep Learning did not result in an instructional structure that teachers considered excessively complex to implement. Nevertheless, because the evaluation involved only three teachers, the score should be interpreted as positive practitioner evidence within the present school context rather than as evidence of universal practicality.

The favourable practitioner responses align with the broader rationale of Teaching Factory, in which clearly organized, production-oriented learning is intended to make the relationship between school activities and occupational practice more explicit. Previous Indonesian studies have reported that TEFA environments can contribute to students' knowledge, practical skills, attitudes, confidence, occupational preparation, and work readiness. At the same time, recent TEFA–Deep Learning research also highlights authentic projects, contextual problem solving, collaboration, and reflection as important features of vocational learning. Although these studies assessed outcomes different from teacher-reported practicality, they support the pedagogical value of providing structured, authentic vocational-learning experiences (Antika et al., 2026; Imran et al., 2024; Rosidah & Sutirman, 2023).

4.3 Within-Group Improvement in Cognitive Learning Outcomes

Student performance showed a clear descriptive improvement during the instructional period. The mean cognitive score increased from 69.50 at pre-test to 87.10 at post-test, representing an increase of 17.60 points. The proportion of students meeting the mastery criterion also increased from 23.3% to 86.7%, while the reported normalized gain of 0.613 was classified as a medium gain. The paired-samples analysis further indicated a statistically significant difference between pre-test and post-test performance. Taken together, these indicators provide convergent evidence of within-group cognitive improvement following implementation of the instructional package.

A plausible pedagogical explanation is that the instructional sequence created repeated opportunities for students to connect abstract mechanical-engineering concepts with concrete production decisions. Meaningful learning was supported by situating welding activities within locally relevant products and applications; mindful learning was operationalized through explicit attention to procedures, safety, quality standards, and self-monitoring; and joyful learning was supported through collaborative production, presentation, feedback, and reflection. This interpretation aligns with the Deep Learning framework, which positions mindful, meaningful, and joyful learning as mutually reinforcing principles and emphasizes learning experiences through understanding, application, and reflection. It is also compatible with TEFA's broader emphasis on authentic industrial problems and production-oriented learning environments (Antika et al., 2026; Chryssolouris et al., 2016; Y. Rahmawati et al., 2025; Syahril et al., 2024).

The observed learning pattern is also broadly consistent with previous vocational-learning research, although the numerical outcomes should not be compared directly because the studies differ in design, participants, interventions, and dependent variables. Regional-potential-based project learning has been used to connect instructional content with locally relevant contexts, while TEFA research has reported favourable outcomes related to knowledge, skills, attitudes, confidence, workplace alignment, and occupational preparation. These findings support the broader proposition that authentic and contextualized vocational activities can provide productive conditions for learning, but they do not constitute direct evidence for the specific cognitive change identified in the present study (Imran et al., 2024; Latifa et al., 2022; Rosidah & Sutirman, 2023; Syahril et al., 2024).

Importantly, the significant pre-test–post-test difference should not be interpreted as demonstrating that the instructional package alone caused the improvement. The study employed one intact class without a comparison group; therefore, maturation, testing effects, history, and other uncontrolled influences cannot be excluded. The findings are consequently better interpreted as evidence of within-group improvement associated with the instructional period, rather than as a causal estimate of instructional effectiveness. This cautious interpretation is consistent with established methodological criticism of the one-group pre-test–post-test design and also aligns with the scope of the research question, which asks what changes were observed rather than whether the intervention caused those changes (Knapp, 2016).

4.4 Contributions, Limitations, and Implications

Taken together, the findings contribute at three interconnected levels. Conceptually, the study provides an explicit operational mapping between regional-potential-based TEFA and mindful, meaningful, and joyful learning. Methodologically, it translates this mapping into an integrated teaching module, LKPD, and assessment instruments rather than leaving the integration at the level of a conceptual model. Empirically, it provides classroom-based evidence concerning expert appraisal, teacher-reported practicality, and within-group cognitive learning change. In this respect, the study extends previous regional-potential and TEFA–Deep Learning research by examining the integration as a complete instructional package within Grade X Basic Mechanical Engineering rather than as a textbook, conceptual model, or qualitative implementation alone (Antika et al., 2026; Latifa et al., 2022; Syahril et al., 2024).

These contributions should nevertheless be interpreted within the boundaries of the study design. The classroom evaluation involved one intact class from one vocational school, which limits the extent to which the findings can be transferred to different institutions, programs, and student populations. The practicality assessment involved only three teachers, so the favourable practitioner rating reflects evidence from the immediate implementation context rather than a population-level estimate. Most importantly, the absence of a comparison group limits causal inference regarding the observed pre-test–post-test improvement (Knapp, 2016).

The scope of the outcome assessment also needs to be distinguished from the broader aims of vocational education. Although performance rubrics and work-attitude observation sheets formed part of the developed instructional package, the present analysis focused on cognitive learning outcomes. Consequently, the findings do not establish improvements in welding performance, work attitudes, critical thinking, motivation, or work readiness. This distinction is particularly relevant because previous TEFA studies have examined several of these broader occupational outcomes; extending the present evaluation to such dimensions would therefore enable a more comprehensive assessment of whether the instructional package supports both cognitive learning and vocational competence (Imran et al., 2024; Rosidah & Sutirman, 2023).

Future research should therefore examine the instructional package across multiple vocational schools and, where feasible, incorporate an appropriate comparison condition. Longer implementation periods would also help determine whether the observed learning changes are sustained over time. Further studies could extend the outcome framework to psychomotor welding performance, occupational attitudes, critical thinking, motivation, and work readiness using appropriate validated measures. Such investigations would provide stronger evidence concerning the transferability, instructional effectiveness, and broader vocational relevance of integrating regional-potential-based TEFA with Deep Learning.

5. Conclusion

This study developed and evaluated a regional-potential-based Teaching Factory instructional package integrated with the mindful, meaningful, and joyful principles of Deep Learning for Grade X Basic Mechanical Engineering. The package comprised a teaching module, student worksheet (LKPD), and assessment instruments organized around orientation, competency preparation, brainstorming, authentic production, and public presentation. The package received an overall expert-appraisal score of 89.06% and a teacher-reported practicality score of 92.22%, both classified as very high. During classroom implementation, students' mean cognitive score increased from 69.50 to 87.10, with a statistically significant pre-test–post-test difference ($p < .001$) and a normalized gain of 0.613, representing a medium gain. These findings indicate that the developed instructional package is feasible for classroom implementation and was accompanied by meaningful within-group improvement in students' cognitive learning outcomes. The study contributes by translating regional-potential-based TEFA and Deep Learning principles into a structured, classroom-ready instructional package for vocational mechanical-engineering education. However, because the evaluation involved one intact class without a comparison group, the observed improvement should not be interpreted as a causal effect of the package alone. Future research should involve multiple schools, comparison groups, longer implementation periods, and broader vocational outcomes, including psychomotor performance, work attitudes, critical thinking, motivation, and work readiness.

Author's declaration

Author contribution

Rizki Samudra As Arif: Conceptualization, methodology, instructional package development, data collection, data analysis, visualization, and manuscript preparation. **Waskito:** Supervision, validation of research design, methodological guidance, critical review, and manuscript revision. **Syahril:** Supervision, expert consultation, validation support, interpretation of findings, and manuscript revision. **Gulzhaina K. Kassymova:** methodological guidance, critical review, and manuscript revision. All authors contributed to the final manuscript review and approved the submitted version.

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Conflict of interest

The authors declare no known financial or non-financial competing interests that could have influenced the design, implementation, analysis, or interpretation of this research.

Data availability

The data supporting the findings of this study, including validation results, practicality evaluations, and pre-test–post-test learning outcome data, are available from the corresponding author upon reasonable request.

Ethical considerations

This study involved educational activities with vocational high school students at SMKN 1 Batipuh, West Sumatra, Indonesia. Formal permission to conduct the research was obtained from the West Sumatra Provincial Education Office through Letter No. 000.9/2907/PSMK/DISDIK-2026. The research was conducted in coordination with the school and in accordance with the conditions specified in the authorization letter, including ensuring that the research activities did not impose undue burdens on the teachers or school and that the collected data were handled in accordance with applicable regulations. Student information was anonymized during data analysis and reporting, and no sensitive personal data were collected.

AI statement

During manuscript preparation, the authors used Grammarly only for grammar checking and language refinement. The authors remain fully responsible for the content, analysis, interpretation, and scientific integrity of the manuscript.

Publisher's and Journal's note

Universitas Negeri Padang, as the publisher, and the Editor of Jurnal Pendidikan Teknologi Kejuruan state that there is no conflict of interest towards this article publication.

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