

# Designing Industry-Based Implementation Guidelines for Welding Engineering Expertise Programs in Vocational Education

Ryan Galih Wicaksono<sup>1\*</sup>, Phil. Imam Mahir<sup>2</sup>, Sugeng Priyanto<sup>3</sup>

<sup>1,2,3</sup> Department of Technology and Vocational Education, Universitas Negeri Jakarta, Jakarta, Indonesia

---

## ARTICLE INFO

### Article history:

Received May 10, 2026

Revised May 20, 2026

Accepted June 01, 2026

Available online June 11, 2026

### Kata Kunci:

Pendidikan vokasi, teknik pengelasan, pembelajaran berbasis industri, pengembangan kompetensi, pedoman implementasi

### Keywords:

Vocational education, welding engineering, industry-based learning, competency development, implementation guidelines



Creative Commons Attribution-ShareAlike 4.0 International License:

## ABSTRAK

*Studi ini bertujuan untuk merancang pedoman implementasi berbasis industri untuk program keahlian teknik pengelasan dalam pendidikan vokasi guna meningkatkan kompetensi lulusan dan kesiapan kerja. Penelitian ini menggunakan pendekatan Penelitian dan Pengembangan (R&D) yang melibatkan guru vokasi, praktisi industri, ahli kurikulum, dan siswa. Data dikumpulkan melalui wawancara, observasi, kuesioner, analisis dokumen, dan diskusi kelompok fokus. Temuan menunjukkan bahwa industri membutuhkan kompetensi teknik pengelasan, keterampilan keselamatan kerja, dan keterampilan lunak profesional. Berdasarkan kebutuhan ini, pedoman implementasi dikembangkan yang mencakup organisasi kurikulum, prosedur pembelajaran praktis, kolaborasi industri, penilaian kompetensi, dan standar keselamatan. Hasil validasi ahli menunjukkan bahwa pedoman tersebut sangat layak dan relevan untuk implementasi pendidikan vokasi. Studi ini menyimpulkan bahwa pedoman implementasi berbasis industri dapat memperkuat keselarasan antara pendidikan vokasi dan kebutuhan industri sekaligus meningkatkan pengembangan kompetensi praktis dan kemampuan kerja lulusan di sektor teknik pengelasan.*

## ABSTRACT

This study aimed to design industry-based implementation guidelines for welding engineering expertise programs in vocational education to improve graduate competency and workforce readiness. The research employed a Research and Development (R&D) approach involving vocational teachers, industrial practitioners, curriculum experts, and students. Data were collected through interviews, observations, questionnaires, document analysis, and focus group discussions. The findings revealed that industries require technical welding competencies, occupational safety skills, and professional soft skills. Based on these needs, implementation guidelines were developed covering curriculum organization, practical learning procedures, industrial collaboration, competency assessment, and safety standards. Expert validation results indicated that the guidelines were highly feasible and relevant for vocational education implementation. The study concludes that industry-based implementation guidelines can strengthen the alignment between vocational education and industrial requirements while enhancing practical competency development and graduate employability in the welding engineering sector.

---

## 1. INTRODUCTION

Vocational education and training (VET) is widely positioned as a mechanism for producing labour-market-relevant skills and competencies, with national systems explicitly seeking to respond to changing social, technological, and labour-market demands through updated vocational strategies and more "transparent and interoperable" training arrangements (Fajrin et al., 2023). In this context, vocational

\*Corresponding author

E-mail addresses: [ryangalihw@gmail.com](mailto:ryangalihw@gmail.com) (First Author)



Creative Commons Attribution-ShareAlike 4.0 International License:

<https://creativecommons.org/licenses/by-sa/4.0/>

curricula are commonly justified by their intended closeness to industry needs, where practical teaching functions as the core pathway through which students convert theoretical knowledge into job-relevant capability (Suyama et al., 2023). Correspondingly, reforms in practical teaching are often framed as necessary because traditional practical teaching modes may become less adequate under conditions of rapid industrial and technological change (Suyama et al., 2023). From a vocational-ability perspective, improving talent cultivation models and strengthening practical training curricula are repeatedly described as central to students' future development and to the capacity of vocational institutions to meet societal requirements for skilled human resources (Hu et al., 2024).

Within VET, welding engineering expertise programs represent a field where educational outcomes are strongly dependent on intensive practice and mastery of foundational techniques. At the vocational school level, welding engineering programs are intended to prepare learners with theoretical knowledge and practical skills to become a skilled welding workforce (Sakti et al., 2022). Welding instruction in vocational contexts has been described as needing to emphasize mastery of skills, knowledge, and attitudes/values required by industry, including basic welding competencies and an understanding of welding defects originating from operator error and equipment conditions (Hoel, 2023). Empirically, welding courses such as Shielded Metal Arc Welding (SMAW) are treated as consequential components of vocational preparation, where pedagogical choices (e.g., case-method learning) have been investigated for their ability to improve learning outcomes in SMAW subjects, reinforcing the centrality of instructional effectiveness to welding competence formation (Sakti et al., 2022). In addition to employability in existing firms, vocational welding learning outcomes have also been studied in relation to entrepreneurial interest, indicating that welding competence development can shape post-graduation pathways and that vocational graduates may face non-trivial transition pressures when moving from school to work (Yıldırım et al., 2023).

Despite the strategic importance of practice-oriented preparation, vocational programs frequently confront structural barriers that inhibit full alignment with occupational standards. A recurrent challenge is the adequacy of practical training environments: where investment in training facilities does not match professional standards, schools may struggle to cultivate qualified technical talent through traditional training models, particularly when equipment, space, and consumables impose substantial costs (Herr et al., 2021). More broadly, practical training curricula may remain "imperfect" relative to contemporary needs, and this deficiency is explicitly linked to weaker enhancement of students' vocational core competencies, making "how to correctly implement the practical training program" a sustained concern for vocational stakeholders (Hu et al., 2024). The fragility of hands-on training capacity was also visible during COVID-19 disruptions, where vocational fields experienced pronounced difficulties when hands-on practical training had to be substituted with virtual tools and online platforms, underscoring that applied learning is not easily replicated by purely remote modalities (Sunarti et al., 2023). While the pandemic is not the primary driver of the present study, this episode further highlights the operational dependence of vocational competence formation on well-managed, in-person practical training systems (Zhang, 2025).

A further set of challenges concerns the education–industry interface and how workplace expectations are translated into teachable and assessable learning. Practical teaching is commonly portrayed as the link that determines whether vocational graduates can connect accurately with workplace requirements and demonstrate solid professional quality (Suyama et al., 2023). Similarly, vocational-ability-oriented reform places explicit emphasis on constructing practical training course curricula and teaching modes that are meaningful for sustainable development and for the effectiveness of talent training programs (Hu et al., 2024). In professional education more generally, practical placements and work-situated learning are described as opportunities to translate theory into professional skills and to develop competence through authentic tasks and guided practice (Aydın & ŞAHİN, 2023). At the policy and institutional level, effective collaboration among ministries, faculties, and practice sites is argued to be important for improving training quality, illustrating the governance dimension of school–practice partnerships and the need for coordinated mechanisms rather than isolated initiatives (Chen et al., 2022). Taken together, these perspectives imply that industry collaboration is not only desirable but also operationally consequential: it shapes whether workplace standards, safety procedures, and performance expectations can be enacted consistently in learning activities (Suyama et al., 2023).

In welding engineering education specifically, the need for structured implementation is amplified because competence depends on repeated, standards-constrained practice and the ability to diagnose and prevent quality failures (e.g., welding defects) that can arise from human and machine factors (Hoel, 2023). However, where practical training systems are under-resourced or inconsistently organized, competency development may be uneven across institutions, and graduates may experience difficulty transitioning into work or deciding post-graduation steps, patterns that have been noted in vocational graduate outcomes discussions, including in welding-related contexts (Herr et al., 2021). These conditions motivate approaches

that more tightly integrate curriculum, practice environments, and assessment into a coherent competency-development pathway, an idea aligned with the view that practical teaching is the central "training ground" for transforming knowledge into employable skill (Suyama et al., 2023), and with arguments that practical training course construction should be systematically improved to raise vocational core competence (Hu et al., 2024).

Accordingly, an industry-based learning approach is frequently promoted as a means to reduce the mismatch between educational outputs and industrial expectations by embedding workplace-relevant practice requirements into the learning process. The general VET rationale for labour-market responsiveness (Fajrin et al., 2023), together with the centrality of practical teaching to workplace connection (Suyama et al., 2023), implies that closer school-industry integration can strengthen the authenticity of training conditions. At the same time, evidence on constraints, such as high facility/equipment demands (Herr et al., 2021) and the operational difficulty of substituting hands-on practice with online methods (Sunarti et al., 2023; Zhang, 2025), suggests that such integration must be supported by explicit, implementable procedures that address learning management, resource use, and competency assessment in realistic school settings.

For these reasons, the development of standardized implementation guidelines becomes a critical quality assurance instrument for welding engineering expertise programs. Where practical training courses remain imperfect, and implementation is an open problem (Hu et al., 2024), and where training quality depends on coordinated collaboration across institutions and practice sites (Chen et al., 2022), guidelines can function as an operational framework to reduce variability in program structure and execution. In effect, they can support consistent organization of practice-oriented curricula, management of practical training activities, and more reliable competency development processes, goals that align with the broader VET expectation of producing labour-market-relevant competencies (Fajrin et al., 2023; Suyama et al., 2023) and with welding education's emphasis on foundational skill mastery and defect-focused understanding (Hoel, 2023). Nevertheless, within the provided literature, welding-focused studies tend to concentrate on specific pedagogical models or learning outcomes in SMAW and related subjects rather than on a comprehensive, operational guideline that integrates curriculum delivery, industrial collaboration, and competency assessment into a single implementable framework (Sakti et al., 2022; Yıldırım et al., 2023). This gap provides the immediate rationale for the present study: designing industry-based implementation guidelines tailored to welding engineering expertise programs in vocational education, with the aim of strengthening consistency, relevance, and workforce readiness in line with industrial standards and contemporary vocational training imperatives (Herr et al., 2021; Chen et al., 2022).

This study aims to: 1) Identify industrial competency requirements in welding engineering education. 2) Design industry-based implementation guidelines for welding engineering expertise programs in vocational education. 3) Evaluate the feasibility and relevance of the developed guidelines through expert and practitioner validation. This research addresses the following questions: 1) What competencies are required by the welding industry for vocational graduates? 2) How should industry-based implementation guidelines for welding engineering expertise programs be designed? And 3) How feasible and applicable are the developed guidelines for vocational education institutions?

This study is expected to provide both theoretical and practical contributions to vocational education development. Theoretically, the study contributes to the literature on industry-based vocational learning and competency-oriented educational implementation. Practically, the developed guidelines may assist vocational schools in improving program quality, strengthening industrial partnerships, and enhancing student competency development. The findings may also serve as references for policymakers, curriculum developers, teachers, and industrial stakeholders in designing more effective vocational education systems that are responsive to workforce demands.

## 2. METHOD

### Research Design

This study used a Research and Development (R&D) approach to design and validate industry-based implementation guidelines for welding engineering expertise programs in vocational education institutions. The R&D method was chosen because this study focused not only on identifying educational problems but also on developing a practical product in the form of implementation guidelines that could be applied in vocational institutions. The research process adopted several stages, including needs analysis, guideline design, expert validation, revision, limited implementation, and final evaluation.

This study also incorporated Design-Based Research (DBR) principles, specifically in the iterative development and refinement of the guidelines through collaboration with education practitioners and

industry stakeholders. This approach enabled the researchers to ensure that the developed guidelines were relevant to educational objectives and industry competency requirements.

### **Research Setting and Participants**

This research was conducted at three vocational education institutions: State Vocational High School 4 Sukabumi, SMKN 53 Jakarta, and SMKN 2 Bandung, which offer welding engineering programs, and at selected industrial companies related to welding and metal fabrication. Participants were purposively selected based on their involvement and expertise in vocational welding education and industrial training. The industrial class population from the three schools was 318, and the sample size was 110 respondents in grade 10. Participants included: Vocational school teachers specializing in welding engineering; School administrators responsible for vocational curriculum implementation; Welding industry practitioners and supervisors; Curriculum and vocational education experts; and students enrolled in welding engineering programs. Industry participants were involved to ensure that the developed guidelines reflected current industry practices, competency standards, and workplace expectations.

### **Data Collection Techniques**

Several data collection techniques were employed in this study to obtain comprehensive and accurate information related to industrial competency requirements and the implementation of welding engineering expertise programs in vocational education. The data collection process involved interviews, observations, document analysis, questionnaires, and Focus Group Discussions (FGD) to ensure data validity and completeness.

Semi-structured interviews were conducted with vocational teachers, industrial practitioners, and curriculum experts to explore challenges in the implementation of welding engineering programs and identify competencies required by industries. The interviews also aimed to gather information regarding curriculum relevance, practical learning activities, industrial collaboration, and competency assessment practices. Direct observations were carried out during vocational workshop activities and industrial training sessions to examine the implementation of practical learning processes. The observations focused on equipment utilization, workshop management, student participation, practical procedures, and the application of occupational health and safety standards in learning environments.

Document analysis was conducted by reviewing relevant documents, including vocational curricula, competency standards, industrial training manuals, assessment guidelines, certification standards, and institutional policies. These documents were analyzed to support the development of industry-based implementation guidelines and ensure alignment with industrial requirements. Questionnaires were distributed to teachers, students, and industrial practitioners to evaluate the relevance, feasibility, clarity, and practicality of the developed implementation guidelines. The questionnaire items used a Likert scale to measure participant perceptions and responses systematically.

Focus Group Discussions (FGD) were conducted with vocational education experts and industrial representatives to obtain collaborative feedback and recommendations regarding the structure, content, and implementation procedures of the proposed guidelines. The discussions also served to validate the suitability of the guidelines with current industrial practices and vocational education needs.

### **Data Analysis Techniques**

The study utilized both qualitative and quantitative data analysis techniques. Qualitative data obtained from interviews, observations, and focus group discussions were analyzed using thematic analysis. The analysis process included data reduction, coding, categorization, interpretation, and conclusion drawing. Quantitative data from questionnaires and validation sheets were analyzed descriptively using percentages, mean scores, and feasibility classifications. The results were used to determine the practicality and appropriateness of the developed guidelines.

## **3. RESULT AND DISCUSSION**

### **Identification of Industrial Welding Competency Needs**

The needs analysis results revealed that the welding industry requires vocational graduates to possess comprehensive competencies consisting of technical skills, occupational safety awareness, and professional attitudes. Data obtained from interviews with industrial practitioners, teachers, and curriculum experts indicated that current vocational learning practices still require significant improvement to align with industrial expectations (see Table 1) fully.

**Table 1. Industrial Competency Requirements for Welding Engineering Expertise Programs**

Competency Category	Competency Indicators	Industrial Importance
Technical Competencies	Shielded Metal Arc Welding (SMAW) operation	Required for basic and structural welding applications
	Gas Metal Arc Welding (GMAW/MIG) operation	Supports industrial manufacturing productivity
	Gas Tungsten Arc Welding (GTAW/TIG) operation	Important for precision welding and high-quality finishing
	Welding blueprint interpretation	Ensures accuracy in welding construction and fabrication
	Material preparation and metal cutting techniques	Supports efficient welding processes
	Welding quality inspection and testing	Maintains product quality standards
	Equipment maintenance and troubleshooting	Prevents operational failures and production delays
Occupational Safety Competencies	Understanding industrial production workflows	Enhances workplace adaptability and productivity
	Knowledge of quality assurance systems	Supports industrial standard compliance
	Proper use of personal protective equipment (PPE)	Minimizes workplace accidents and injuries
	Understanding welding safety procedures	Ensures safe welding operations
	Hazard identification and risk management	Reduces operational risks
	Fire prevention and emergency response procedures	Supports emergency preparedness
	Safe handling of welding equipment and materials	Prevents equipment misuse and workplace hazards
Soft Skills Requirements	Communication skills	Supports effective workplace interaction
	Teamwork and collaboration	Improves coordination in industrial settings
	Work discipline	Enhances productivity and responsibility
	Problem-solving abilities	Supports operational decision-making
	Adaptability to industrial environments	Facilitates adjustment to workplace culture

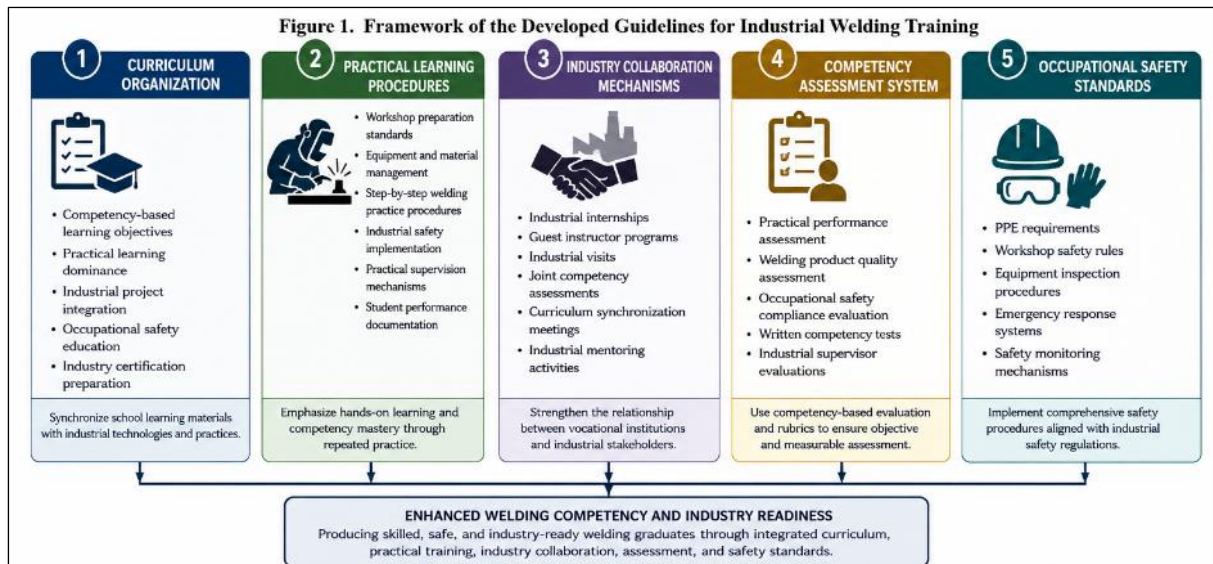
Table 1 presents the industrial competency requirements identified for welding engineering expertise programs in vocational education. The findings indicate that industries require students to master three major competency areas: technical competencies, occupational safety competencies, and soft skills competencies. The technical competencies focus on students' ability to operate various welding methods such as SMAW, GMAW/MIG, and GTAW/TIG, as well as their understanding of blueprint interpretation, material preparation, quality inspection, equipment maintenance, and industrial production systems. These competencies are considered essential because welding industries prioritize technical precision, operational efficiency, and product quality standards.

The occupational safety competencies emphasize the importance of implementing industrial-standard safety procedures during welding activities. Industries expect students to understand the use of personal protective equipment (PPE), hazard identification, emergency response procedures, and safe equipment handling. This finding indicates that workplace safety has become a critical component of welding engineering education due to the high-risk nature of welding operations. In addition to technical and safety competencies, industries also highlighted the importance of soft skills. Communication abilities, teamwork, discipline, problem-solving skills, and adaptability are considered necessary for improving student readiness to work in industrial environments. Industrial supervisors stated that graduates with strong technical skills but limited professional attitudes often encounter difficulties adapting to workplace

culture and organizational systems. Overall, the results demonstrate that vocational welding education should integrate technical competencies, occupational safety standards, and professional soft skills into learning activities to better align graduate competencies with industrial workforce demands.

### Development of the Implementation Guidelines

Based on the needs analysis results, the researchers developed industry-based implementation guidelines for welding engineering expertise programs. The guidelines were designed to support vocational institutions in organizing competency-oriented learning aligned with industrial standards. The developed guidelines consisted of five major components (see Figure 1).



**Figure 1. Framework of the Developed Guidelines for Industrial Welding Training**

Figure 1 presents the framework of the developed guidelines for industrial welding training in vocational education, consisting of five integrated components: curriculum organization, practical learning procedures, industry collaboration mechanisms, competency assessment systems, and occupational safety standards. The framework emphasizes competency-based curricula aligned with industrial needs, hands-on practical learning, and strong collaboration between vocational institutions and industries. It also highlights the importance of objective competency assessments and the implementation of industrial-standard safety procedures during welding activities. The integration of these components is intended to enhance students' technical competencies, workplace safety awareness, professional skills, and industry readiness. Overall, the framework demonstrates that effective welding engineering education requires systematic coordination between curriculum development, practical training, industrial partnerships, assessment systems, and safety management to produce skilled and workforce-ready graduates.

### Validation Results

The developed implementation guidelines were evaluated by vocational education experts, welding practitioners, and teachers to determine their feasibility and applicability.

#### Expert Validation Results

Expert validators assessed the guidelines based on content relevance, clarity, practicality, and industrial alignment. The evaluation results showed high levels of feasibility (see Table 2).

**Table 2. Expert Validation Results**

Assessment Aspect	Mean Score	Category
Content Relevance	4.68	Very Feasible
Guideline Clarity	4.55	Very Feasible
Practical Applicability	4.47	Very Feasible
Industrial Alignment	4.72	Very Feasible
Assessment System	4.50	Very Feasible

The average overall score was 4.58, indicating that the guidelines were categorized as "Very Feasible."

**Practitioner Feedback**

Industrial practitioners evaluated the developed guidelines positively and considered them relevant to current industrial needs. They emphasized the importance of safety standards, competency-based assessment, and industrial exposure in improving student competencies and workforce readiness (see Table 3).

**Table 3. Practitioner Recommendations for Guideline Improvement**

<b>Recommendation</b>	<b>Purpose</b>
Increasing exposure to automated welding technologies	Improve student understanding of modern industrial systems.
Strengthening digital welding simulation training	Enhance practical skills through technology-based learning.
Expanding industrial internship duration	Increase workplace experience and industrial adaptability.

Table 1 shows that industrial practitioners recommended strengthening technology integration and workplace exposure in welding education. The recommendations emphasize the importance of automated welding systems, digital simulation training, and longer industrial internships to improve student competencies, practical experience, and readiness to adapt to modern industrial environments.

**Teacher Evaluation Results**

Teachers evaluated the practicality of implementing the guidelines within vocational learning environments. Most teachers agreed that the guidelines were systematic, easy to understand, and supportive of competency-based learning implementation (see Table 4).

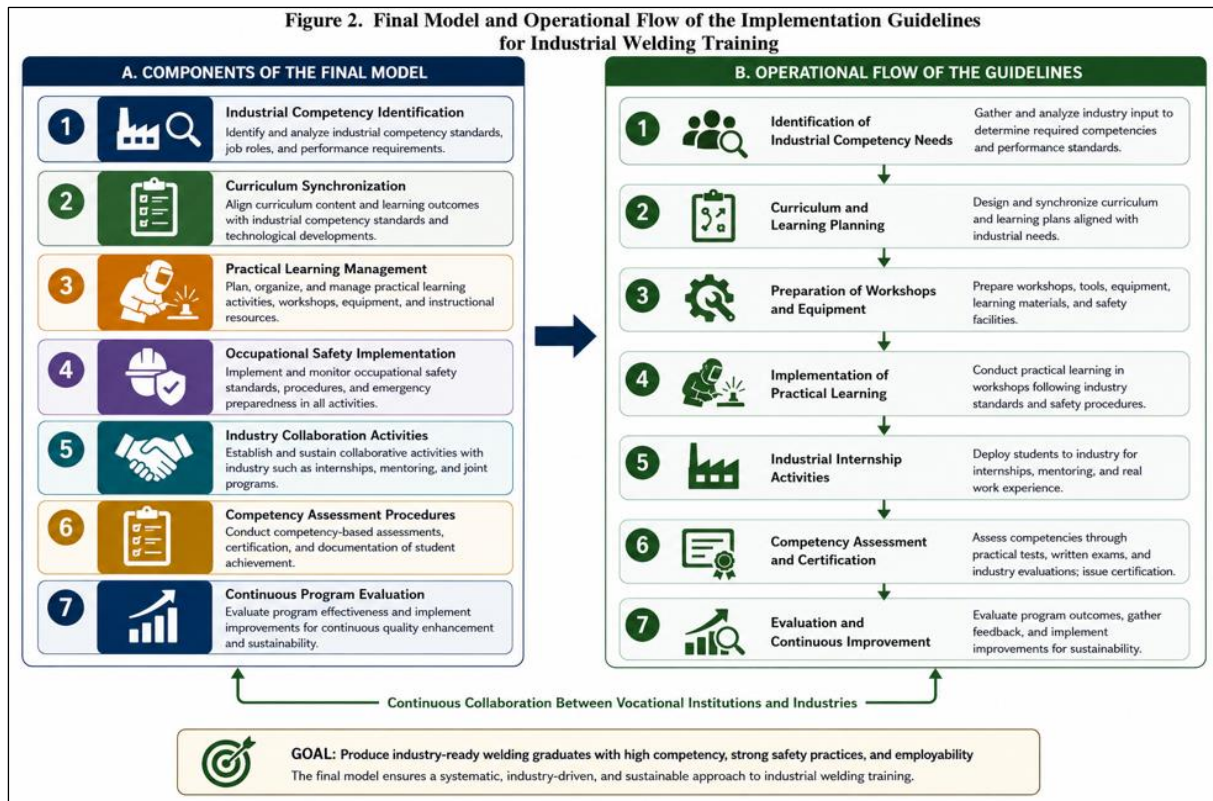
**Table 4. Teacher Perceptions of the Benefits of the Implementation Guidelines**

<b>Guideline Support Areas</b>	<b>Benefits for Teachers</b>
Organizing practical learning activities	Helps teachers structure systematic and competency-based practical learning
Conducting competency assessments	Assists in implementing objective and measurable student evaluations
Managing workshop safety procedures	Supports the implementation of industrial-standard safety practices
Collaborating with industrial partners	Facilitates communication and cooperation with industries

Table 4 indicates that teachers perceived the implementation guidelines as beneficial for improving vocational learning management. The guidelines assisted teachers in organizing practical activities, conducting competency-based assessments, implementing workshop safety procedures, and strengthening collaboration with industrial partners. These findings suggest that the guidelines support more systematic, safe, and industry-oriented welding education implementation.

**Final Model of the Implementation Guidelines**

Following the validation and revision stages, the final implementation guideline model was established. The final model consisted of interconnected implementation stages (see Figure 2).



**Figure 2. Final Model and Operational Flow of the Implementation Guidelines for Industrial Welding Training**

Figure 2 illustrates the final model and operational flow of the implementation guidelines for industrial welding training. The model consists of seven interconnected components designed to ensure that vocational education aligns with industrial competency requirements and workforce demands. The first component, Industrial Competency Identification, focuses on analyzing industrial standards, job roles, and performance expectations as the foundation for curriculum development. The second component, Curriculum Synchronization, ensures that vocational learning outcomes, instructional materials, and training activities are aligned with current industrial technologies and competency standards. The third component, Practical Learning Management, emphasizes the organization of workshops, equipment, instructional resources, and hands-on learning activities to support effective competency mastery.

The fourth component, Occupational Safety Implementation, integrates industrial safety standards, emergency preparedness, and monitoring systems into all practical learning activities. The fifth component, Industry Collaboration Activities, strengthens partnerships between vocational institutions and industries through internships, mentoring, collaborative programs, and industrial participation in training activities. The sixth component, Competency Assessment Procedures, applies competency-based evaluation methods, certification systems, and documentation of student achievements to measure learning outcomes objectively. The seventh component, Continuous Program Evaluation, emphasizes continuous monitoring and improvement of the training program to maintain quality, sustainability, and relevance to industrial developments.

The operational flow presented on the right side of the figure demonstrates the sequential implementation process of the guidelines. The process begins with identifying industrial competency needs, followed by curriculum and learning planning, workshop and equipment preparation, implementation of practical learning, industrial internship activities, competency assessment and certification, and finally evaluation and continuous improvement. This flow indicates that the training system is cyclical and adaptive, allowing feedback and industrial input to improve the program continuously. Overall, the figure highlights that continuous collaboration between vocational institutions and industries is essential for producing industry-ready welding graduates with strong technical competencies, occupational safety awareness, and employability skills.

The study's claim that welding-vocational guidelines align with industry competency requirements is consistent with evidence that vocational education is expected to be competency-based and responsive

to Industry 4.0-driven workplace change (Astuti et al., 2022), and that employer standards can drive competency-based education models (Elbarrad & Belassi, 2023). In welding specifically, industrial practice spans manufacturing sectors (e.g., automotive, shipbuilding, aerospace), implying that curricula must reflect diverse, current processes and quality demands (Ma et al., 2022), including increasing automation and robotic welding adoption (Liu et al., 2022; Singh et al., 2022).

The emphasis on integrating technical skills with employability-oriented soft skills is supported by higher-education evidence that technical/technology-focused competency approaches alone may be insufficient, motivating broader pedagogies (e.g., challenge-based learning) that develop professional capabilities (Vilalta-perdomo et al., 2022), alongside explicit alignment to employer needs (Elbarrad & Belassi, 2023). Bridging school-to-work gaps through structured industry-education collaboration is also consistent with industry-based learning models (e.g., "teaching factory") designed to resemble real work systems and procedures (Sunarja & Maharani, 2023). Finally, prioritizing occupational safety is strongly justified: welding is hazardous, involving toxic fume and gas exposures with documented health risks (Nwogueze et al., 2024), and OHS competency development is a stated requirement within competency-based vocational preparation for industry entry (Ismara et al., 2021).

The reported expert/practitioner validation of the guideline's feasibility is consistent with broader evidence that industry standards increasingly shape competency-based education to ensure graduates meet employer expectations, implying that systematic, industry-referenced procedures are a plausible mechanism for improving implementation quality (Elbarrad & Belassi, 2023; Astuti et al., 2022). For welding, emphasizing structured practice aligned to industrial workflows is also consistent with the sector's shift toward automated/robotic welding systems that operationalize repeatable procedures and quality control, thereby making "industry-like" sequencing and standards educationally relevant (Liu et al., 2022; Singh et al., 2022). More generally, digitized industrial workplaces increasingly model and analyze factual manual workflows, reinforcing the value of explicitly specified work-activity procedures as a basis for training and evaluation (Patalas-Maliszewska et al., 2021).

The guideline's collaboration components (e.g., internships and joint assessment) align with vocational-education arguments that institutions should leverage partnership networks with external parties and emphasize the integrated development of skills, knowledge, and attitudes needed by industry (Srinatriyo et al., 2023). Finally, competency-based assessment emphasizing performance is coherent with welding's quality-critical nature (defects directly affect product quality), motivating product/performance evaluation rather than purely theoretical testing (Ma et al., 2022).

The study's emphasis on industry-based, competency-oriented vocational education aligns with prior evidence that industry standards increasingly drive competency-based education to meet employer needs (Elbarrad & Belassi, 2023) and that vocational programs must adapt to Industry 4.0 competency demands (Astuti et al., 2022). Its use of authentic, work-like practice and workplace exposure is consistent with industry-based learning models (e.g., teaching factory) intended to resemble real work systems (Sunarja & Maharani, 2023) and with calls for vocational institutions to leverage external partnership networks to build industry-relevant skills, attitudes, and values (Srinatriyo et al., 2023). The preference for performance-based competency assessment also fits welding's quality-critical context, where process variability produces defects that directly affect product quality, supporting product/performance evaluation over purely theoretical testing (Ma et al., 2022; Elbarrad & Belassi, 2023).

The study's added contribution is the integrated framework combining curriculum synchronization, structured industrial workflows, collaboration mechanisms, and assessment within one guideline, an approach supported by evidence that industrial workflows can be explicitly modeled/standardized in digitized workplaces (Patalas-Maliszewska et al., 2021), and that welding practice is increasingly organized around automated/robotic procedures and standards (Liu et al., 2022; Singh et al., 2022). Its strong occupational-safety focus is also consistent with welding's well-documented hazard profile from fume and gas exposure, reinforcing safety as a core competency rather than a peripheral topic (Nwogueze et al., 2024; Ismara et al., 2021).

#### 4. CONCLUSION

This study aimed to design industry-based implementation guidelines for welding engineering expertise programs in vocational education. The findings revealed that vocational welding education requires stronger alignment with industrial competency standards to improve graduate readiness and employability. The needs analysis identified several essential competencies demanded by industries, including technical welding skills, occupational safety competencies, and professional soft skills such as communication, teamwork, and problem-solving abilities.

Based on these findings, the study successfully developed comprehensive implementation guidelines consisting of curriculum organization, practical learning procedures, industry collaboration mechanisms, competency-based assessment systems, and occupational safety standards. The guidelines

were designed to support vocational institutions in implementing welding engineering programs that reflect real industrial practices and workplace expectations. The validation results demonstrated that the developed guidelines were categorized as highly feasible and relevant for vocational education implementation. Expert evaluators, industrial practitioners, and teachers agreed that the guidelines provide systematic and practical procedures for organizing industry-oriented learning activities. Limited implementation findings also showed positive impacts on practical learning management, student engagement, and competency development.

Overall, the study confirms that industry-based implementation guidelines can strengthen the relevance of vocational welding education, improve practical competency achievement, and support the preparation of workforce-ready graduates who are adaptable to industrial transformation and technological advancement.

## 5. REFERENCES

- Astuti, M., Arifin, Z., Nurtanto, M., Mutohhari, F., & Warju, W. (2022). The Maturity Levels of the Digital Technology Competence in Vocational Education. *International Journal of Evaluation and Research in Education (Ijere)*, 11(2), 596. <https://doi.org/10.11591/ijere.v11i2.22258>
- Aydın, T., & ŞAHİN, A. B. (2023). Perspectives of the Dental Educators With Regard to Online Education. *Cumhuriyet Dental Journal*, 26(1), 54–62. <https://doi.org/10.7126/cumudj.1228802>
- Chen, T.-C., Yu, J., & Golmohammadi, A.-M. (2022). Application of Sustainable Education Innovation in the Integrated Teaching of Theory and Practice Adopted in the Auto Chassis Course. *Discrete Dynamics in Nature and Society*, 2022(1). <https://doi.org/10.1155/2022/7737231>
- Elbarrad, S. S., & Belassi, W. (2023). Chartered Professional Accountant's Competencies: The Synergy Between Accounting Education and Employers' Needs—evidence From Alberta. *Higher Education Skills and Work-Based Learning*, 13(2), 423–442. <https://doi.org/10.1108/heswbl-09-2022-0183>
- Fajrin, M., Purwantono, P., Irzal, I., Rahim, B., & Zaus, A. A. (2023). The Effectiveness of the Case Method to Improve Student Learning Outcomes in the SMAW Subject. *Jurnal Pendidikan Teknologi Kejuruan*, 6(4), 270–277. <https://doi.org/10.24036/jptk.v6i4.34723>
- Herr, L., Jih, M., Shin, J., Chae, Y. K., Lee, H.-S., Choi, S. C., & Nam, O. H. (2021). The Perspective of Undergraduate Dental Students on Web-Based Learning in Pediatric Dentistry During the COVID-19 Pandemic: A Korean Multicenter Cross-Sectional Survey. *BMC Medical Education*, 21(1). <https://doi.org/10.1186/s12909-021-02928-w>
- Hoel, L. (2023). The Significance of Embodied Learning in Police Education. *European Journal of Policing Studies*, 6(2), 138–155. <https://doi.org/10.5553/ejps/2034760x2022001004>
- Hu, J., Chen, R., Wang, X., Lu, G. R., Zhang, M., & Huang, X. (2024). Evaluating the Effectiveness of a Novel Training Model in Dental Preclinical Regenerative Endodontic Education. *International Endodontic Journal*, 58(2), 334–345. <https://doi.org/10.1111/iej.14169>
- Ismara, K. I., Suharjono, A., & Supriadi, D. (2021). Ubiquitous Learning in Occupational Health and Safety for Vocational Education. *International Journal of Evaluation and Research in Education (Ijere)*, 10(1), 285. <https://doi.org/10.11591/ijere.v10i1.20823>
- Liu, Q., Chen, C., & Chen, S. (2022). Key Technology of Intelligentized Welding Manufacturing and Systems Based on the Internet of Things and Multi-Agent. *Journal of Manufacturing and Materials Processing*, 6(6), 135. <https://doi.org/10.3390/jmmp6060135>
- Ma, N., Gao, X., Tian, M., Wang, C., Zhang, Y., & Gao, P. P. (2022). Magneto-Optical Imaging of Arbitrarily Distributed Defects in Welds Under Combined Magnetic Field. *Metals*, 12(6), 1055. <https://doi.org/10.3390/met12061055>
- Nwogueze, B. C., Ofili, M. I., Anachuna, K. K., & Mbah, A. O. (2024). Serum Zinc Levels and Body Composition Variability as Trajectory for Hyperlipidemic and Dyslipidemic Effect Among Welders Exposed to Welding Fumes and Smoking: A Biomarker for Cardiovascular Health. *Toxicology Reports*, 12, 607–613. <https://doi.org/10.1016/j.toxrep.2024.05.008>
- Patalas-Maliszewska, J., Halikowski, D., & Damaševičius, R. (2021). An Automated Recognition of Work Activity in Industrial Manufacturing Using Convolutional Neural Networks. *Electronics*, 10(23), 2946. <https://doi.org/10.3390/electronics10232946>
- Sakti, A. M. T., Ajis, S. Z. M., Azlan, A. A., Kim, H. J., Wong, E., & Mohamad, E. (2022). Impact of COVID-19 on School Populations and Associated Factors: A Systematic Review. *International Journal of Environmental Research and Public Health*, 19(7), 4024. <https://doi.org/10.3390/ijerph19074024>

- Singh, A., Kalaichelvi, V., DSouza, A. S., & Karthikeyan, R. (2022). GAN-Based Image Dehazing for Intelligent Weld Shape Classification and Tracing Using Deep Learning. *Applied Sciences*, 12(14), 6860. <https://doi.org/10.3390/app12146860>
- Srinatriyo, Y., Suhartadi, S., & Yoto. (2023). Application of the Problem-Based Learning Model to Improve Students' Understanding of Welding Defect Material. *Paedagogia Jurnal Pendidikan*, 12(2), 431–446. <https://doi.org/10.24239/pdg.vol12.iss2.444>
- Sunarja, D., & Maharani, O. D. (2023). The Implementation of Teaching Factory Through Department Division in Hospitality Skill Programme at Metland Tourism Vocational School. *Indonesian Journal of Educational Development (Ijed)*, 4(2), 139–149. <https://doi.org/10.59672/ijed.v4i2.2684>
- Sunarti, L. S., Arodes, E. S., Diani, Y. H., & Salshabila, A. A. (2023). The Impact of COVID on Microbiology Examination Result With Its Further Analysis Based on Student's Gender and Place of Residence. *Asian Journal of Research in Infectious Diseases*, 13(1), 32–42. <https://doi.org/10.9734/ajrid/2023/v13i1258>
- Suyama, N., Inoue, K., Sorasak, S., Thawisuk, C., & Watanabe, M. (2023). Reflection on Feasibility and Usability of Interactive Online International Exchange Program for Occupational Therapy Students. *Discover Education*, 2(1). <https://doi.org/10.1007/s44217-023-00031-4>
- Vilalta-perdomo, E. L., Michel-Villarreal, R., & Thierry-Aguilera, R. (2022). Integrating Industry 4.0 in Higher Education Using Challenge-Based Learning: An Intervention in Operations Management. *Education Sciences*, 12(10), 663. <https://doi.org/10.3390/educsci12100663>
- Yıldırım, T. Ö., KARATEPE, H. K., & Şen, H. T. (2023). The Relationship Between Stress and Professional Attitude of Nursing Students During the COVID-19 Pandemic. *Gümüşhane Üniversitesi Sağlık Bilimleri Dergisi*, 12(3), 940–950. <https://doi.org/10.37989/gumussagbil.1095479>
- Zhang, Y. (2025). Research on Vocational Education Practice Teaching Mode Under the Background of "Internet Plus." *International Journal of Web-Based Learning and Teaching Technologies*, 20(1), 1–18. <https://doi.org/10.4018/ijwltt.382589>