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Competency Based Training for SMAW 2F in Vocational Education of Islamic Boarding Schools

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***Abstract*—*Vocational education in Islamic boarding schools often lacks structured training aligned with industry standards, particularly in Shielded Metal Arc Welding (SMAW) for the 2F horizontal fillet position, which is widely used in structural assembly and fabrication. This study aimed to develop and evaluate a Competency-Based Training (CBT) program to improve students' technical competency, safety awareness, and institutional sustainability. The methodology used included needs assessment, theoretical instruction, supervised practical training, and trainer capacity building. A pre-test and post-test design was used to measure knowledge gains, while practical performance was evaluated using the Training Success Rate (TSR), Welding Quality Index (WQI), Safety Compliance Rate (SCR), and Program Sustainability Index (PSI). Results showed significant cognitive improvement, with the mean score increasing from 48.7 to 86.4 (TER = 1.77). The practical training achieved a TSR of 84% and a WQI of 81.7, meeting entry-level fabrication standards. Safety compliance reached 94%, and the PSI reached 150%, confirming institutional readiness to sustain the program independently. In conclusion, the CBT model effectively bridges the gap between informal vocational training and industry needs by integrating theoretical reinforcement, practical implementation, safety monitoring, and trainer development.*

***Keywords*—** *Competency-Based Training, SMAW, vocational education, Islamic boarding schools, welding safety.*

I. INTRODUCTION

Vocational education is a vital pathway for preparing skilled workers in industries such as metal fabrication and construction[1], [2]. Welding, particularly Shielded Metal Arc Welding (SMAW), is one of the most widely practised techniques in these sectors. Among the different welding positions, the 2F horizontal fillet weld is fundamental because it is commonly applied in structural assembly, lightweight steel frameworks, and component fabrication[3], [4]. Mastery of this position is essential to ensure weld quality, consistency, and workplace safety.

In many non-formal education settings, including Islamic boarding schools, vocational training often falls short of industry standards[5]. Students are typically limited to basic practices such as striking an arc and producing straight beads, without systematic knowledge of parameters such as current regulation, electrode selection, welding angles, heat control, and defect analysis[6]. Consequently, welds produced are inconsistent and fail to meet industrial requirements. The absence of structured training modules, standard operating procedures, and safety practices further reduces the effectiveness of vocational education in this context[7].

This situation highlights a clear gap between the skills taught in pesantren and the demands of the labour market. Without standardised training, students face reduced employability and limited opportunities for entrepreneurship in welding services, despite the high demand for such skills in regions such as West Java. Addressing this gap requires an innovative approach that integrates competency-based training, structured learning materials, and safety protocols into vocational education systems.

Competency-Based Training (CBT) has been widely recognised as an effective method in vocational education because it emphasises measurable, directly relevant practical skills[8][9]. Applying CBT principles to SMAW 2F training enables students to progress from theoretical understanding to hands-on practice, supported by visual learning materials and standardised evaluation. This approach not only improves technical competence but also strengthens safety awareness and prepares learners for employment[10], [11].

Therefore, the present study develops and evaluates a competency-based training program for SMAW 2F in an Islamic boarding school environment. The program aims to enhance students' technical competence, create standardised training modules and SOPs for sustainable education, reinforce safety practices through the use of personal protective equipment and structured workshop management, build trainer capacity to ensure continuity, and establish a replicable model of vocational training for non-formal institutions. By achieving these objectives, the study helps bridge the gap between informal vocational training and industrial standards. It also supports the Sustainable Development Goals, particularly SDG 4 on quality education and SDG 8 on decent work and economic growth, by fostering the development of skilled, employable, and safety-conscious workers in community-based education systems.

II. LITERATURE REVIEW

A. The Concept of Competency-Based Education (CBE) in Indonesia and Its Implementation in Vocational Schools

Competency-Based Education (CBE) has emerged as a central paradigm in vocational education, emphasising measurable skills aligned with industry needs. In Indonesia, CBE has been widely adopted to address the mismatch between vocational curricula and labour market needs. Studies confirm that CBE improves technical competency in manufacturing and welding by integrating structured modules, standardised assessments, and industry-based practices[12]. CBE evaluations bridge the gap between academic learning and

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employability, ensuring that graduates are prepared for wage employment and entrepreneurship. Vocational Education and Training (TVET) oriented toward Character-Based Education (CBE) is crucial for achieving Quality Education and Decent Work and Economic Growth.

B. Case Study of Vocational Education in Islamic Boarding Schools

Traditionally, Islamic boarding schools prioritised religious education, but recent transformations have introduced vocational training to enhance students' employability[13]. Research shows that integrating vocational education with religious values strengthens character development and technical skill acquisition. Evaluations reveal a persistent gap between Islamic boarding school-based vocational training and industry standards. Islamic boarding school students often lack a systematic understanding of welding parameters, safety protocols, and defect analysis, resulting in outputs that fall short of industry standards. Experiential learning models in Islamic boarding schools remain underdeveloped, with limited structured modules and standard operating procedures[14]. These findings underscore the need for a competency-based approach to improve vocational training in Islamic boarding schools, ensuring alignment with industry expectations while preserving the institution's cultural and spiritual identity.

C. SMAW Training Modules in Vocational Schools

Shielded Metal Arc Welding (SMAW) is a core competency in vocational education and is widely applied in the construction and fabrication industries. The 2F horizontal fillet welding position is particularly significant because it is frequently used in structural assembly and light steel frames[15]. Competency-based SMAW modules have been shown to improve students' technical abilities, especially when supported by visual learning media, simulation technology, and standardised assessment tools. The training centre emphasises the importance of structured modules and safety practices, including the use of personal protective equipment and adherence to standard operating procedures (SOPs)[16], to ensure welding quality and workplace safety. This structured approach not only improves technical performance but also prepares students for certification and employment in welding-related industries.

III. METHODOLOGY

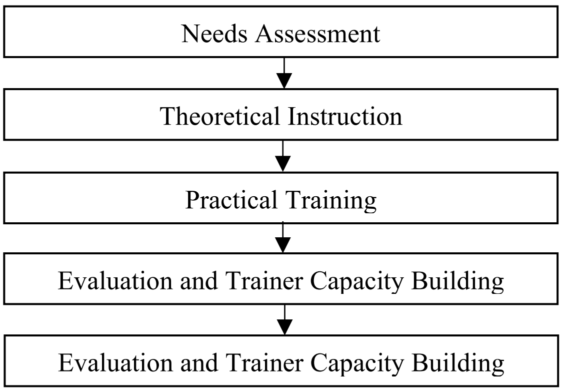

Fig. 1. Research Method

A. Needs Assessment

The initial phase involved a comprehensive assessment of the training context at Pesantren Quantum Bekasi. Observations and interviews revealed that students had only basic welding knowledge, limited to arc ignition and straight-bead formation. They lacked exposure to standard welding positions, particularly 2F horizontal fillet welding, which is widely used in light steel fabrication and construction[17]. The assessment identified critical gaps in technical understanding, safety practices, and learning materials. This phase also mapped the readiness of the pesantren's workshop facilities and participant motivation, which served as the basis for module design and learning planning[18].

B. Theoretical Instruction

The second phase focused on delivering structured theoretical instruction aligned with industry standards. Participants were introduced to the principles of Shielded Metal Arc Welding (SMAW), including current flow, electrode classification, polarity selection, arc length control, and slag formation. Instruction emphasised the geometry and mechanics of the 2F position, supported by visual aids, including diagrams, posters, and standard operating procedures (SOPs)[16]. The theory sessions are designed to build conceptual clarity before practical engagement, using interactive discussions and guided demonstrations to reinforce learning.

C. Practical Training

Hands-on training is conducted in stages, beginning with straight welding exercises and progressing to fillet welds in the 2F position[19]. Each participant practices electrode manipulation, angle control, and heat management under direct supervision. The trainer provides individual feedback and technique correction, ensuring that students understand the procedural steps necessary for consistent weld quality. Training emphasises repetition, visual inspection, and defect analysis, enabling learners to identify and correct common welding errors. Safety protocols are strictly enforced during the practical sessions.

D. Evaluation

Evaluation was conducted through both formative and summative assessments. Visual inspection techniques were used to assess weld quality, focusing on bead uniformity, penetration, and the minimisation of defects. To ensure objectivity, several quantitative indicators were applied:

1. Training Success Rate (TSR): percentage of participants achieving welds that meet quality standards.

$$TSR = \frac{N_{success}}{N_{total}} x100\%$$

$N_{success}$ is the number of participants whose welding results meet the criteria, while is the total number of participants. This formula calculates the proportion of students whose welding results meet the predetermined quality criteria compared to the total number of participants.

2. Weld Quality Index (WQI): composite measure integrating strength (S), defect rate (D), and

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consistency (C) with weighted importance factors (w_1, w_2, w_3).

$$WQI = \frac{w_1 \cdot S + w_2 \cdot (1 - D) + w_3 \cdot C}{w_1 + w_2 + w_3}$$

The strength of the joint (S), the defect rate (D), and the consistency of the weld (C). The weighting factor (w_1, w_2, w_3) is used to adjust the assessment priorities according to industry standards. This index provides a balanced evaluation of weld performance by combining mechanical strength, defect minimization, and dimensional consistency.

3. Training Effectiveness Ratio (TER): ratio comparing average pre-test and post-test scores

$$TER = \frac{Score_{post}}{Score_{pre}}$$

This ratio compares the average score of participants before training ($Score_{pre}$) with the score after training ($Score_{post}$).This ratio measures the relative increase in knowledge and skills, which indicates the effectiveness of the training intervention.

4. Safety Compliance Rate (SCR): percentage of participants adhering to PPE usage and SOP compliance.

$$SCR = \frac{N_{compliant}}{N_{total}} x100\%$$

$N_{compliant}$ is the number of participants who fully comply with safety regulations.

This indicator evaluates adherence to safety protocols, reflecting the integration of occupational safety into the training process. These formulations provided a robust framework for analyzing training outcomes beyond descriptive observation, ensuring that both technical performance and safety compliance were quantitatively assessed.

E. Trainer Capacity Building and Sustainability

To ensure program continuity, a Training of Trainers (ToT) module was implemented for pesantren instructors. This included reinforcement of theoretical knowledge, demonstration of 2F techniques, and instruction on visual inspection standards. Trainers were equipped with SOPs, evaluation rubrics, and scheduling tools to facilitate independent delivery of future training cycles. Sustainability was quantified using the Program Sustainability Index (PSI):

$$PSI = \frac{T_{trained}}{T_{required}} x100\%$$

$T_{trained}$ is the number of trainers who have successfully completed the Training of Trainers *(ToT)*, while $T_{required}$ is the minimum number of trainers required to ensure the sustainability of the program at the institution. The PSI value is expressed as a percentage, so the higher the PSI value, the greater the institution's ability to continue training independently without relying on external parties.

IV. Results and Discussion

A. Needs Assessment

The initial phase aimed to identify baseline cognitive and procedural competencies in SMAW before implementing the Competency-Based Training (CBT) program. A structured pre-test covering SMAW fundamentals, electrode classification, current regulation, polarity selection, 2F horizontal fillet welding theory, and welding safety was administered to 25 participants.

The results indicated limited theoretical mastery. Most participants demonstrated only partial understanding of basic welding concepts and insufficient knowledge of positional welding principles and parameter configuration. Conceptual gaps were particularly evident in electrode selection, heat control, and polarity adjustment.

Workshop observation further revealed that participants' prior experience was predominantly procedural rather than competency-oriented. While the majority were able to perform basic arc striking and straight-bead formation, none demonstrated a structured understanding of the 2F horizontal fillet welding position. Previous welding activities were conducted through repetitive practice without systematic explanation of welding geometry, heat input management, or defect mechanisms.

These findings indicate deficiencies across three essential domains: positional control, parameter configuration, and theoretical comprehension. From a vocational competency perspective, the baseline profile reflects misalignment between informal workshop exposure and industry-referenced fabrication standards.

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TABLE 1. Summarises the baseline competency distribution of participants prior to the CBT intervention

Description	Value
Number of Participants	25
Maximum Possible Score	100
Mean Pre-test Score	48.7 / 100
Participants Limited to Basic Arc Striking	80%
Prior Understanding of 2F Welding Position	0%
Lacking Electrode Classification Knowledge	72%
Lacking Current & Polarity Understanding	65%

B. Theoretical Instruction

Following the identification of baseline competency gaps, structured theoretical instruction was implemented using a Competency-Based Training (CBT) framework. The instructional phase was designed to strengthen conceptual understanding before participants engaged in practical welding exercises. The learning materials focused on welding geometry in the 2F horizontal fillet position, electrode classification and selection, current and polarity configuration, heat input control, slag formation, and defect identification.

Instructional delivery combined explanation, visual demonstration, and guided discussion. Technical diagrams and structured Standard Operating Procedures (SOPs) were introduced to clarify welding angles, electrode positioning, and

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parameter adjustment. Emphasis was placed on linking theoretical principles with practical implications, particularly in controlling bead shape, penetration depth, and defect prevention.

Post-instruction evaluation indicated measurable improvement in conceptual comprehension. Participants demonstrated the ability to explain appropriate electrode selection based on material conditions, justify current settings, and describe the correct electrode angle required for 2F welding. During guided questioning, participants showed improved procedural reasoning rather than relying solely on mechanical repetition.

The structured theoretical phase reduced the conceptual ambiguities identified during the needs assessment stage. Participants began to associate welding practice with parameter control and positional strategy, reflecting a transition from experience-based execution to competency-based understanding. This cognitive reinforcement provided a stable foundation for the subsequent practical training phase.

TABLE 2. Pre-test and Post-test Comparison.

Indicator	Pre-test	Post-test	Improvement
Mean Score	48.7	86.4	+77%
TER		1.77	

C. *Practical Training*

The practical phase involved supervised hands-on welding exercises progressing from straight beads to 2F horizontal fillet welds. Performance was evaluated using visual inspection criteria aligned with entry-level fabrication standards, including bead uniformity, penetration adequacy, and defect minimization.

Out of 25 participants, 21 successfully met the predefined quality criteria. This resulted in a Training Success Rate (TSR) of 84%.

To ensure objective evaluation, weld performance was further assessed using a composite Weld Quality Index (WQI) integrating strength, defect minimization, and bead consistency. The calculated WQI was 81.7, indicating acceptable technical performance for beginner-level structural applications.

TABLE 3. Practical Training Performance

Indicator	Value
Participants Meeting Quality Criteria	21
Training Success Rate (TSR)	84%
Weld Quality Index (WQI)	81.7

D. *Evaluation and Trainer Capacity Building*

Safety integration was assessed through direct monitoring of PPE usage and SOP compliance during practical sessions. The average Safety Compliance Rate (SCR) reached 94%, reflecting strong adherence to occupational safety standards.

To ensure sustainability, a Training of Trainers (ToT) session was conducted. Three instructors completed the program, exceeding the minimum requirement of two trainers. The resulting Program Sustainability Index (PSI) reached 150%, indicating institutional readiness to continue future training cycles independently.

TABLE 4. Evaluation and Sustainability Indicators

Indicator	Value
Safety Compliance Rate (SCR)	94%
Trainers Completing ToT	3
Minimum Trainers Required	2
Program Sustainability Index (PSI)	150%

Discussion

Structured progression from initial deficiencies to measurable competency gains was observed following the implementation of the Competency-Based Training (CBT) model. The needs assessment revealed a limited theoretical foundation and insufficient awareness of parameters, confirming that prior exposure was predominantly procedural rather than competency-oriented. Such conditions are characteristic of informal vocational environments in which repetitive practice substitutes structured conceptual instruction. The baseline profile, therefore, justified the need for a systematic instructional intervention aligned with industry standards.

The theoretical instruction phase directly addressed the identified gaps by reinforcing welding geometry, electrode selection strategy, heat input control, and defect mechanisms. The increase in the mean score from 48.7 to 86.4, reflected in a Training Effectiveness Ratio (TER) of 1.77, indicates substantial cognitive improvement. More critically, qualitative observation revealed a shift in reasoning patterns: participants transitioned from mechanically executing welding tasks to demonstrating parameter-based justification and positional control awareness. This transformation aligns with the fundamental principles of CBT, which emphasize mastery of performance-based competencies rather than rote procedural repetition.

Practical outcomes further validate the instructional design. A Training Success Rate (TSR) of 84% indicates that most participants were able to translate theoretical understanding into acceptable 2F weld performance. The Welding Quality Index (WQI) score of 81.7 confirms that weld outputs met entry-level fabrication standards. The integration of structured supervision and corrective feedback appears to have reduced defect occurrence and improved bead consistency, demonstrating the interdependence between cognitive preparation and psychomotor execution.

Safety integration strengthened the intervention's institutional impact. A Safety Compliance Rate (SCR) of 94% reflects effective internalization of occupational safety procedures. In informal workshop contexts, adherence to safety protocols is frequently underemphasized; therefore, the systematic integration of PPE monitoring and SOP enforcement represents an important institutional improvement beyond technical skill acquisition.

The Program Sustainability Index (PSI) of 150% demonstrates institutional readiness to continue the training model independently. The inclusion of a Training of Trainers (ToT) component transforms the intervention from a temporary workshop into a scalable educational framework. This sustainability dimension distinguishes the present model from short-term skill-based initiatives that lack long-term institutional integration.

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While the structured CBT framework demonstrated measurable improvements across cognitive, technical, safety, and sustainability domains, several limitations must be acknowledged. The intervention was conducted within a single institutional setting with a limited participant cohort, which may restrict broader generalizability. Weld quality assessment relied primarily on structured visual inspection rather than mechanical strength or destructive testing. Additionally, long-term competency retention was not evaluated, leaving the durability of learning outcomes to future investigation.

Despite these limitations, the study contributes a multi-dimensional evaluation framework integrating TER, TSR, WQI, SCR, and PSI indicators. The combination of performance measurement and trainer capacity development enhances institutional scalability and provides a replicable model for vocational education in non-formal training environments.

V. Conclusion

The implementation of a structured Competency-Based Training (CBT) model improved welding competency in a non-formal vocational training environment. The initial needs assessment identified clear gaps in theoretical understanding, welding position control, and parameter configuration. These findings showed that previous learning relied on repetitive practice without structured conceptual reinforcement.

The training program combined theoretical instruction, supervised practical exercises, measurable performance indicators, safety monitoring, and development of trainer capacity. Participants increased their theoretical understanding and demonstrated the ability to apply parameter-based reasoning during welding practice. An 84% Training Success Rate and a Weld Quality Index of 81.7 indicate that most participants achieved acceptable entry-level fabrication standards. High safety compliance and the Program Sustainability Index confirm that the institution can sustain the training model independently.

Effective vocational competency development requires a balanced approach to reinforcing knowledge, practical execution, safety awareness, and institutional support. The structured CBT framework provides a practical, replicable model for vocational institutions seeking to transition from repetition-based instruction to competency-oriented training.

Future implementation should involve a larger participant group, comparison with alternative instructional models, and mechanical strength testing to strengthen technical validation. Long-term monitoring is also necessary to evaluate knowledge retention and sustained welding performance.

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