

Analysis and Mapping of Technical Competency Needs for TVET Teachers in the Era of Industry 4.0

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Abstract

Vocational education in Indonesia still faces challenges, especially regarding limited teacher access to technical competency training due to industry needs. This study aims to map and analyze the access of Vocational High School (SMK) teachers to technical training in 10 areas of expertise in West Java. The method used is quantitative descriptive with a survey of 356 productive teachers from a population of 3,254. Measurement of technical competency refers to the Indonesian National Qualification Framework (KKNI) Level IV Certification Scheme. The study results show that teacher access to training is still low, with only 32.4% of 130 competency units accessed. Training organized by the government through the Center for the Development of Vocational Education Quality Assurance (BBPPMPV) has only been accessed by 19.4% of teachers, while 13% accessed training independently. Digital competency is the skill with the lowest achievement in all areas of expertise. This low access to training impacts the skills gap between teachers and industry needs, which has implications for the readiness of SMK graduates to face the world of work. These findings emphasize the need for an upskilling model based on industry needs involving government, industry, and training institutions. Increasing the frequency and quality of training can be done through industry-based schemes, digital platforms, and blended learning. In addition, strategic policies that ensure equal access to training for teachers in various regions are important to improve the quality of vocational education. This step is expected to improve the skills of productive vocational school teachers so that they are more relevant to technological developments and industry demands.

1. Introduction

Vocational education at the secondary level in Indonesia is called Vocational High School (SMK) to produce graduates who have practical skills and are ready for industrial work (Aprilia Santika, Eva Riris Simanjuntak, Rizky Amalia, 2023) (Disas, 2018). The competence of teachers determines the readiness to work and the quality of vocational high school graduates. These incredibly productive teachers can provide learning according to the needs of the world of work and industry (Riska et al., 2023) (Sutrisna & Rozak, 2023). Teachers, as educators, have an important role in equipping students with relevant competencies. However, the facts are that many

vocational high school teachers in Indonesia still face significant challenges related to mastering technical competencies that are related to industrial needs (Masnah et al., 2024). These competency limitations have an impact on the quality of learning in vocational schools, so vocational school graduates are often not ready to face the demands of specific skills needed in various industrial sectors (Kamaludin et al., 2022) (Nurjanah et al., 2022).

The gap between the technical competence of vocational high school teachers and the competency standards in the industry still exists in various fields of expertise. The use of technology in various industries changes very rapidly and is often not comparable to the curriculum and learning in schools (Jumde et al., 2023). Therefore, teachers are required to improve their competence with continuous competency development, one of which is by participating in various competency training. Teachers' mastery of technical competencies must also be in line with the development of relevant learning methods so that students can efficiently master the latest skills needed by Industry (Khan et al., 2022; Tomory, 2023). This gap occurs due to various factors, including limited teacher access to technical competency training provided by the government or non-government, the limited technical competency training institutions needed by the industry, lack of industry involvement in the teacher training process, and limited infrastructure support in many vocational high schools (Konovalov et al., 2022; Kebede & Asgedom, 2024).

Limited access to technical competency training programs organized by the government and non-governmental institutions has a significant impact on improving teacher competency. In fact, training that refers to the Indonesian National Work Competency Standards (SKKNI) should help teachers update their skills to remain relevant to industrial developments (Fairman et al., 2020). Limited training for vocational high school teachers in various fields of expertise occurs mainly for teachers in areas where access to training institutions is very limited (Parvin, 2017; Luschei & Zubaidah, 2012). The opportunity for teachers in various regions to access training is highly dependent on budget availability, capacity limitations, and other factors

This article is the result of a study aimed at mapping and analyzing access and needs of vocational high school teachers for technical competency training with a case study of productive teachers in 10 (ten) areas of expertise of vocational high schools in West Java. The number of Vocational High Schools (SMK) in West Java is currently 2,933, including 288 public schools and 2,645 private schools. Meanwhile, there are 55,587 teachers spread across public and private vocational high schools, and only 9,761 people (17.56%) are productive subject teachers. At the same time, the rest are non-productive subject teachers (Results of Vocational Educator Map Analysis, 2022). From the results of access mapping and needs analysis, a new training model would be designed. Upskilling and upgrading programs allow teachers to continuously update their knowledge in accordance with the latest developments in science and technology (Bonita Destiana, 2017). This model is designed to provide a holistic approach to improving the qualifications and abilities of vocational school teachers so that they can provide more relevant, dynamic, and industry-demand-appropriate learning. The skilled vocational school teacher model and graduates who are ready to work can make a positive contribution to economic growth (Santoso, 2014).

2. Method

The study used a quantitative approach with a descriptive method. The descriptive method was used to describe the survey results as a questionnaire to determine the technical competency needs of vocational high school teachers in West Java. The descriptive method was chosen to present a systematic picture of the data collected and to map the existing competency gaps. Data was collected through structured questionnaires distributed to productive teachers in vocational high schools. The data obtained were analyzed using descriptive statistics to calculate the frequency distribution and percentage to measure the technical competency training the teachers received. This percentage value describes the proportion of teachers who have received training in a particular competency field so that gaps and differences can be identified between regions in competency development.

2.1 Instrument

The research instrument is a questionnaire designed based on indicators of technical competency in the KKNI Level IV Certification Scheme and the Center for Development of Quality Assurance of Vocational Education (known as Balai Besar Pengembangan Penjaminan Mutu Pendidikan Vokasi – Bidang Mesin dan Teknik Industri or BBPPMPV BMTI) training program based on each expertise competency. The research object is limited to ten areas of expertise consisting of Building Modeling and Information Design, Construction and Sanitation Business, Machining Engineering, Light Vehicle Engineering, Welding Engineering, Industrial Automation Engineering, Software Engineering, Culinary Arts, Fashion Design, and Logistics Engineering. Technical competency is measured using a Guttman scale questionnaire with a score of 1-0 with Yes-No answer alternatives. Respondent characteristics are classified by region, age, and education level. The questionnaire was distributed online via Google Forms in collaboration with the West Java Provincial Education Office.

2.2 Sample

The subjects of the study were productive teachers in several vocational schools in West Java. The sampling technique used in the study was purposive sampling with a set of criteria. The population size taken was the number of productive teachers in vocational schools in West Java with ten areas of expertise, amounting to 3,254 people. The determination of sample numbers was carried out using the Slovin formula with a percentage error (5%) so that the results of the calculation obtained a sample size of 356 people.

3. Result and Discussion

3.1 Demographics

Table 1 *Sample demographics*

Description	Frequency	Percentage (%)
Gender		
Man	269	70.1%
Woman	115	29.9%
Age		
Less than 23 years	3	0.8%
24-29	64	16.7%
30-35	97	25.3%
36-41	63	16.4%
42-47	79	20.6%
48-53	42	10.9%
54-60	36	9.4%
Level of Education		
Undergraduate	349	90.9%
Post Graduate	35	9.1%
Employee Status		
civil servant	98	25.5%
PPPK	160	41.7%
Honorary	126	32.8%
Functional Position		
Main Teacher	9	2.3%
Associate Teacher	32	8.3%
Young Teacher	55	14.3%
First Teacher	192	50%
There isn't any	96	25%
Work Experience		
Less than 1 year	6	1.6%
1-5 years	108	28.1%
6-10 years	92	23.7%
More than 10 years	178	46.4%

Respondent demographics (Table 1) show a male predominance in the manufacturing and engineering technology fields, in line with the global trend where men still dominate vocational education in the engineering sector, while fields such as culinary arts and fashion are more popular with women (Zhou & Chen, 2025; UNESCO, 2021). Social factors and gender stereotypes continue to influence participation in vocational education in various countries, especially in women's access to technical training (Tikly et al., 2020; Simovicova & Urbancíková, 2023). Regarding age, most respondents are in the 30-47 year range, a productive age with sufficient work experience to enhance the effectiveness of practice-based learning (CEDEFOP, 2022). Although more than 90% of teachers have at least a bachelor's degree (S1), a significant challenge in many developing countries is the lack of productive teachers

with industry experience, who play a crucial role in skills-based vocational teaching (Wahyuni et al., 2022; ADB, 2023).

Globally, the gap between vocational education and industry needs remains a significant challenge (World Economic Forum, 2023). Countries with advanced vocational systems, such as Germany and Switzerland, have succeeded in bridging this gap through apprenticeship programs and close partnerships between industry and educational institutions (Busemeyer & Trampusch, 2021). In contrast, in many developing countries, limited policies, training infrastructure, and low industry involvement are still obstacles to producing a workforce ready to face global market demands (ILO, 2022; ADB, 2023). Therefore, this study emphasizes the need for adaptive strategies that not only improve the competence of vocational teachers but also strengthen the linkages between education and the industrial world to ensure the readiness of graduates in global competition.

3.2 Policy on Technical Competency Standards in Indonesia

The Indonesian Government's policy on technical competency standards for vocational high school teachers is carried out as a strategic step to improve the quality of vocational education that is relevant to industry needs (Sayuti, 2017). The implementation of this policy is carried out through government institutions that have the main function of compiling, developing, and monitoring competency standards in accordance with the Indonesian National Work Competency Standards (SKKNI). Technical competencies for all expertise programs in vocational high schools refer to KKNI level IV and the Upskilling and Re-skilling Program of the Center for the Development of Vocational Education Quality Assurance (BBPPMPV). This institution is a technical implementing unit (UPT) under the Ministry of Education, Culture, Research, and Technology (Kemendikbud Ristekdikti), Directorate General of Vocational Education. This unit is divided into several fields that oversee several vocational high school expertise programs. Diagrammatically, the structure of the management and grouping of technical competency units in each area of expertise can be seen in Figure 1.

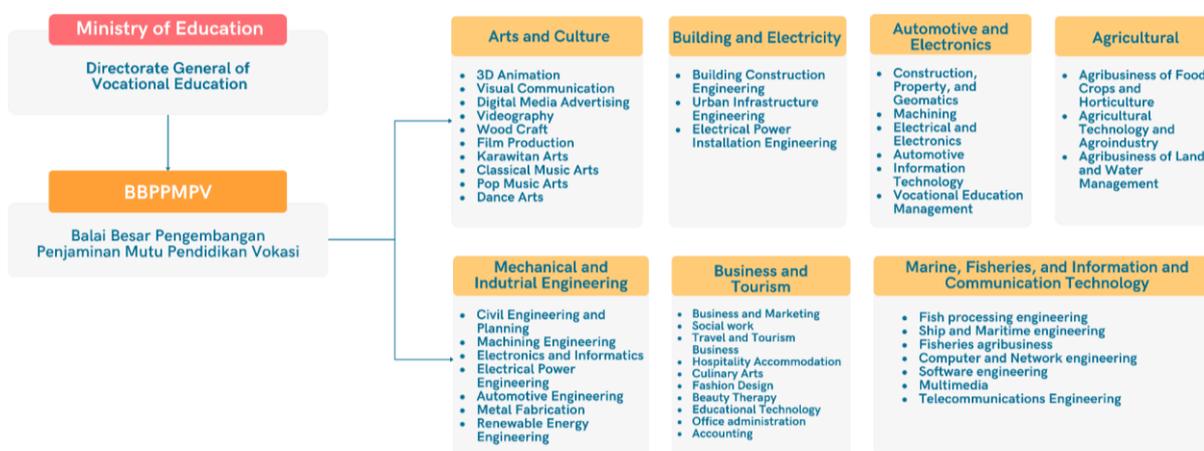


Fig. 1 Mapping of BBPPMPV expertise groups and technical competency units source: kemendikbud.go.id (redrawn by the researcher) mapping access to technical competency training

3.3 Mapping Access to Technical Competency Training

Mapping technical competency data of vocational high school teachers can provide a clear picture of the level of teacher competency achievement and their access to competency improvement training in their respective fields of expertise (Wahyuni et al., 2020). Mapping was done by analyzing questionnaire data based on the Guttman scale, which measures teacher involvement in technical competency training programs with alternative answers (1 = Yes, have attended training; 0 = No, have not attended training). The level of teacher participation in training is based on the proportion of teachers who have attended training compared to the respondents in each field of expertise. Mapping data only includes training participation, excluding independent learning or informal training that can improve teacher competency. In addition, mapping does not consider other factors that influence access to training, such as financial constraints, time constraints, or lack of information about training opportunities. Through this mapping, competency gaps and areas that require further development can be identified, and more targeted and relevant training programs can be designed to improve the quality of teaching and the readiness of graduates to face the world of work (Tian et al., 2023), (Raj et al., 2024). Mapping access to technical competency training for SMK teachers in this study is based on the focus of vocational revitalization from the Renstra of the

Directorate General of Vocational Education in selecting the Field of Expertise. The focus of revitalization of 3 (three) of the 4 (four) fields of work, namely Machinery and Construction), Creative Economy, and Hospitality, which are divided into 10 fields of expertise (Table 2).

Table 2 *Technical competence of vocational high school teachers based on KKNI Level IV competency units*

Expertise Program	Competency Unit	Average Percentage	Category
Building Information and Modeling Design	Wood Finishing, Use of Woodworking Equipment and Machine Operation, Building Construction Budgeting with Ms. Project Application, Rendering and Post Production of 3D Animation Modeling, 2D Animation, Building Modeling with BIM-based Applications, Construction Cost Estimation, Drawing Roads and Bridges, Structural Drawing, Architectural Drawing, General/Core Competency Units	34%	Low
Construction and Property Business	Wood finishing, Use of equipment and machine operation, Building Construction Budgeting with Ms. Project	6%	Low
Machining Techniques	Lathe machine operation, Shielded Metal ARC Welding, Gas Tungsten ARC Welding (GTAW), Metrology, 3D Model with CAD, CNC Machine Operation, Use of CAD CAM software, CNC Programming, Lathe and Milling machine operation, Professional assistant Machine tools, CNC machine operator, Machine tool operator, Lathe machine operator	36%	Low
Light Vehicle Engineering	Motorcycle engine maintenance injection system, Light vehicle maintenance and repair, Engine management system, electronic fuel system maintenance, Vehicle AC system maintenance, light vehicle periodic maintenance, light vehicle EFI system maintenance, basic introduction to heavy equipment maintenance, engine overhaul, car brake and ABS maintenance, Power transfer system maintenance, steering and power steering system maintenance, automatic transmission maintenance, car AC system maintenance, suspension system maintenance and light vehicle spooling balancing, light vehicle periodic maintenance, light vehicle injection system maintenance, conventional light vehicle system maintenance	35%	Low
Welding Techniques	Shielded metal ARC welding (SMAW), Gas tungsten ARC welding (GTAW), Gas metal ARC welding (GMAW), Visual welding inspector, FCAW welding techniques for LKP instructors, Ducting system, Advanced TIG welding (GTAW) 1 and Advanced 2, Advanced MIG welding (SMAW) 1 and Advanced 2, Advanced manual arc welding (SMAW) 1, Advanced 2, and Advanced 3, Advanced oxyacetylene welding (OAW), basic MIG welding (GMAW) and TIG welding (GTAW), application of basic welding techniques	32%	Low
Industrial Automation Engineering	Use of multimeter/Avo, maintaining and repairing programmable logic control (PLC), PLC operation, Installing industrial electrical automation installations, installing and connecting maintenance systems, installing PLC installations, Operation, and maintenance of SMK CoE TOI equipment, Assembly of electronic equipment and systems, pneumatic systems, and electrical systems, operation and maintenance of electronic systems, pneumatic systems, and electrical systems, operation and maintenance of electronic equipment, pneumatic equipment, and electrical equipment	55%	Low

Expertise Program	Competency Unit	Average Percentage	Category
Logistics Engineering	Supply chain management, warehouse and distribution management, warehouse assistant manager, warehouse administrative supervisors (logistics supervisor), warehouse operations supervisor (warehouse supervisors), Inventory control specialist, administrative warehouse officer, warehouse operations officer	18%	Low
Software engineering	Database Foundation, Java foundation, Technopreneurship in RPL field, Basic level android application, Mobile application creation, Desktop application creation, Object-oriented programming, Framework based web programming, Web programming, Database creation, Software design	41%	Low
Culinary art	Management of catering and restaurant businesses, processing and arranging food using fusion techniques, management of catering businesses, processing of various pastry and bakery products, management of various Indonesian cakes, food and beverage services in restaurants, processing of various Indonesian, Asian, and Continental foods, Food production (patisserie), food production (operations), food production (cookery)	27%	Low
Fashion	Photoshop for textile design, fashion business plan, CAD-based digital fashion pattern making, Digital fashion design illustration, 3D Fashion design, work title, design realization, fashion pattern making, fashion design making, fashion drawing making	40%	Low
Average		32.4%	Low

Technical competency training for vocational high school teachers refers to the KKNi Level IV competency standards with competency units in each field of expertise. The data in Table 2 illustrates the cumulative achievement of teacher access to technical competency training, formally organized by the government through BMTI, and training accessed by teachers in non-governmental institutions. Of all respondents who responded, an average of 32.4% showed that teacher access to technical competency training in each field of expertise was still low/lacking. This low percentage causes a significant gap in improving the technical competency of vocational high school teachers, especially in expertise programs directly related to Industry 4.0 and the development of modern technology (Asuncion et al., 2023; Antonietti et al., 2022). Many factors cause low teacher access to various types of competency training, including budget allocation for teacher training at government-appointed training bodies is not optimal, uneven distribution of opportunities for teachers, low industry involvement, readiness of training facilities and infrastructure (Zindi & Sibanda, 2023) (Mainali & Bhurtel, 2024) (Subekti et al., 2024). Teacher access to quality training for vocational high school teachers mainly occurs in areas with limited resources, remote training locations, inflexible training times, and limited budget and accessibility to participate in intensive training (Sudirman & Suharsih, 2018), (Wang et al., 2025). This condition causes a gap that impacts the overall quality of vocational education because teachers do not have the latest skills needed to meet the demands of the labor market (Nambiar et al., 2019; Jamaludin et al., 2023; Shahbazi & Ahmady, 2022), (Wahyudi & Pambudi, 2023). The quality of teachers in mastering technical skills according to standards dramatically determines the quality of vocational school graduates and their readiness to meet the labor market demands (Chigbu & Nekhwevha, 2022; Anwar et al., 2023).

Technical competency training in the areas of expertise in Property and Construction Business and Logistics (Table 2) Engineering is still below average. The absence or low access to training in these areas will potentially cause vocational school graduates in related fields not to have the skills required by Industry (Li, 2022). This study also found that, in addition to the KKNi technical competency units, some teachers have accessed various competency units needed by Industry from various training institutions, for example, python programming, PHP (Hypertext Processor) programming, 2 and 3-dimensional educational games, metamesta, 3D generalist, construction and property technology, plumbing training, fuso service technician education program, and industrial mechanical maintenance. This means that improving the technical competency of teachers in each area of expertise is very dynamic, and the importance of access to developments in competency needs in Industry.

These findings need to be analyzed in more depth to see the various causal factors, and it is also necessary to examine whether all competency units standardized by the KKNl are highly relevant to industry needs.

3.4 Analysis of Technical Competency Training Needs for Vocational High School Teachers

Teachers' technical competence is one of the factors that influence the quality of learning and the readiness of vocational school graduates to face the job market (Kulpa-Puczyńska, 2014). Expanding access to more comprehensive and intensive training for vocational school teachers is needed, especially in rapidly developing fields such as industrial automation engineering and software engineering (Hennessy et al., 2022; Mukul & Büyüközkan, 2023). Improving training programs that are in line with technological developments and industry needs will help vocational school teachers improve their competence and have an impact on improving the quality of vocational education in Indonesia (Inderanata & Sukardi, 2023) (L. Widaningsih et al., 2024) (Maknun et al., 2025). Structured training programs that are relevant to industry needs can significantly improve teachers' technical skills and have a positive impact on the readiness of vocational school graduates (Barrick, 2018). A competency-based training approach that refers to the specific needs of each expertise program can help improve teacher competence more effectively (Serdenciuc, 2013).

The policy of implementing training requires further study, considering the increasing development of technical competencies needed by the industry. The development of training that is more evenly distributed and relevant to industrial developments will support the improvement of the quality of teaching in vocational schools and, ultimately, increase the competitiveness of vocational school graduates in the labor market (Loveder, 2021). A cooperation scheme between the government, training institutions, and Industry is needed to provide easily accessible training programs, especially for areas of expertise with low access levels (Chohan & Hu, 2020; Zamiri & Esmaeili, 2024). Analysis of needs in each field of expertise based on findings and demands of the industrial world, at least the competency units that are a priority in each field of expertise can be identified as follows:



Fig. 2 Digital skills needed for TVET teachers

Skills needed in the digital era (Figure 2) adopt research findings that highlight critical skills needed by the manufacturing industry (Trevisan et al., 2024). Digital skills are categorized into 7 (seven) specific categories related to the application of technology in the industrial era 4.0. This study was adopted to be related to the competency needs of productive vocational high school teachers in construction, welding, machining, light vehicle engineering, industrial automation engineering, logistics engineering, software engineering, culinary, and fashion. The application of advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and robotics in vocational high school learning has the potential to increase teacher readiness in teaching skills that are relevant to industry needs (Tew et al., 2022). IoT allows devices and systems to be automatically connected via an internet network, which can be applied in various fields, such as industrial automation and sensor-based machine monitoring. IoT in vocational education can improve students' technical skills and help them understand more complex production processes (Chookaewet al., 2024). However, the main challenge in implementing this technology is teachers' lack of understanding and skills in integrating IoT into the curriculum. Therefore, industry-based training and a hands-on learning approach involving the practical use of IoT devices are needed so that teachers can understand the basic concepts and their applications in the industrial world (Dubey & Kumar, 2025).

In addition to IoT, AI also plays an important role in the transformation of vocational education. AI can be used in adaptive learning systems that can adjust materials to the abilities and needs of individual students, thereby increasing the effectiveness of learning (Zawacki-Richter et al., 2019). In industry, AI is often used for data analysis, production process optimization, and business intelligence processing, making it an important skill for vocational high school students. Teachers still have difficulty understanding the concept of AI due to the lack of experience and resources available in schools (Molefi et al., 2024). Therefore, teacher training that combines theory and practice, such as AI-based online courses and workshops with industry experts, can be a solution to improve teachers' understanding of this technology.

Robotics is also important in vocational education, especially in engineering and manufacturing. Robots in learning allow students to acquire skills in programming, mechatronics, and industrial automation that are highly needed in various sectors of modern industry (Benetti, 2012). However, the challenges in implementing robotics in vocational schools are teacher readiness and limited school infrastructure (Sapounidis & Alimisis, 2021; Ghosh & Ravichandran, 2024). Many teachers do not have experience in programming and operating robots, so they need special project-based training to develop their skills directly. Approaches such as Project-Based Learning (PBL) can be an effective method to improve the skills of teachers and students in the field of robotics (Ates & Aktamis, 2024). In addition, collaboration between vocational schools, universities, and industry is also needed to provide better resources and support the integration of advanced technology into the vocational school curriculum.

Operation and monitoring of production systems integrated with IoT allows for industrial automation engineering teachers to teach to respond to the needs and work standards in the industry. Data analysis through AI can be utilized by teachers in software engineering and logistics engineering, such as using big data and machine learning to optimize product production and distribution stages. The use of IoT as an integrated system allows real-time data from various devices, such as Building Information Modeling (BIM) modeling, which is used to design, build, and manage project management, which systematically provides efficiency to the construction process (Kim et al., 2012) (Shehzad et al., 2021). The teaching process of productive teachers is required to implement technology efficiently in achieving industrial sustainability goals.

4. Conclusion

Mapping technical competency data of vocational high school teachers provides an overview of how far the skills possessed by teachers are by national standards and needs and identifies gaps that occur. The study results show that teacher competency achievements and access to competency improvement training in their respective fields of expertise are still low. Low teacher access to training occurs mainly in areas with limited resources, remote training locations, inflexible training times, and limited budget and accessibility to participate in intensive training. This condition causes gaps that impact the quality of vocational education because teachers do not have the latest skills needed to meet the labor market demands. The results of mapping access to training and analysis of the causal factors can identify the need to design more targeted and relevant training programs to improve the quality of teaching and the readiness of graduates to face the world of work. In addition to the national standards of technical competencies needed by vocational high school teachers in the era of the Industrial Revolution 4.0, the need to adjust the competency units trained for teachers must be relevant to industry needs. The research findings also identified several competency units, especially those related to digital competencies, that teachers can access outside of formal training provided by government institutions. Thus, the mapping of needs from the results of this study is critical to be developed in the form of an upskilling model for technical competencies for vocational high school teachers with a collaboration strategy between the government, universities providing vocational high school teachers, training institutions, and industry. Based on the conclusions of the research results, it is recommended that the need for different types of training be analyzed, competency-based training curricula should be designed, effective learning methods developed, collaboration with the industrial world should be developed, and the implementation of training should be periodically evaluated.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **Study conception and design:** Lilis Widaningsih, Muktiarni; **Data collection:** Sri Rahayu, Vina Dwiyananti; **Analysis and interpretation of results:** Lilis Widaningsih, Wiwi Widaningsih, Muktiarni; **Draft manuscript preparation:** Vina Dwiyananti, Wiwi Widaningsih. All authors reviewed the results and approved the final version of the manuscript.*

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