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## Strengthening Data Literacy Among Vocational High School Students Through a Service-Learning-Based Data Science Training Program

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**Abstract.** Data literacy has become a critical competency in the digital era, particularly for vocational high school students who are expected to meet the evolving demands of data-driven industries. However, many vocational education institutions in Indonesia have not yet adequately integrated data science skills into their curricula, resulting in a gap between educational outcomes and workforce requirements. To address this challenge, a Service-Learning-based community engagement program was implemented to strengthen students' foundational competencies in data science. This community service program was conducted at SMK Muhammadiyah 3 Banjarmasin and involved 30 students from the Software Engineering Department. Adopting a Service Learning approach, the program consisted of needs assessment, instructional workshops, guided practice sessions, mentoring, and evaluation activities. Training modules covered data science fundamentals, data management and visualization using Microsoft Excel Pivot Tables, and introductory Python programming. Program effectiveness was assessed using a pre-test and post-test design, complemented by participant satisfaction surveys. The findings revealed a substantial improvement in participants' data literacy competencies. The average score increased from 50.1 in the pre-test to 81.9 in the post-test, representing an improvement of 31.8 points or 63.5%. The highest learning gains were observed in the Microsoft Excel module due to its practical and interactive learning activities. Participant feedback was highly positive, with 92% of students rating the program as good or very good. The results indicate that hands-on and application-oriented learning activities effectively facilitate the acquisition of foundational data science skills among vocational students.

**Keywords:** Data Literacy; Data Science Education; Service Learning; Vocational High School; Community Engagement

### 1. Introduction

The rapid advancement of digital transformation has fundamentally changed the competencies required in the contemporary workforce (Call, 2022; Gandhi, 2026). Among these competencies, data literacy has emerged as a critical skill that enables individuals to collect, manage, analyze, interpret, and communicate data effectively for decision-making

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purposes. In the context of Industry 4.0 and the digital economy, organizations increasingly rely on data-driven strategies, making data literacy and data science competencies essential for future employability (Angelelli et al., 2024; Bakir et al., 2025; Saura et al., 2024). Likewise, the concept of computational thinking by Li et al. (2020) and Liao et al. (2024) emphasizes the importance of analytical reasoning and problem-solving skills that underpin modern data science practices. Consequently, educational institutions are expected to equip students with foundational data competencies to prepare them for increasingly technology-oriented workplaces.

Recent studies have highlighted the growing importance of integrating data science education into secondary and vocational education systems. Data literacy has been recognized as a key component of twenty-first-century skills, alongside critical thinking, collaboration, communication, and digital competence (Mahmud & Wong, 2022). Research conducted by Nurbekova et al. (2020) demonstrated that experiential and project-based learning approaches significantly improve students' computational thinking and technological competencies. Similarly, Watson (2014) argued that early exposure to data analytics concepts can enhance students' readiness to engage in digital innovation and evidence-based decision-making. These findings suggest that practical and learner-centered approaches are effective strategies for developing foundational data competencies among young learners.

Vocational education institutions in many developing countries continue to face challenges in integrating data science competencies into their curricula. In Indonesia, vocational high schools (Sekolah Menengah Kejuruan/SMK) play a strategic role in preparing graduates for direct entry into the workforce. However, studies have revealed a persistent mismatch between vocational curricula and the skills demanded by industry. Sabirin & Sulistiyarini (2021) reported that many SMK programs have not fully adapted to the growing demand for digital and analytical competencies, resulting in a skills gap among graduates. Students often possess basic computer literacy but have limited exposure to data analysis tools such as Microsoft Excel Pivot Tables, Python programming, and data visualization techniques, which are increasingly required in modern workplaces.

Universities have an important responsibility to contribute to societal development through knowledge transfer and capacity-building initiatives. Service Learning (SL) has been widely recognized as an effective pedagogical and community engagement approach that combines academic expertise with community needs while generating reciprocal benefits for both institutions and beneficiaries (Salam et al., 2019; Schultes et al., 2025). Unlike conventional outreach programs, Service Learning emphasizes active participation, experiential learning, reflection, and sustainable community impact. Through this approach, higher education institutions can support schools and local communities in addressing educational challenges while simultaneously enriching the learning experiences of university educators and students.

Although previous studies have examined technology training, computational thinking development, and digital literacy interventions among secondary school students, there remains limited evidence regarding Service-Learning-based data science education programs targeting vocational high school students, particularly in Indonesia. Existing studies predominantly focus on formal classroom instruction or short-term technical training, with relatively little attention given to university-community



partnerships that integrate community service objectives with data literacy development. Furthermore, documented community service initiatives specifically addressing foundational data science competencies using practical tools such as Microsoft Excel and Python remain scarce, especially within the vocational education context of Kalimantan. This gap highlights the need for evidence-based models that demonstrate how universities can contribute to strengthening digital competencies among vocational students through structured community engagement activities.

The significance of this community service program lies in its potential to bridge the gap between vocational education outcomes and industry expectations while promoting meaningful collaboration between higher education institutions and schools. By introducing practical data science concepts and analytical tools through a Service Learning framework, the program contributes to the development of workforce-relevant competencies and supports the broader goal of digital transformation in education. Moreover, the initiative provides a replicable model for community engagement in technology education that can be adapted by other institutions facing similar challenges.

Therefore, this community service project aimed to strengthen data literacy among vocational high school students through a Service-Learning-based data science training program at SMK Muhammadiyah 3 Banjarmasin. Specifically, the program sought to: (1) introduce fundamental concepts of data science and data literacy; (2) develop practical skills in data manipulation and visualization using Microsoft Excel and Python; (3) evaluate participants' knowledge improvement through pre-test and post-test assessments; and (4) assess participant satisfaction with the training program as an indicator of community engagement effectiveness.

## 2. Methods

This community service program employed a Service-Learning (SL) approach to strengthen data literacy competencies among vocational high school students (Ng *et al.*, 2024; Resch & Schrittester, 2023; Warner, 2020). Service Learning was selected because it integrates academic expertise with community needs through experiential and participatory learning activities, enabling participants to acquire practical knowledge while addressing educational challenges within their local context. The program was conducted at SMK Muhammadiyah 3 Banjarmasin, South Kalimantan, Indonesia, involving 30 students from the Software Engineering Department (*Rekayasa Perangkat Lunak/RPL*). The participants were selected based on recommendations from school administrators and their interest in enhancing digital and analytical skills relevant to future workplace demands.

The implementation of the program consisted of four sequential stages: needs assessment, training preparation, instructional delivery, and evaluation. During the needs assessment stage, discussions were conducted with school management and teachers to identify students' prior knowledge, technological resources, and competency gaps related to data science and data literacy. The results indicated that although students possessed basic computer skills, they had limited experience in data analysis, data visualization, and programming applications. Based on these findings, training materials were developed to align with participants' learning needs and vocational backgrounds.

The instructional phase combined lectures, demonstrations, hands-on practice, and



mentoring sessions. Three training modules were delivered: (1) Introduction to Data Science and Data Literacy, which introduced the concepts of data, information, and data-driven decision making; (2) Data Management and Visualization Using Microsoft Excel, focusing on data cleaning, sorting, filtering, Pivot Tables, and chart creation; and (3) Introduction to Python Programming for Data Analysis, covering basic programming concepts and simple data processing techniques. Throughout the activities, participants were encouraged to engage actively in practical exercises and collaborative problem-solving tasks using real-world datasets.

Program effectiveness was evaluated using a one-group pre-test and post-test design. Before the training commenced, participants completed a pre-test designed to assess their baseline understanding of data science concepts and analytical tools. Following the completion of all training activities, the same assessment instrument was administered as a post-test. In addition, participants completed a satisfaction questionnaire to evaluate the quality and relevance of the training program. The collected data were analyzed descriptively using mean scores, standard deviations, score differences, and percentage improvements to determine the effectiveness of the Service-Learning-based intervention in improving students' data literacy competencies.

Table 1 Stages of the Service-Learning-Based Data Science Training Program

Stage	Activities	Expected Outcomes
Needs Assessment	Discussions with school administrators and teachers; identification of students' competency gaps	Identification of training needs and participant characteristics
Training Preparation	Development of learning modules, teaching materials, and assessment instruments	Availability of structured and contextually relevant training materials
Instructional Delivery	Lectures, demonstrations, hands-on practice, mentoring, and reflection activities	Improvement of students' knowledge and practical skills in data science
Evaluation	Pre-test, post-test, and participant satisfaction survey	Measurement of learning outcomes and program effectiveness

Table 1 summarizes the implementation stages of the community service program. The framework illustrates how the Service-Learning approach was systematically applied, beginning with the identification of community needs and continuing through instructional activities and outcome evaluation. This structured process ensured that the training content was aligned with participants' existing competencies and learning requirements while facilitating active engagement throughout the program. Furthermore, the integration of practical exercises, mentoring, and assessment activities enabled participants to develop foundational data science skills and provided measurable evidence regarding the effectiveness of the intervention.

### 3. Results and Discussion

The Service-Learning-based data science training program was successfully



implemented at SMK Muhammadiyah 3 Banjarmasin with the participation of 30 students from the Software Engineering Department. Throughout the program, participants engaged in a series of learning activities designed to strengthen their understanding of data literacy and introductory data science concepts. The training combined theoretical instruction with hands-on practice, enabling students to directly apply analytical techniques using Microsoft Excel and basic Python programming. Active participation was observed during workshop sessions, particularly during practical exercises involving data manipulation, visualization, and simple programming tasks.

Several indicators were examined, including participants' learning outcomes and the broader educational implications of the program. Quantitative assessment was conducted through pre-test and post-test evaluations administered before and after the training activities. The results were complemented by observations made during instructional sessions and reflections on the implementation of the Service-Learning approach. The following sections present the findings regarding participants' competency improvements, the effectiveness of the instructional approach, and the implications of the program for vocational education and workforce readiness.

### 3.1. Improvement of Participants' Data Literacy Competencies

The effectiveness of the Service-Learning-based data science training program was evaluated through pre-test and post-test assessments administered to 30 vocational high school students. The results indicate a substantial improvement in participants' knowledge and understanding of data science concepts, data management techniques, data visualization, and introductory programming skills. Prior to the training, the average pre-test score was 50.1 (SD = 6.81), suggesting that participants possessed limited baseline knowledge of data science and analytical tools. Following the completion of the training activities, the average post-test score increased to 81.9 (SD = 4.29), resulting in a mean improvement of 31.8 points or a relative gain of 63.5%.

The findings demonstrate that all participants experienced positive learning gains. Individual score increases ranged from 25 to 38 points, and no participant recorded a lower score in the post-test compared to the pre-test. These results suggest that the training materials and instructional methods were effective across different levels of prior knowledge. Furthermore, the decrease in standard deviation from the pre-test to the post-test indicates that participants' competencies became more evenly distributed after the intervention, reflecting a reduction in knowledge disparities among students.

Table 2 Summary of Pre-Test and Post-Test Results (n = 30)

Assessment	Mean Score	Standard Deviation
Pre-Test	50.1	6.81
Post-Test	81.9	4.29
Mean Gain	31.8	-
Percentage Improvement	63.5%	-

Table 2 presents a clear indication of a substantial improvement in students' data literacy competencies following the implementation of the Service-Learning-based data science training program. The mean pre-test score of 50.1 (SD = 6.81) reflects a relatively



low and heterogeneous level of prior knowledge among participants regarding data science concepts and analytical tools. After the intervention, the mean post-test score increased significantly to 81.9 (SD = 4.29), demonstrating a strong overall enhancement in students' understanding and skills. The reduction in standard deviation from 6.81 to 4.29 also suggests that participants' learning outcomes became more consistent, indicating a narrowing gap in competency levels among students. Furthermore, the mean gain of 31.8 points, equivalent to a 63.5% improvement, highlights the effectiveness of the training program in significantly strengthening foundational data literacy skills through hands-on and experiential learning activities.

The substantial increase in learning outcomes indicates that practical and application-oriented learning activities successfully facilitated the acquisition of foundational data science competencies. These findings support previous studies emphasizing the effectiveness of experiential learning and technology-based training in improving digital skills among secondary school students (Dahri et al., 2023; Eliaser Sinlae et al., 2025).

### *3.2. Effectiveness of the Service-Learning-Based Training Approach*

The findings indicate that the Service-Learning-based training approach significantly contributed to improving participants' data literacy competencies. This pedagogical model integrates community service activities with academic learning, allowing students to gain both theoretical knowledge and practical experience. Unlike traditional lecture-centered instruction, Service-Learning emphasizes active participation, collaboration, and experiential engagement. Through this approach, vocational students were encouraged to become active learners who directly applied newly acquired skills to real-world tasks. Such engagement enhanced their understanding of data-related concepts while fostering greater motivation and responsibility throughout the learning process.

During the Microsoft Excel training module, participants developed essential data management and analysis skills through hands-on activities involving Pivot Tables and Pivot Charts. Students learned how to organize, summarize, and visualize datasets, enabling them to transform raw data into meaningful information. These practical exercises strengthened their ability to interpret patterns and trends, which are fundamental competencies in data-driven decision-making. By actively manipulating datasets rather than passively receiving information, students developed a deeper conceptual understanding of data analysis and became more capable of applying analytical thinking to authentic workplace and academic contexts.

Similarly, the Python programming module provided participants with valuable exposure to basic coding and computational thinking. For many vocational students, programming represented a new and potentially challenging subject. However, the guided hands-on approach reduced learning barriers and promoted confidence in using digital technologies. Students were encouraged to experiment with code, identify errors, and develop solutions independently while receiving support from facilitators. This process nurtured critical thinking, creativity, and problem-solving abilities. As a result, abstract programming concepts became more accessible and meaningful, contributing to higher levels of student engagement and learning effectiveness.

The effectiveness of the program can be interpreted through Kolb's Experiential Learning Theory (Haritha & Rao, 2024; Healey & Jenkins, 2000), which posits that



learning occurs through a cyclical process involving concrete experience, reflective observation, abstract conceptualization, and active experimentation. Throughout the training, participants experienced each stage of this learning cycle. They engaged in practical tasks using Excel and Python, reflected on the outcomes of their activities, connected these experiences to theoretical concepts, and subsequently applied their knowledge in new exercises. This experiential process facilitated deeper knowledge construction and enhanced participants' confidence in utilizing digital tools for data analysis and decision-making.

The Service-Learning framework strengthened the collaborative relationship between Sari Mulia University and SMK Muhammadiyah 3 Banjarmasin. The program created opportunities for university lecturers and facilitators to share knowledge and expertise while simultaneously addressing the educational needs of vocational students. This reciprocal partnership reflects the fundamental principles of Service-Learning, which emphasize mutual benefit and shared learning experiences among all stakeholders. Consequently, the program not only improved students' technical competencies in data literacy but also reinforced the social responsibility of higher education institutions in supporting community development through meaningful educational engagement.

Table 3 Effectiveness of the Service-Learning-Based Training Approach

Learning Aspect	Program Implementation	Observed Impact
Active Participation	Students actively engaged in Excel and Python exercises	Increased learning engagement and motivation
Experiential Learning	Direct practice in data processing and programming	Improved understanding of abstract concepts
Data Analysis Skills	Use of Pivot Tables and Pivot Charts	Enhanced ability to analyze and interpret data
Problem-Solving Skills	Completion of Python coding exercises	Strengthened critical thinking and problem-solving abilities
Self-Confidence	Continuous mentoring and facilitator support	Increased confidence in using digital technologies
University-School Collaboration	Partnership between Sari Mulia University and SMK Muhammadiyah 3 Banjarmasin	Facilitated knowledge transfer and mutual learning benefits

Table 3 summarizes the effectiveness of the Service-Learning-based training approach across multiple learning dimensions. Active student participation in Excel and Python activities enhanced engagement and motivation, while experiential learning opportunities enabled participants to better understand complex concepts through direct application. The development of data analysis skills was evident through students' ability to utilize Pivot Tables and Pivot Charts effectively, whereas Python-based exercises strengthened critical thinking and problem-solving competencies. Facilitator mentoring played an important role in increasing students' confidence in applying digital technologies. In addition, the collaborative partnership between Sari Mulia University and SMK Muhammadiyah 3 Banjarmasin facilitated meaningful knowledge exchange and



embodied the reciprocal nature of Service-Learning, generating benefits for both the educational institution and the community partner.

### *3.3. Implications for Vocational Education and Workforce Readiness*

The findings of this community service program provide significant insights into the role of vocational education in preparing students for the challenges of a rapidly evolving digital economy. As industries increasingly adopt data-driven technologies and digital transformation strategies, the demand for employees who possess analytical, technological, and problem-solving competencies continues to grow. However, many vocational education institutions still face challenges in integrating practical data science skills into their curricula. This mismatch often creates a gap between the competencies acquired by graduates and the expectations of employers. The successful implementation of this training program demonstrates that targeted interventions can help bridge this gap by equipping students with essential digital competencies that are highly relevant to contemporary labor market needs.

A notable implication of the program is the confirmation that foundational data science competencies can be effectively introduced at the vocational secondary education level. The significant improvement in participants' assessment scores indicates that students are capable of understanding and applying basic concepts of data analysis when provided with appropriate instructional support. The use of accessible tools such as Microsoft Excel and introductory Python programming offers a practical and scalable pathway for integrating data science education into vocational learning environments. These tools enable students to develop analytical thinking, computational reasoning, and digital literacy skills without requiring advanced technical infrastructure, making them particularly suitable for vocational schools with diverse resource capacities.

The findings suggest that data science education should not be viewed solely as preparation for careers in information technology. The competencies developed through the training are transferable across multiple occupational sectors, including business administration, finance, manufacturing, logistics, and public services. Modern workplaces increasingly rely on data to support operational efficiency, strategic planning, and decision-making processes. Consequently, students who possess data literacy and analytical skills are likely to have a competitive advantage in the labor market. By introducing these competencies at an early stage, vocational institutions can better prepare graduates to adapt to technological changes and contribute effectively to data-driven work environments.

Another important implication concerns the strategic role of university-community partnerships in strengthening educational quality and local capacity development. The collaboration between higher education institutions and vocational schools creates opportunities for knowledge transfer, resource sharing, and professional mentoring that may not otherwise be available. Through structured community engagement initiatives, universities can contribute directly to addressing educational challenges while simultaneously fulfilling their social responsibility mandates. The positive outcomes achieved in this program demonstrate that such partnerships can serve as an effective mechanism for reducing skill gaps and expanding access to emerging fields such as data science, particularly in regions where specialized educational resources remain limited.

The program highlights the potential of Service-Learning-based data science training as a sustainable model for workforce preparation in the digital era. The integration of



practical instruction, experiential learning, and continuous mentoring created a learning environment that encouraged active participation and meaningful skill development. Beyond improving technical competencies, the approach fostered confidence, adaptability, and lifelong learning attitudes among participants. These attributes are increasingly recognized as essential components of workforce readiness in the twenty-first century. Therefore, the replication and expansion of similar initiatives could contribute substantially to strengthening vocational education systems, enhancing digital inclusion, and supporting broader workforce development efforts in response to ongoing technological transformation.

Table 4 Implications for Vocational Education and Workforce Readiness

Key Implication	Evidence from the Program	Potential Impact
Bridging the Skills Gap	Significant improvement in assessment scores	Aligns vocational education outcomes with industry needs
Development of Data Literacy	Training in Microsoft Excel and Python	Enhances analytical thinking and digital competencies
Workforce Readiness	Exposure to practical data analysis tasks	Prepares students for data-driven work environments
Transferable Skills	Problem-solving and technology utilization across activities	Applicable across multiple industries and occupations
University-Community Partnership	Collaboration between university and vocational school	Strengthens educational quality and local capacity development
Sustainable Learning Model	Service-Learning, mentoring, and experiential learning approach	Supports long-term workforce development and digital inclusion

Table 4 illustrates the broader implications of the program for vocational education and workforce readiness. The significant improvement in students’ competencies demonstrates the potential of vocational institutions to bridge existing skill gaps through the integration of practical data science training. The development of data literacy through Microsoft Excel and Python instruction enhanced students’ analytical and digital capabilities, while hands-on learning experiences increased their readiness for data-oriented workplaces (Arruda et al., 2025; Kelvin et al., 2024). The acquisition of transferable skills, including problem-solving and technology utilization, further supports employability across various industrial sectors. Additionally, the successful collaboration between the university and the vocational school highlights the value of community-based partnerships in expanding educational opportunities and strengthening local capacity. The Service-Learning framework, combined with mentoring and experiential learning, offers a sustainable model for preparing vocational students to meet the evolving demands of the digital workforce.

#### 4. Conclusions

The findings of this study demonstrate that the Service-Learning-based data science training program effectively strengthens vocational high school students’ data literacy competencies. The significant improvement between pre-test and post-test results



indicates that students were able to develop a better understanding of fundamental data science concepts, including data management, visualization, and introductory programming. The combination of Microsoft Excel and basic Python programming provided an accessible and practical learning pathway that enabled students to transform abstract concepts into applicable skills through direct experience and guided practice.

Beyond cognitive improvement, the program also contributed to more equitable learning outcomes among participants, as shown by the reduction in score variability after the intervention. This suggests that the Service-Learning approach not only enhances individual achievement but also helps minimize competency gaps among students with different initial levels of understanding. The experiential learning cycle, which integrates practice, reflection, and application, proved effective in fostering deeper engagement and sustained learning motivation in a vocational education context.

The study highlights the broader relevance of integrating Service-Learning into vocational education to prepare students for the demands of a data-driven workforce. By fostering collaboration between higher education institutions and vocational schools, the program created meaningful knowledge transfer and capacity building that align with industry needs. Therefore, the Service-Learning-based data science training model can be considered a promising approach for strengthening digital competencies and enhancing workforce readiness in the era of digital transformation.

### Conflict of Interest

The authors declare no conflict of interests.

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