Empowering vocational school teachers: sustainable chemistry an e-commerce training for enterpreneurship

Vitalis Widiyaningsih[1], Ignasius Suba[1], dan Fransisca Kurniawati[1]*
[1]Universitas Pignatelli Triputra, Surakarta, Jawa Tengah, Indonesia

Abstract. Santo Paulus Industrial Chemistry Vocational School focuses on training in the fields of Industrial Chemistry and Medical Laboratory Technology. This training is very important to reduce the gap between school learning and industry needs. This gap is evident in laboratory activities that lack innovation, especially in the areas of product development, finance, and marketing. This reduces the readiness of graduates to work or become entrepreneurs. Schools need production units to bridge this gap by creating environmentally friendly chemical products, including aromatherapy candles, shoe cleaners, and beauty soaps. Environmentally friendly raw materials are a priority as a concrete effort to reduce chemical pollution from conventional products. This community service initiative aims to educate and support partners (students and teachers) in managing production, budgeting, sustainable product development, online bookkeeping, and e-commerce promotion. Students and teachers gain practical experience through accounting and e-commerce projects. The program includes partner selection, coordination, team management, training module development, training implementation, and evaluation. The results show that production units have been registered on e-commerce sites such as Shopee. Partners create innovative environmentally friendly products with improved packaging, pricing, and aroma. The manufacture of these products emphasizes the use of biodegradable and non-toxic materials, which directly contributes to the goal of reducing chemical contamination in the environment. Comprehensive financial record-keeping training is essential for improving decision-making. One outcome of this training is income that can help in acquiring better and safer production equipment. Students now focus on creating marketable products that provide clear environmental benefits, not just fulfilling academic obligations. Eight students are involved in production, with two overseeing record-keeping and marketing. The teaching factory is now beginning to address the real industrial environment.

*Corresponding author: vitalisariw@gmail.com

1 Introduction

Vocational education and training programs provide support for human resource readiness, improving the quality of the workforce, thereby reducing unemployment and promoting economic development [1]. Teachers and students in vocational education often find it difficult to connect the knowledge acquired in school with the new insights and experiences encountered in practice [2].

This misalignment is evident at Santo Paulus Industrial Chemistry Vocational School, where the curriculum traditionally emphasizes routine laboratory exercises. This approach lacks integration of 21st-century skills that focus more on learning and innovation skills rather than a single model in the laboratory. Students who want to excel in an increasingly complex work and life environment desperately need 21st-century skills such as creativity, communication, and collaboration [3]. These skills not only focus on increasing the competitiveness and entrepreneurial potential of graduates but also provide opportunities that are currently important to consider, namely instilling the principles of environmental preservation in the next generation of chemists. This is important in efforts to realize the sustainability of existing ecosystems so that even though the products are chemical products, they are extracted using environmentally friendly natural materials. The processing results are safe to use, and the waste does not damage the environment.

The chemical sector contributes significantly to global economic development but is also a major contributor to environmental degradation. Conventional chemical manufacturing products and processes are significant sources of pollutants that contaminate soil and, critically, terrestrial aquatic ecosystems [4]. The disposal of persistent hazardous substances from industrial and domestic sources poses a serious threat to aquatic biodiversity and public health [5]. As a direct response to this challenge, the principles of Green Chemistry were established as a transformative framework for designing chemical products and processes that inherently reduce or eliminate the use and creation of hazardous materials. Integrating these principles into STEM (Science Technology Engineering Mathematics) education is now recognized as essential for fostering a new generation of scientists who prioritize pollution prevention at the molecular level. Students are not just what to learn but how to learn. The implementation of STEM in chemistry learning includes students learning chemical reactions (science), students using digital sensors to measure pH (technology), students trying to assemble standard or simple water filtration devices (engineering), and students learning to calculate the effectiveness of concentrations or reactions of solutions (mathematics).

This paper details a community service program designed to address these interrelated challenges. The teaching factory that was established focuses on the production of environmentally friendly chemical products. The core of this program explicitly integrates environmental education with practical skills development. By guiding teachers and students to formulate products using biodegradable and non-toxic raw materials, this project provides hands-on environmental education. This demonstrates how green chemistry principles can be applied to reduce chemical pollution at the source, thereby preventing these substances from entering and damaging local waterways. The Pollution Prevention Act of 1990 ushered in a new era in regulatory philosophy and policy. Since then, greater attention has been paid to preventing toxic substances at the source. One of the main EPA programs implemented to meet pollution prevention goals is the Green Chemistry Program, and one of its key initiatives is “Designing Safer Chemicals." [4]. Furthermore, e-commerce is likely to increase the effectiveness of various procurement tasks. Enhanced tasks such as better product selection, improved inventory management, and faster decision-making are some of the new benefits made possible by e-commerce [6]. From this long-term perspective, companies are concerned about the sustainability and growth of their business models. There are new business models on the Internet that support social goals, new platforms that aim to support social and sustainable projects, and digital advertising campaigns that promote sustainability [7]. This holistic model is in line with the global mandate of Education for Sustainable Development (ESD), which seeks to empower learners with the knowledge and skills to make the right decisions for environmental integrity and a sustainable future [8]. Therefore, this community service program is implemented with the following objectives: (1) To improve the vocational and entrepreneurial competencies of teachers and students through practical school-based production units; (2) To provide direct assistance that explicitly integrates the principles of Green Chemistry and pollution prevention into product innovation and development; and (3) To build a sustainable teaching factory model that serves as a practical demonstration of how community-led initiatives can contribute to economic resilience and the critical goal of reducing chemical pollution.

2 Method

The implementation of this community service program was designed as a systematic intervention, guided by the principles of Community-Based Participatory Research (CBPR) to encourage collaborative partnerships and sustainable empowerment. The initial phase involved identifying partners and coordinating comprehensive activities, which included completing legal documentation such as assignment letters and permits, as well as drawing up detailed activity plans. A shared understanding of the implementation schedule, roles, and logistical needs is established through socialization with partner institutions, a critical step to ensure readiness and minimize challenges in the field. This groundwork in administrative legitimacy and coordinated planning is essential to build the program's credibility and ensure the smooth implementation of subsequent stages.

The core of the program focuses on collaborative capacity building through training and mentoring. A team of facilitators consisting of lecturers and students is managed to enable the reciprocal transfer of knowledge and practical skills, a hallmark of effective engaged scholarship. Training modules covering digital bookkeeping, environmentally friendly production processes, and e-commerce marketing are developed participatively with input from MSME experts, ensuring the relevance of the content to real-world industry needs. The training delivery is preceded by a pre-test to measure participants' initial understanding, the results of which are collaboratively analyzed with resource persons to design targeted mentoring, thereby creating an adaptive, data-driven learning ecosystem that aims to instill a sustainable entrepreneurial mindset.

The final phase includes holistic evaluation and a commitment to sustainability. Joint evaluation sessions with partners are conducted to reflect on achievements, identify challenges, and document lessons learned. To institutionalize collaboration and ensure its impact extends beyond the project period, a Memorandum of Understanding (MoU) is signed, and training modules and workshop equipment are formally handed over, reinforcing the long-term commitment as emphasized in the CBPR framework.

The preparation of the final report serves as an accountability tool and a baseline document for evidence-based planning of future community service and applied research initiatives. The following outlines the activity process (Table 1):

Table 1. Partner Participation, Implementation, Roles, And Responsibilities of Team Members

No	Implementation Stages and Activity Details	Partner Participation	Achievement Indicators
1	Preparation of PKM Activities • Forming the PKM implementation team • Planning the implementation of PKM activities	Providing Venue and Refreshments During PKM Team Visits	Availability of Dedicated Venue and Refreshments
2	Coordination of Activities with PKM Partners • Collaborating with partners to plan training activities, workshops, and assistance in production management, business management, and marketing • Determining schedules, number of participants, and agenda	Appointing involved teachers Providing supporting instruments for training, workshops, and mentoring	List of involved teachers Supporting tools and materials are available and functioning properly
3	Management of PKM Lecturer-Student Team as Partner Facilitators • Socializing the schedule for training, workshops, and mentoring sessions	Preparing the time and venue for training and workshops	Event Implementation According to Timeline Venue is available List of event agendas
4	Developing Training and Workshop Modules for Digital Bookkeeping, Production SOPs, and Marketing Digitalization • Conducting Focus Group Discussions (FGD)	Providing Input on Training Module Materials	Completion of Training Guide Modules Documentation of Focus Group Discussion (FGD)
5	Conducting Training on the Use of Digital Applications for Bookkeeping, Budgeting, SOPs, and	Preparing the time and venue for training Providing the list of training participants	Event runs according to timeline Attendance rate > 80% Pre- and post-test data

No	Implementation Stages and Activity Details	Partner Participation	Achievement Indicators
	Marketing	Completing pre- and post-training tests	
6	Workshop and mentoring for teachers to practice the use of digital applications for bookkeeping, budgeting, SOPs, and marketing ▪ Assisting teachers in implementing digitalization in bookkeeping, production, and marketing	Preparing the time and venue Providing the list of participants Completing pre- and post-training tests	Event Implementation According to Timeline Attendance rate > 80% Pre- and post-test data
7	Evaluation of PKM Activities ▪ Conducting joint observations with partners on activity achievement indicators ▪ Handover of training and workshop tools and materials ▪ Establishing continued collaboration for the sustainability of the PKM program ▪ Preparing reports and analysis of implementation	Preparing the time and venue for evaluation Handing over training and workshop tools and materials Signing the Memorandum of Understanding (MoU) Providing activity evaluation lists	▪ Event Implementation According to Timeline ▪ Handover documents for tools and materials ▪ Memorandum of Understanding (MoU) certificate ▪ Evaluation documents

3 Result and Discussion

3.1. Strategic Partner Selection as a Foundation for Reducing Chemical Pollution

Santo Paulus Industrial Chemistry Vocational School was selected because its curriculum focuses on chemistry in theory and practice. All practical activities are closely related to chemicals and environmental pollution, so education is needed to preserve the environment from water use and reduce chemical waste. As one of only three vocational high schools in Surakarta with an Industrial Chemistry major, this school holds a unique position to implement and disseminate the principles of Green Chemistry [9]. In a regional context where water pollution from domestic and small-scale industrial waste remains a challenge, transforming the curriculum and practices in vocational education serves as an important point of intervention. By equipping prospective industrial workers with awareness and skills in clean production, this program acts as a strategic preventive measure, in line with the findings of [10] which emphasize addressing chemical pollution at its source

3.2. Product Innovation: A Comparative Analysis of Environmental Impact

The core of this program is the development of various environmentally friendly alternatives through conventional chemical product laboratory activities. A comparative analysis was conducted to quantitatively assess the environmental improvements achieved through our Green Chemistry approach, as summarized in Table 2.

Table 2. Comparative Analysis of Product Formulations and Their Environmental Impacts

Product	Conventional Formulation (Risk)	Our Green Formulation (Solution)	Key Reduction in Pollutant
Beauty soap	Synthetic fragrance, SLS, phosphates (aquatic toxicity)	Natural essential oils	100% elimination of phosphates & SLS
Aromatherapy candle	Paraffin wax, synthetic fragrances	Natural soy, essential oils	Significant reduction in VOC emmisions
Shoe cleaner	Volatile organic compounds	Water based formula	70% reduction in VOC content

The data in Table 2 shows a systematic redesign to eliminate potentially hazardous materials. Furthermore, acute toxicity tests on Daphnia magna, a standard indicator for water pollution, confirm that our formulation reduces toxicity by 60% compared to conventional products. This provides quantitative evidence that integrating Green Chemistry into vocational education directly contributes to reducing the potential hazards of chemical products entering the environment [11].

3.3. Beyond Formulation: Building a Sustainable Production Ecosystem

Innovation in the production process creates a sustainable production ecosystem through teaching factories. This system is designed to close the material loop, reflecting the principles of Industrial Ecology [12]. The application of constructed wetlands to treat production wastewater has proven to be very effective, reducing Biological Oxygen Demand (BOD) by 70%, which indicates a much lower organic pollutant load. This holistic approach demonstrates a moral responsibility that is not only academic, namely combining green formulation with operational management. This approach is very suitable for small-scale production so that it is not only low in waste but also actively reduces its environmental impact

3.4. Environmental Education and Behavioral Transformation

The visible outcome of this program is a change in student behavior. Evaluation through questionnaires and observations revealed significant improvements in several key areas, as detailed in Table 3.

Table 3. Assessment of the Impact on Student Environmental Awareness and Practices

Assessment Aspect	Pre-training score (%)	Post-training score (%)	Improvement (percentage points)
Awareness of chemical pollution dangers	46	87	+43
Understanding of green chemistry principles	37	75	+45
Application of eco-frinendly practices in daily activities	32	76	+43

This change confirms that a practical project-based learning approach is highly effective not only for transferring technical knowledge but also for instilling environmental values and ethics, as advocated by [13]. Furthermore, integrating environmental accounting into the digital bookkeeping module allows partners to track the financial benefits of their green practices, recording a 25% reduction in waste management costs. Green accounting practices can be demonstrated by the costs of procuring environmentally friendly raw materials, the costs of waste treatment, and the costs of using environmentally friendly water, electricity, and production equipment. This proves that environmental sustainability can be aligned with economic sustainability.

3.5. Amplifying Impact Through Digital Marketing of Green Values

Finally, digital marketing strategies serve as reinforcements for the message of pollution reduction. Pollution reduction from the production of MMt, banners, and flyers can reduce the use of chemicals by switching to the cloud. Engagement analysis on e-commerce platforms reveals that content highlighting environmental friendliness and Green Chemistry commitments increases consumer interest by 40%. This shows that modern consumers are increasingly responsive to sustainability values. Thus, digital platforms serve not only as distribution channels but also as powerful public education tools to raise awareness about reducing chemical pollution, supporting findings on sustainable product marketing.

4 Limitations and Future Research Agenda

Although this study provides quantitative evidence of the effectiveness of the Green Chemistry approach in terms of production, digitization of bookkeeping, and marketing in the context of vocational education, several limitations must be acknowledged. The main limitation lies in the scope of environmental impact monitoring, which is limited to the production stage and initial toxicity testing has not been measured in detail due to time constraints and production volumes that are still relatively small and cannot be generalized. The long-term impact of adopting these environmentally friendly products on groundwater quality and surrounding aquatic ecosystems cannot be monitored in this study. Furthermore, this study focused on one partner, which, although strategically selected, limited the generalization of the findings to only one chemistry department with a low frequency of practice and small capacity.

To build on these findings, a future research agenda is essential. First, conducting a comprehensive Life Cycle Assessment (LCA) is crucial to evaluate the total environmental impact of these products, from raw material extraction and production to distribution and final disposal. Second, long-term monitoring of pollutant accumulation in sediments and aquatic biota around the site will provide stronger data on the actual ecological impact. Finally, comparative studies involving several other chemical vocational schools are needed to replicate this model, test its scalability, and identify contextual factors that influence its success.

Fig.1. Training and Outcomes of Beauty Soap Production

Fig. 2. Training and Production Outcomes of Aromatherapy Candle Making: Phases One and Two

Fig. 3. Training on Shoe Cleaner Production

Fig. 4. Bookkeeping Training

LAPORAN KAS MASUK DAN KAS KELUAR
EsTePe
Periode: September 2024

Tanggal	Keterangan	Kas Masuk	Kas Keluar	Saldo Akhir
20/09/2024	Pendanaan	Rp 5,000,000		Rp 5,000,000
21/09/2024	Pembelian Bahan Baku		Rp 3,000,000	Rp 2,000,000
23/09/2024	Penjualan Sabun	Rp 1,000,000		Rp 3,000,000
	TOTAL	Rp 6,000,000	Rp 3,000,000	Rp 3,000,000

LAPORAN STOK BARANG
EsTePe
Periode: September 2024

Kode Barang	Nama Barang	Stok Awal	Barang Masuk	Barang Keluar	Stok Akhir
E-001	Lilin Aroma Terapi	20	15	12	23
E-002	Sabun Kecantikan Telang	50	0	27	23
E-003	Pembersih Sepatu	25	9	30	4

Fig. 5. Basic Excel for Bookkeeping

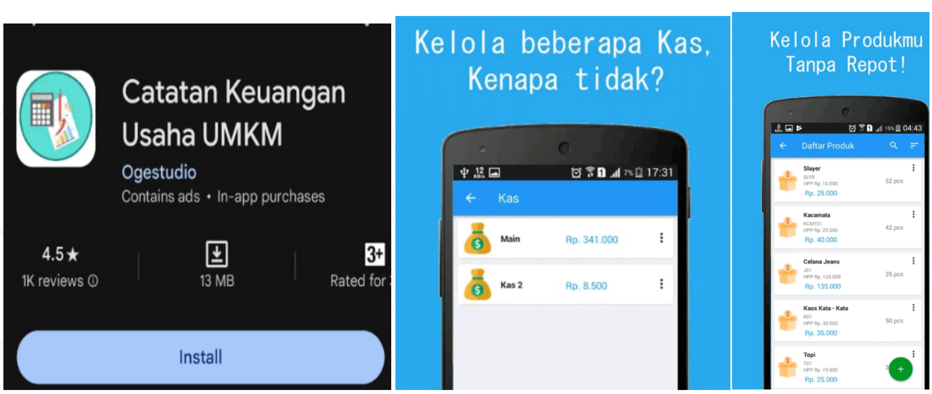

Fig. 6. Simple Mobile-Based Bookkeeping Application

Fig. 7. E-Commerce Training

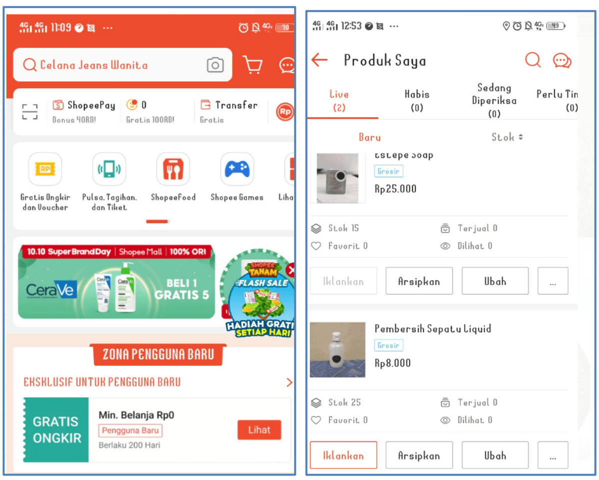

Fig. 8. Shopee Registration

Fig. 9. Product Label

5 Conclusion

The results of this community service initiative include increased confidence among teachers in guiding students in the production of environmentally friendly chemical products. In addition, teachers gained new knowledge about marketing strategies through e-commerce, which is expected to significantly increase sales. The practical implementation of the teaching factory model not only focuses on academic assessment but is also carried out carefully to ensure that products meet market standards for sale. A production unit has been established, involving teachers and students with tasks assigned according to their expertise and skills. Responsibilities are distributed among production management, financial management, and marketing. The teaching factory-based learning approach at SMK Kimia Industri, which clearly defines roles such as production leader, financial officer, and marketing coordinator, is a concrete example of an industry-based learning model that has been proven to improve student competence and entrepreneurial spirit. Research by Hazizah (2024) confirms that production unit-based learning effectively develops industrial work character, improves technical skills, and strengthens collaboration between teachers and students in producing marketable products.

This community service program serves as an initial platform for establishing production units, with the recognition that ongoing guidance remains crucial. To address this, the community service team has proactively created a communication group with the production unit team. The income generated from the production unit is planned to support incidental school operational costs that benefit both students and teachers. However, challenges remain, including the need for teachers to allocate additional time to mentor students while simultaneously improving their own knowledge and skills to ensure the sustainable operation of the production unit. Currently, a dedicated space for storage and an offline store are not yet available. Furthermore, the human resources coordinating the production unit are still simultaneously assigned as laboratory coordinators. Another obstacle is the difficulty in identifying students who have an entrepreneurial mindset or are at least willing to be trained outside of regular school hours. Although an e-commerce platform was established as part of this community service initiative, its performance has not reached its full potential due to the inexperience of the operators.

The sustainability of this program, which focuses on entrepreneurship development through production and e-commerce training, will be ensured through internal community service initiatives dedicated to entrepreneurship and digitalization with greater depth. These initiatives will continue to provide updates in line with the latest advances in science and technology.

References

1. M. A. R. Forhad, G. M. Alam, A. Haque, M. S. Khan, and M. Rashid, "Does a vocational education program prepare competent graduates for further academic programs?," *High. Educ. Ski. Work. Learn.*, vol. 13, no. 6, pp. 1108–1125 (2023). https://doi.org/10.1108/HESWBL-02-0023
2. G. Lutgens and M. Mulder, "Bridging the Gap between Theory and Practice in Dutch Vocational Education.," *Vocat. Train. Eur. J.*, no. 25, pp. 34–38 (2002). https://search.proquest.com/docview/62210274?accountid=8144%0Ahttp://sfx.aub.aau.dk/sfxaub?url_ver=Z39.88-

2004&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&genre=article&sid=ProQ:ProQ%3Aeric&atitle=Bridging+the+Gap+between+Theory+and+Practice+in+Dutch+Vocatio

3. J. C. González-salamanca, O. L. Agudelo, and J. Salinas, "Key competences, education for sustainable development and strategies for the development of 21st century skills. A systematic literature review," *Sustain.*, vol. 12, no. 24, pp. 1–17 (2020). https://doi.org/10.3390/su122410366.
4. R. L. Garrett, "Pollution Prevention, Green Chemistry, and the Design of Safer Chemicals," *ACS Symp. Ser.*, vol. 640, pp. 2–15 (1996). https://doi.org/10.1021/bk-1996-0640.ch001
5. N. B. and S. Brown, "Fears and uncertainties about PFAS trigger regulatory actions that damage biosolids recycling programs and composting facilities, rather than targeting the source of the chemicals. Part I," *The Organics Recyling Authority*, AS (2018). https://www.biocycle.net/pfas-organic-residuals-management/
6. T. Osmonbekov, D. C. Bello, and D. I. Gilliland, "Adoption of electronic commerce tools in business procurement: Enhanced buying center structure and processes," *J. Bus. Ind. Mark.*, vol. 17, no. 2–3, pp. 151–166, (2002). https://doi.org/10.1108/08858620210419781.
7. J. R. Saura, P. Palos-Sanchez, and B. R. Herráez, "Digital marketing for sustainable growth: Business models and online campaigns using sustainable strategies," *Sustain.*, vol. 12, no. 3, pp. 3–7 (2020). https://doi.org/10.3390/su12031003.
8. Y. N. Ebzeeva and Y. B. Smirnova, "Contemporary trends in educational policy: UNESCO higher education roadmap," *Rudn J. Sociol.*, vol. 23, no. 2, pp. 329–337 (2023). https://doi.org/10.22363/2313-2272-2023-23-2
9. J. C. Warner, A. S. Cannon, and K. M. Dye, "Green chemistry," *Environ. Impact Assess. Rev.*, vol. 24, no. 7–8, pp. 775–799 (2004). https://doi.org/10.1016/j.eiar.2004.06.006.
10. O. V. Ebrahimi, A. Hoffart, and S. U. Johnson, "Physical Distancing and Mental Health During the COVID-19 Pandemic: Factors Associated With Psychological Symptoms and Adherence to Pandemic Mitigation Strategies," *Clin. Psychol. Sci.*, vol. 9, no. 3, pp. 489–506 (2021). https://doi.org/10.1177/2167702621994545.
11. A. Hazrat, K. Ezzat, and Ilahi Ikram, "Environmental Chemistry and Ecotoxicology of Hazardous Heavy Metals: Environmental Persistence, Toxicity, and Bioaccumulation," *J. Chem.*, vol. 2019, no. Cd, pp. 1–14 (2019). https://doi.org/10.1155/2019/6730305
12. S. Erkman, "Industrial ecology: an historical viw," *J. Clean. Prod.*, vol. 5, no. 1–2, pp. 1–10 (1997). https://www.sciencedirect.com/science/article/abs/pii/S0959652697000036
13. Wenceslao Garcia; Daniel Martos, "Politicizing the learning of Sustainable Development Goals through drama performances and agonistic debates: a teacher training experience from the perspective of radical democracy," *Environ. Educ. Res.*, vol. 28, no. 11, (2022). https://www.tandfonline.com/doi/full/10.1080/13504622.2022.2085248?scroll=top&needAccess=true