Prisma Sains: Jurnal Pengkajian Ilmu dan
Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com

July 2026. Vol. 14, No. 3
p-ISSN: 2338-4530
e-ISSN: 2540-7899
pp. 1187-1199

From Verification-Based Practicum to Product-Oriented Teaching Factory: A Needs Analysis in Chemistry Teacher Education

[1,2]*Ahmadi, [3]Aliefman Hakim, [3]Jamaluddin, [3]Iwan Sumarlan, [4]Baiq Risni Maripa

[1]Student Doctoral Department of Science Education, University of Mataram, Mataram, Indonesia
[2]Department of Chemistry Education, Mandalika University of Education, Mataram, Indonesia
[3]Doctoral Department of Science Education, Postgraduate Studies, University of Mataram, Mataram, Indonesia
[4]Indonesian Publication Center, Mataram, Indonesia

*Corresponding Author e-mail: ahmadi@undikma.ac.id

Received: May 2026; Revised: June 2026; Published: July 2026

Abstract

Although product-based chemistry practicum and teaching factory studies have been discussed separately, limited empirical diagnostic evidence explains readiness gaps, perception differences, and institutional support needs before a teaching factory-oriented chemistry practicum model is developed. This study aimed to identify empirical needs for developing a product-oriented teaching factory model in chemistry practicum within chemistry teacher education. A descriptive quantitative needs-analysis design was used with substantive interpretation of aggregate questionnaire and observation responses. Participants were 20 chemistry education students and 6 lecturers from two universities in Mataram, Indonesia. The analysis focused on current practicum characteristics, teaching factory understanding and interest, soft skills, barriers, authentic product potential, and partnership needs. The findings indicate that practicum activities remain strongly verification-oriented: 15 of 20 students (75%) reported that procedures strictly followed manuals without modification, while 3 of 6 lecturers (50%) perceived practicum as balanced between verification and exploration. Teaching factory literacy was still limited, with 16 of 20 students (80%) reporting low understanding or no familiarity with the concept. Nevertheless, all students expressed interest in authentic product-based practicum, and all lecturers recognized the importance of developing the model. Main barriers included limited equipment and materials, short practicum time, dense curriculum or standard procedures, and students' low confidence in trying new approaches. These findings provide initial design considerations, not evidence of model effectiveness. Future development should begin with concept orientation, flexible product-based modules, simple quality testing, structured soft-skill rubrics, and sustainable external partnership mechanisms.

Keywords: Chemistry practicum; Needs analysis; Product-based learning; Teaching factory; Teacher education

How to Cite: Ahmadi, A., Hakim, A., Jamaluddin, J., Sumarlan, I., & Maripa, B. R. (2026). From Verification-Based Practicum to Product-Oriented Teaching Factory: A Needs Analysis in Chemistry Teacher Education. *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *14*(3), 1187–1199. https://doi.org/10.33394/j-ps.v14i3.20533

https://doi.org/10.33394/j-ps.v14i3.20533

INTRODUCTION

Chemistry laboratory work in higher education should function as more than a place for verifying theories. It is a learning environment in which students integrate theoretical knowledge, scientific methods, laboratory skills, safety awareness, and evidence-based reasoning into coherent practice. In chemistry teacher education, laboratory experiences are especially important because prospective teachers are expected to understand both chemical concepts and how laboratory activities can be designed pedagogically. Recent literature emphasizes that meaningful laboratory learning requires students to design procedures, make informed decisions, interpret data, and connect experimental actions with conceptual understanding (Galloway & Bretz, 2015a, 2015b; Seery, 2020). When practicum activities rely too heavily on cookbook or verification procedures, students may become proficient at following manuals but have fewer opportunities to practice creativity, problem-solving, and scientific decision-making. Thus, chemistry practicum needs to move gradually toward more contextual, open, and product-oriented learning experiences.

One approach that can connect academic laboratory work with authentic professional practice is the teaching factory. The teaching factory paradigm was initially developed in manufacturing and vocational education to connect educational processes with industrial practices through hands-on production, authentic problem-solving, quality standards, and workplace interactions (Chryssolouris et al., 2016; Mavrikios et al., 2018). The concept does not simply replicate a factory in a school or university. Rather, it integrates learning objectives, process standards, production scenarios, quality benchmarks, collaboration, and products or services with practical utility. Learning factory and teaching factory environments have been shown to support competence development by situating learners in work-like contexts (Abele et al., 2015, 2017; Tisch et al., 2016). In chemistry education, this approach can be translated into product-based practicums such as soap production, cleaning agent formulation, simple cosmetics, organic fertilizer, bioplastics, natural dyes, or other household chemical products. Product-oriented chemistry practicum can integrate chemical concepts with formulation, safety, quality control, cost efficiency, and user needs.

Previous studies have provided important knowledge about product-based chemistry practicum and teaching factory implementation. For example, liquid soap formulation enriched with hibiscus flower extract has been reported to support students' problem-solving while integrating saponification, surfactant chemistry, pH control, and natural product chemistry (Ahmadi & Maripa, 2022). Similarly, bath soap production using coconut oil and rose flower extract illustrates how product-oriented practicum can integrate physicochemical analysis, organoleptic evaluation, and quality-control standards (Maripa & Ahmadi, 2023). In broader educational contexts, teaching factory research has emphasized facility design, vocational learning, industrial networks, business models, and competency-based education (Baena et al., 2017; Kautsar et al., 2022; Mavrikios et al., 2019; Prinz et al., 2016; Wahjusaputri et al., 2020; Wahjusaputri & Bunyamin, 2022). These studies show the potential of product-based and production-oriented learning, but they do not fully explain how chemistry teacher education programs should diagnose their initial readiness before designing a teaching factory-based practicum model.

The remaining gap is therefore not whether product-based learning or teaching factory ideas are useful in general, but how ready chemistry teacher education contexts are to adopt them. More specifically, little empirical diagnostic evidence is available about students' and lecturers' perceptions of current practicum characteristics, their understanding of teaching factory, the soft skills already developed through practicum, the barriers that may hinder implementation, and the forms of support needed for model development. This gap is important because a teaching factory model cannot be designed only from theoretical recommendations. It should be grounded in the realities of laboratory resources, curriculum structure, students' confidence, lecturers' readiness, and external partnership possibilities. Student and lecturer perspectives are complementary: students describe the learning experience as enacted, whereas lecturers describe practicum design, management, and curriculum constraints.

This study is positioned as a preliminary empirical diagnostic study, not as an intervention study or a test of model effectiveness. Its contribution is to identify readiness gaps, perception differences, and institutional support needs that can inform the development of a product-oriented teaching factory model for chemistry practicum. The study addresses the following research questions:

1) How do students and lecturers perceive current chemistry practicum characteristics?
2) What levels of teaching factory understanding and interest are evident among students and lecturers?
3) How are soft skills, especially creativity and innovation, developed through current practicum?
4) What barriers, authentic product opportunities, and partnership conditions influence model development?
5) What preliminary design considerations can be derived for developing a teaching factory-based chemistry practicum model?

METHODS

Research Design

This study used a descriptive quantitative needs-analysis design with substantive interpretation of response patterns. The design was selected because the objective was to map initial needs and readiness, not to test causal relationships or the effectiveness of an intervention. The phrase "substantive interpretation" is used deliberately because the available data consisted of closed-response questionnaire and observation recapitulations; no interviews, focus group discussions, open-ended responses, or systematic field-note data were analyzed. Therefore, the study does not claim to be a qualitative study. The needs-analysis orientation is appropriate because a teaching factory practicum model should be developed only after laboratory conditions, student experiences, lecturer readiness, and partnership opportunities have been identified.

Participants

Participants consisted of two respondent groups: 20 chemistry education students and 6 lecturers. The students had direct experience participating in chemistry practicum activities, including manual-guided procedures, group work, and laboratory equipment or material use. The lecturers were involved in chemistry practicum planning, implementation, or management. Respondents came from chemistry education programs at Mandalika University of Education and State Islamic University of Mataram. Purposive sampling was used because the study required information from individuals who had direct knowledge of chemistry practicum practices. Available participant information is summarized in Table 1. Because the retained dataset consisted of aggregate recapitulations, more detailed demographic information, such as gender, semester level, exact institutional distribution, lecturer teaching experience, and practicum courses handled, could not be reconstructed and is acknowledged as a study limitation.

Before the empirical findings are interpreted, the participant context should be made explicit because the needs analysis involved two respondent groups with different roles. Table 1 therefore presents the available participant profile and the characteristics retained in the aggregate dataset.

Table 1. Participant profile and available characteristics

Group	n	Selection basis	Available characteristics
- Students	20	Purposive; direct chemistry practicum experience	Chemistry education students from two universities in Mataram; detailed gender, semester, and institution-by-institution distribution were not retained in the aggregate dataset.
- Lecturers	6	Purposive; involved in practicum planning, implementation, or management	Chemistry education lecturers from the same program context; detailed teaching experience and practicum course distribution were not retained in the aggregate dataset.

Note: Only aggregate participant information was retained in the dataset. Missing demographic details are treated as a limitation rather than reconstructed.

Instruments

Two preliminary diagnostic instruments were used: a student questionnaire and a lecturer observation questionnaire. Each instrument contained 18 closed-response items grouped around practicum characteristics, local material and product potential, teaching factory understanding, soft skills, implementation barriers, external partner involvement, and support needs. The instruments used categorical frequency or level responses, such as always, frequently, occasionally, rarely, never; very high, high, sufficient, low; and selected barrier categories. Table 2 presents the instrument blueprint and examples of indicators. The instrument was treated as a diagnostic mapping tool rather than a standardized psychometric scale. Content validity was approached through item-to-construct alignment with the study focus: teaching factory, product-based practicum, soft skills, barriers, and support needs. However, because only aggregate percentage recapitulations were available for analysis, item-level data, item-total correlations, Cronbach's alpha, and content validity index values could not be calculated. This limitation reduces the strength of measurement claims and is explicitly considered when interpreting the findings.

Because the study used closed-response diagnostic instruments, the instrument structure needs to be shown before the results are reported. Table 2 presents the questionnaire blueprint, dimensions, and example indicators used to map the needs for a teaching factory-based chemistry practicum.

Table 2. Questionnaire blueprint and example indicators

Dimension	Student indicators	Lecturer indicators	Example response format
- Laboratory resources and local materials	Equipment/material availability; local alternative material use.	Facility availability; local material utilization opportunity.	Frequency/level categories
- Current practicum design	Procedure rigidity; opportunity to modify procedures.	Verification-exploration balance; practicum management.	Categorical descriptions
- Teaching factory and product orientation	Teaching factory understanding; product-based practicum interest; authentic product experience.	Teaching factory understanding; course integration; authentic product potential; model importance.	Very high to low; categorical options
- Soft skills	Creativity; teamwork; communication; safety; problem-solving; responsibility; time management; critical thinking.	Student creativity; structured creativity and innovation training; soft-skill integration.	Always to never; very high to low
- Barriers and support needs	Confidence; equipment/materials; time; fixed procedures; guidance; partner involvement.	Equipment/materials; curriculum density; time; partner involvement; support required.	Selected barrier categories

Note: The instruments were used for preliminary diagnosis. They were not treated as standardized psychometric scales.

Procedures and Ethical Considerations

Data were collected as a preliminary diagnostic survey in chemistry practicum contexts. Students and lecturers completed instruments related to their practicum experiences and perceptions. Responses were summarized anonymously in aggregate form before manuscript analysis. Participation was treated as voluntary, and the results are reported without identifying individual respondents or institutions beyond the general program context. Because this study used anonymized aggregate data from an initial needs analysis, the reporting focus is placed on practicum improvement rather than individual performance evaluation.

Data Analysis

Data were analyzed using descriptive statistics in the form of frequencies and percentages. Frequencies were calculated from the aggregate percentages by using the relevant sample size (n = 20 for students and n = 6 for lecturers). For the lecturer group, percentage values such as 16.7%, 33.3%, and 66.7% represent only 1, 2, and 4 respondents, respectively; therefore, both frequency and percentage are reported to avoid misleading interpretation. No inferential statistical test was conducted because the sample was small, purposively selected, and intended for preliminary needs mapping. Interpretation followed three steps: identifying actual practicum conditions, comparing student and lecturer perceptions, and deriving preliminary design considerations for a product-oriented teaching factory practicum model. The findings are therefore interpreted as initial evidence for prototype design, not as generalizable evidence for all chemistry education programs.

RESULTS

This section presents empirical results before interpretation. Frequencies and percentages are reported together because the sample, especially the lecturer group, is small. Student percentages are based on n = 20, whereas lecturer percentages are based on n = 6.

Current Chemistry Practicum Characteristics

Student responses indicate that current chemistry practicum activities remain strongly verification-oriented. Fifteen of 20 students (75%) stated that practicum procedures completely followed the module without modification, 4 students (20%) stated that procedures generally remained fixed but occasionally allowed modification, and 1 student (5%) stated that practicum character varied depending on the instructor. No student reported routine freedom to construct practicum procedures independently. Lecturer responses were more moderate: 2 of 6 lecturers (33.3%) assessed practicum as completely verification-based, 1 lecturer (16.7%) assessed it as mostly verification with minimal exploration, and 3 lecturers (50.0%) assessed it as balanced between verification and exploration. No lecturer perceived current practicum as predominantly exploratory-innovative.

After establishing the participant and instrument context, the first empirical result concerns the character of existing practicum activities. Table 3 presents the distribution of student and lecturer responses regarding verification, exploration, and flexibility in current chemistry practicum.

Table 3. Current practicum characteristics reported by students and lecturers

Respondent	Indicator / response category	Frequency	Percentage
Students (n = 20)	- Procedures fully followed modules without modification.	15	75.0%
	- Procedures generally fixed but occasionally allowed modification.	4	20.0%
	- Practicum character varied depending on instructor.	1	5.0%
	- Routine freedom to construct procedures independently.	0	0.0%
Lecturers (n = 6)	- Completely verification-based.	2	33.3%
	- Mostly verification with minimal exploration.	1	16.7%
	- Balanced between verification and exploration.	3	50.0%
	- Predominantly exploratory-innovative.	0	0.0%

Note: Percentages for lecturers should be interpreted cautiously because n = 6; for example, 16.7% represents one lecturer.

Teaching Factory Understanding and Interest

The data show high interest in product-based practicum but limited teaching factory understanding. Among students, only 1 of 20 (5%) reported very good understanding of teaching factory, 3 students (15%) reported sufficient understanding, 9 students (45%) had heard the term but did not understand it well, and 7 students (35%) had never heard of it. Thus, 16 of 20 students (80%) were in low-understanding or unfamiliar categories. Despite this limited understanding, 13 students (65%) expressed very high interest and 7 students (35%) expressed interest in authentic product-based practicum. Interest in a specific teaching factory model was also high, with 11 students (55%) expressing very high interest, 8 students (40%) expressing interest, and 1 student (5%) expressing sufficient interest. Lecturer data also indicated partial readiness: 1 of 6 lecturers (16.7%) understood teaching factory, 3 lecturers (50.0%) sufficiently understood it, and 2 lecturers (33.3%) had low understanding. Course integration was also incomplete, with 3 lecturers (50.0%) reporting sufficient integration and 3 lecturers (50.0%) reporting insufficient integration.

The next issue is whether respondents understood the teaching factory concept and whether they were interested in product-oriented practicum. Table 4 summarizes the response distribution related to teaching factory understanding, student interest, and lecturer perceptions of course integration.

Table 4. Teaching factory understanding, product-based practicum interest, and course integration

Respondent	Indicator / response category	Frequency	Percentage
Students (n = 20)	- Teaching factory understanding: heard and understood very well	1	5.0%
	- Teaching factory understanding: heard and sufficiently understood	3	15.0%
	- Teaching factory understanding: heard but did not understand well	9	45.0%
	- Teaching factory understanding: never heard	7	35.0%
	- Interest in authentic product-based practicum: very high	13	65.0%
	- Interest in authentic product-based practicum: interested	7	35.0%
	- Interest in teaching factory model: very high	11	55.0%
	- Interest in teaching factory model: interested	8	40.0%
	- Interest in teaching factory model: sufficient	1	5.0%
Lecturers (n = 6)	- Teaching factory understanding: understand	1	16.7%
	- Teaching factory understanding: sufficient	3	50.0%
	- Teaching factory understanding: low	2	33.3%
	- Teaching factory integration in courses: sufficient	3	50.0%
	- Teaching factory integration in courses: insufficient	3	50.0%
	- Teaching factory model considered important/very important	6	100.0%

Note: Some indicators are reported as aggregate categories because the retained dataset consisted of percentage recapitulations.

Soft Skills and Creativity Indicators

Several soft skills were already trained through current practicum. Teamwork was reported as always trained by 12 of 20 students (60%) and frequently trained by 8 students (40%). Communication was reported as always trained by 12 students (60%), frequently by 6 students (30%), and occasionally by 2 students (10%). Laboratory safety was reported as always trained by 12 students (60%), frequently by 7 students (35%), and occasionally by 1 student (5%). Responsibility for equipment and materials was reported as always trained by 14 students (70%) and frequently by 6 students (30%). Time management was reported as always trained by 13 students (65%), frequently by 6 students (30%), and occasionally by 1 student (5%). Creativity was less strong: only 4 students (20%) rated creativity development as very high, while 8 students (40%) rated it high and 8 students (40%) rated it sufficient. Lecturer assessments were more cautious: 2 of 6 lecturers (33.3%) rated student creativity as high, 3 lecturers (50.0%) as sufficient, and 1 lecturer (16.7%) as low. For structured creativity and innovation training, no lecturer selected always; 4 lecturers (66.7%) selected frequently, 1 lecturer (16.7%) occasionally, and 1 lecturer (16.7%) rarely.

In addition to cognitive and procedural aspects, the needs analysis also examined soft-skill development in current practicum. Table 5 presents the response distribution for collaboration, communication, safety, responsibility, time management, problem-solving, creativity, and innovation indicators.

Table 5. Soft skills and creativity indicators in current chemistry practicum

Respondent	Indicator / response category	Frequency	Percentage
Students (n = 20)	- Teamwork always trained	12	60.0%
	- Teamwork frequently trained	8	40.0%
	- Communication always trained	12	60.0%
	- Communication frequently trained	6	30.0%
	- Communication occasionally trained	2	10.0%
	- Workplace/laboratory safety always trained	12	60.0%
	- Workplace/laboratory safety frequently trained	7	35.0%
	- Workplace/laboratory safety occasionally trained	1	5.0%
	- Responsibility for equipment/materials always trained	14	70.0%
	- Responsibility for equipment/materials frequently trained	6	30.0%
	- Time management always trained	13	65.0%
	- Time management frequently trained	6	30.0%
	- Time management occasionally trained	1	5.0%
	- Creativity development very high	4	20.0%
	- Creativity development high	8	40.0%
	- Creativity development sufficient	8	40.0%
Lecturers (n = 6)	- Student creativity high	2	33.3%
	- Student creativity sufficient	3	50.0%
	- Student creativity low	1	16.7%
	- Structured creativity/innovation training always	0	0.0%
	- Structured creativity/innovation training frequently	4	66.7%
	- Structured creativity/innovation training occasionally	1	16.7%
	- Structured creativity/innovation training rarely	1	16.7%

Note: Rows report the response categories available in the aggregate recapitulation.

Barriers, Product Potential, and Partnership Conditions

The main student-reported barrier was low confidence in trying new approaches, selected by 7 of 20 students (35%). Other barriers were limited equipment and materials (6 students, 30%), short practicum time (4 students, 20%), overly fixed procedures (2 students, 10%), and insufficient lecturer or laboratory staff guidance (1 student, 5%). Lecturer responses emphasized institutional and curricular barriers: 3 of 6 lecturers (50.0%) identified limited equipment and materials, 2 lecturers (33.3%) identified dense curriculum and standard procedures, and 1 lecturer (16.7%) identified limited practicum time. Product-generating experience was present but not dominant. Only 1 of 20 students (5%) reported that practicum always produced usable products, 7 students (35%) reported frequently, 10 students (50%) occasionally, and 2 students (10%) never. Partnership involvement was also limited: 15

students (75%) had never been involved in external collaboration but were interested, 2 students (10%) had been involved one to three times in the last two years, 2 students (10%) reported that partnership plans existed but were not implemented, and 1 student (5%) had never been involved and was less interested. Among lecturers, 4 of 6 (66.7%) stated that partner collaboration had existed but was not routine, 1 lecturer (16.7%) reported ongoing collaboration, and 1 lecturer (16.7%) reported no partner involvement.

Finally, the analysis examined implementation barriers, authentic product experience, product potential, and partnership conditions. Table 6 summarizes these data to show the practical support needed for gradual development of a product-oriented teaching factory model.

Table 6. Barriers, authentic product experience, product potential, and partnership conditions

Respondent	Indicator / response category	Frequency	Percentage
Students (n = 20)	- Main barrier: low confidence in trying new approaches	7	35.0%
	- Main barrier: limited equipment and materials	6	30.0%
	- Main barrier: short practicum time	4	20.0%
	- Main barrier: overly fixed procedures	2	10.0%
	- Main barrier: insufficient lecturer/laboratory staff guidance	1	5.0%
	- Practicum always produced usable products	1	5.0%
	- Practicum frequently produced usable products	7	35.0%
	- Practicum occasionally produced usable products	10	50.0%
	- Practicum never produced usable products	2	10.0%
	- Never involved in partner collaboration but interested	15	75.0%
	- Involved in partner collaboration 1-3 times in last two years	2	10.0%
	- Partner collaboration planned but not realized	2	10.0%
	- Never involved and less interested	1	5.0%
Lecturers (n = 6)	- Main barrier: limited equipment and materials	3	50.0%
	- Main barrier: dense curriculum and standard procedures	2	33.3%
	- Main barrier: limited practicum time	1	16.7%
	- Practicum material potential for authentic products: large/very large	4	66.7%
	- Practicum material potential for authentic products: moderate/other	2	33.3%
	- Partner collaboration existed but was not routine	4	66.7%
	- Partner collaboration ongoing	1	16.7%
	- No partner involvement	1	16.7%

Note: Support needs were interpreted from these barrier and partnership patterns, not from inferential statistics.

DISCUSSION

Verification-Oriented Practicum as an Initial Design Problem

The dominance of verification procedures should be interpreted as an initial design problem rather than a complete weakness. Verification-based practicum remains useful for developing basic laboratory techniques, procedural discipline, and safety awareness. However, when this format dominates, students may experience laboratory work as rule-following rather than scientific decision-making. This finding is consistent with laboratory education literature stating that students need opportunities to understand why procedures are performed, not only how to complete them (Agustian et al., 2019; Seery, 2020). The difference between student and lecturer perceptions is also important. Lecturers were more likely to perceive practicum as balanced, while students experienced it as fixed and manual-dependent. This gap may occur because lecturers evaluate the intended design of practicum, whereas students evaluate the enacted experience during laboratory sessions. Therefore, a teaching factory-based model should not simply add product tasks; it should redesign the learning flow so that students gradually move from guided verification to controlled modification, formulation decisions, quality testing, and product improvement.

A cautious implication is that chemistry practicum transformation should be incremental. The data do not support a claim that transformation has already occurred. Instead, they suggest that initial modules should combine procedural scaffolding with structured spaces for decision-making. For example, students may first follow safety and basic production protocols, then compare alternative formulations, select local materials, test product quality, document evidence, and revise prototypes. Such scaffolding is aligned with problem-solving research in chemistry, which emphasizes guiding students from procedural work toward strategic reasoning (Yuriev et al., 2017).

Teaching Factory Readiness Gap and Concept Orientation Needs

The second major interpretation concerns the readiness gap between interest and understanding. Students expressed very high interest in authentic product-based practicum, but most did not understand teaching factory well. Lecturers also showed partial understanding and incomplete course integration. This combination suggests psychological readiness but insufficient conceptual readiness. Teaching factory requires shared understanding of production flow, division of roles, quality standards, workplace safety, documentation, partner needs, and product evaluation. Literature on teaching factory emphasizes that the model functions as a collaborative learning-production system rather than a simple product-making activity (Chryssolouris et al., 2016; Mavrikios et al., 2018, 2019).

Thus, before full model implementation, a concept-orientation stage is needed for both students and lecturers. Orientation can introduce teaching factory principles, examples of chemistry products, simple quality standards, roles in production teams, and ethical-safety requirements. This stage is necessary to prevent product-based practicum from becoming another procedural activity with a different output. In chemistry teacher education, it is also important to connect product-oriented laboratory work with pedagogical reflection because students are prospective teachers who need to understand how such practicums can later be adapted for school laboratory learning.

Soft Skills, Creativity, and Structured Innovation

Current practicum appears to support collaboration, communication, responsibility, safety, and time management. These skills commonly emerge because students work in groups, share equipment, follow safety rules, and complete activities within scheduled laboratory time. However, creativity and innovation were not equally strong. This difference indicates that group work alone does not guarantee creative learning. Creativity requires tasks that permit students to make decisions, compare alternatives, manage uncertainty, and evaluate the consequences of their choices. Project-based learning studies show that richer student outcomes occur when learners are given opportunities to design, negotiate, produce, and present solutions (Guo et al., 2020; Kokotsaki et al., 2016).

For teaching factory-based chemistry practicum, creativity can be built into the model through formulation variation, local material selection, product testing, cost and safety analysis, packaging design, and product improvement. These activities should be accompanied by explicit rubrics for creativity, collaboration, communication, problem-solving, and responsibility. Without rubrics and process documentation, lecturers may observe group activity but have limited evidence of individual and team competence development. Therefore, soft-skill assessment should become an explicit component of model design.

Implementation Ecosystem: Facilities, Time, Confidence, Curriculum, and Partners

The barriers identified by students and lecturers show that teaching factory practicum requires an implementation ecosystem, not only revised worksheets. Students emphasized confidence, while lecturers emphasized equipment, materials, curriculum density, and time. These perspectives are complementary. Students need safe opportunities to try alternative formulations without fear of failure, whereas lecturers need manageable modules, sufficient materials, aligned learning outcomes, and institutional support. Learning factory literature also emphasizes that competence-oriented implementation depends on the alignment of objectives, processes, resources, and learning environments (Abele et al., 2015, 2017; Tisch et al., 2016).

A feasible initial strategy is to start with low-cost, safe, and locally relevant products such as liquid soap, solid soap, simple cleaning agents, natural extracts, or organic fertilizer. Product selection should match available laboratory capacity and basic quality testing equipment. Time constraints may be addressed by separating activities into pre-laboratory planning, laboratory production, post-laboratory testing, and product presentation. Partnerships can begin with local schools, campus business units, cooperatives, community groups, or small and medium enterprises rather than large industries. The finding that collaboration existed but was not routine suggests the need for simple partnership mechanisms, such as partner need identification, product feedback forms, guest practitioner sessions, or limited product trials.

Limitations

Several limitations must be considered. First, the sample was small and purposively selected, consisting of only 20 students and 6 lecturers from two institutions, so the findings cannot be generalized broadly to all chemistry education programs. Second, the dataset consisted of aggregate percentage recapitulations; consequently, detailed participant characteristics, raw item-level responses, reliability coefficients, item-total statistics, and deeper subgroup analysis were unavailable. Third, the instruments functioned as preliminary diagnostic tools and were not supported by psychometric reliability evidence. Fourth, the study relied on self-report and observation recapitulations without interviews, focus group discussions, open-ended responses, or classroom/laboratory field notes. Fifth, no teaching factory intervention was implemented, so the study cannot claim model effectiveness. These limitations mean that the findings should be read as preliminary design considerations for prototype development, not as final evidence that a teaching factory practicum model is effective.

CONCLUSION

This study indicates that developing a product-oriented teaching factory model in chemistry practicum is a relevant need in the examined chemistry teacher education context. Current practicum activities remain largely verification-oriented from the student perspective, while lecturers perceive a more balanced but still not predominantly exploratory pattern. Students and lecturers show strong interest in product-oriented practicum, but teaching factory understanding and course integration remain limited. Current practicum has supported several soft skills, especially collaboration, communication, safety, responsibility, and time management, but creativity and innovation require more explicit structure.

The main scientific finding is that model development should begin gradually through concept orientation, flexible product-based modules, simple quality testing, soft-skill rubrics, and partnership mechanisms. The evidence should be interpreted cautiously because the study used a small purposive sample, aggregate data, and preliminary diagnostic instruments. Future research should develop and validate teaching factory-based chemistry practicum prototypes, test them on a limited scale, and examine their effects on creativity, problem-solving, scientific communication, and entrepreneurial readiness. Interviews or focus group discussions are also needed to understand student and lecturer reasoning more deeply.

RECOMMENDATION

Based on this preliminary needs analysis, the development of a product-oriented teaching factory practicum should be implemented gradually through concept orientation, flexible modules, and realistic laboratory adaptation. Students and lecturers first need shared understanding of teaching factory principles, product workflow, safety, quality standards, documentation, and pedagogical reflection. Practicum modules should move from guided verification toward controlled formulation, simple product testing, revision, and presentation, using safe, low-cost, locally relevant products such as soap, cleaning agents, natural extracts, or organic fertilizer. Lecturers should integrate explicit rubrics for creativity, innovation, collaboration, communication, responsibility, problem-solving, time management, and laboratory safety. Institutional support is also required through improved access to basic tools and materials, better time allocation, lecturer training, and sustainable partnerships with schools, campus business units, cooperatives, community groups, or small enterprises. Further research should develop and validate prototypes through limited trials, richer observations, interviews, and product documentation.

ACKNOWLEDGMENTS

The authors express their gratitude to the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia (Kemdiktisaintek) for funding this research through the PPS-PDD research scheme. The authors also thank Universitas Mataram and its Institute for Research and Community Service for administrative support during the research implementation. Appreciation is extended to the chemistry education students and lecturers who contributed to the preliminary survey and observation data. The authors acknowledge support for manuscript structuring, language refinement, and formatting.

FUNDING INFORMATION

This research was funded by the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia (Kemdiktisaintek) through the PPS-PDD research scheme, under contract number 237/C3/DT.05.00/PL-BARU/2026 and derivative contract number 3951/UN18.L1/PP/2026.

AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Ahmadi	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Aliefman Hakim	✓	✓	✓	✓			✓	✓		✓	✓			✓
Jamaluddin	✓	✓	✓	✓										✓
Iwan Sumarlan		✓		✓		✓		✓		✓				
Baiq Risni Maripa			✓		✓		✓		✓			✓		

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

Abele, E., Chryssolouris, G., Sihn, W., Metternich, J., ElMaraghy, H., Seliger, G., Sivard, G., ElMaraghy, W., Hummel, V., Tisch, M., & Seifermann, S. (2017). Learning factories for future oriented research and education in manufacturing. *CIRP Annals, 66*(2), 803-826. https://doi.org/10.1016/j.cirp.2017.05.005

Abele, E., Metternich, J., Tisch, M., Chryssolouris, G., Sihn, W., ElMaraghy, H., Hummel, V., & Ranz, F. (2015). Learning factories for research, education, and training. *Procedia CIRP, 32*, 1-6. https://doi.org/10.1016/j.procir.2015.02.187

Agustian, H. Y., Seery, M. K., & Zhang, X. (2019). A framework for learning in the chemistry laboratory. *Israel Journal of Chemistry, 59*(6-7), 546-553. https://doi.org/10.1002/ijch.201800093

Ahmadi, A., & Maripa, B. R. (2022). Praktikum sabun cair dengan ekstrak bunga sepatu: Mengembangkan pemecahan masalah mahasiswa kimia melalui kimia terapan [Liquid soap practicum with hibiscus flower extract: Developing chemistry students' problem-solving through applied chemistry]. *Indonesian Journal of STEM Education, 4*(1), 51-60.

Baena, F., Guarin, A., Mora, J., Sauza, J., & Retat, S. (2017). Learning factory: The path to Industry 4.0. *Procedia Manufacturing, 9*, 73-80. https://doi.org/10.1016/j.promfg.2017.04.022

Chryssolouris, G., Mavrikios, D., & Rentzos, L. (2016). The teaching factory: A manufacturing education paradigm. *Procedia CIRP, 57*, 44-48. https://doi.org/10.1016/j.procir.2016.11.009

Galloway, K. R., & Bretz, S. L. (2015a). Measuring meaningful learning in the undergraduate chemistry laboratory: A national, cross-sectional study. *Journal of Chemical Education, 92*(12), 2006-2018. https://doi.org/10.1021/acs.jchemed.5b00538

Galloway, K. R., & Bretz, S. L. (2015b). Measuring meaningful learning in the undergraduate general chemistry and organic chemistry laboratories: A longitudinal study. *Journal of Chemical Education, 92*(12), 2019-2030. https://doi.org/10.1021/acs.jchemed.5b00754

Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research, 102*, Article 101586. https://doi.org/10.1016/j.ijer.2020.101586

Kautsar, A., Wiyono, G., Mulia, M., Iqbal, M., & Al-Fairusy, M. (2022). Teaching factory model development in vocational high schools. *Al-Ishlah: Jurnal Pendidikan, 14*(4), 6347-6360. https://doi.org/10.35445/alishlah.v14i4.2461

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools, 19*(3), 267-277. https://doi.org/10.1177/1365480216659733

Maripa, B. R., & Ahmadi, A. (2023). Pengaruh penambahan ekstrak bunga mawar terhadap kualitas sabun mandi berbasis minyak kelapa [Effect of rose flower extract addition on the quality of coconut oil-based bath soap]. *Indonesian Journal of STEM Education, 5*(1), 26-34.

Mavrikios, D., Georgoulias, K., & Chryssolouris, G. (2018). The teaching factory paradigm: Developments and outlook. *Procedia Manufacturing, 23*, 1-6. https://doi.org/10.1016/j.promfg.2018.04.029

Mavrikios, D., Georgoulias, K., & Chryssolouris, G. (2019). The teaching factory network: A new collaborative paradigm for manufacturing education. *Procedia Manufacturing, 31*, 398-403. https://doi.org/10.1016/j.promfg.2019.03.062

Priemer, B., Eilerts, K., Filler, A., Pinkwart, N., Rosken-Winter, B., Tiemann, R., & Upmeier zu Belzen, A. (2020). A framework to foster problem-solving in STEM and computing education. *Research in Science & Technological Education, 38*(1), 105-130. https://doi.org/10.1080/02635143.2019.1600490

Prinz, C., Morlock, F., Freith, S., Kreggenfeld, N., Kreimeier, D., & Kuhlenkotter, B. (2016). Learning factory modules for smart factories in Industrie 4.0. *Procedia CIRP, 54*, 113-118. https://doi.org/10.1016/j.procir.2016.05.105

Rentzos, L., Doukas, M., Mavrikios, D., Mourtzis, D., & Chryssolouris, G. (2014). Integrating manufacturing education with industrial practice using teaching factory paradigm: A construction equipment application. *Procedia CIRP, 17*, 189-194. https://doi.org/10.1016/j.procir.2014.01.126

Seery, M. K. (2020). Establishing the laboratory as the place to learn how to do chemistry. *Journal of Chemical Education, 97*(6), 1511-1514. https://doi.org/10.1021/acs.jchemed.9b00764

Succi, C., & Canovi, M. (2020). Soft skills to enhance graduate employability: Comparing students and employers' perceptions. *Studies in Higher Education, 45*(9), 1834-1847. https://doi.org/10.1080/03075079.2019.1585420

Tisch, M., Hertle, C., Abele, E., Metternich, J., & Tenberg, R. (2016). Learning factory design: A competency-oriented approach integrating three design levels. *International Journal* *of Computer Integrated Manufacturing, 29*(12), 1355-1375. https://doi.org/10.1080/0951192X.2015.1033017

Wahjusaputri, S., & Bunyamin, B. (2022). Development of teaching factory competency-based for vocational secondary education in Central Java, Indonesia. *International Journal of Evaluation and Research in Education, 11*(1), 353-360. https://doi.org/10.11591/ijere.v11i1.21709

Wahjusaputri, S., Fitriani, S., & Syarif, S. (2020). Developing the teaching factory learning media in a public vocational high school. *Jurnal Pendidikan Vokasi, 10*(1), 69-79. https://doi.org/10.21831/jpv.v10i1.30222

Yuriev, E., Naidu, S., Schembri, L. S., & Short, J. L. (2017). Scaffolding the development of problem-solving skills in chemistry: Guiding novice students out of dead ends and false starts. *Chemistry Education Research and Practice, 18*(3), 486-504. https://doi.org/10.1039/C7RP00009J