ITEJ
Indonesian Technology and Education Journal
E-ISSN: 2985-8216; P-ISSN: 2985-8208
https://journal.diginus.id/index.php/ITEJ

# Implementation of Teaching Factory in Mathematics Learning: A Qualitative Survey of Students' Trigonometric Concept Understanding and Building Construction Reasoning Literacy

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**ARTICLE INFO**

***Keywords:***

Building Construction Reasoning Literacy; Building Modeling and Information Design; Teaching Factory; Trigonometric Conceptual Understanding; Vocational Education.

***Article History***

Received: March 31, 2026
Revised : May 26, 2026
Accepted : July 30, 2026

**ABSTRACT**

Mathematics instruction in the Building Modeling and Information Design program requires students not only to master trigonometric concepts but also to develop reasoning literacy for interpreting building construction models within authentic vocational contexts. However, many vocational high school students continue to experience difficulties in connecting abstract trigonometric concepts with practical construction tasks. Although previous studies have investigated trigonometric conceptual understanding and Teaching Factory implementation, limited research has examined the integration of trigonometric conceptual understanding and building construction reasoning literacy within Teaching Factory-based mathematics learning. This study aimed to examine students' trigonometric conceptual understanding and their reasoning literacy regarding building construction models during the implementation of Teaching Factory-based mathematics learning. A descriptive qualitative survey design was employed involving 40 tenth-grade students enrolled in the Building Modeling and Information Design program. Data were collected through a trigonometric concept understanding test, a building construction reasoning literacy questionnaire, and semi-structured interviews, and were analyzed using descriptive qualitative techniques. The findings revealed that 45% of the students demonstrated a moderate level of trigonometric conceptual understanding, 40% achieved a high level, and 15% were classified in the low category. Similarly, the majority of students exhibited a moderate level of reasoning literacy regarding building construction models, indicating that conceptual understanding and reasoning literacy developed at varying levels within the Teaching Factory learning environment. These findings demonstrate that Teaching Factory-based mathematics learning provides a meaningful vocational context for strengthening the relationship between trigonometric conceptual understanding and reasoning literacy, thereby supporting the application of mathematics in authentic building construction tasks.



**To cite this article** : Liunima, A., Wijonarko, B., Wibudiarty, A. D. C., Atikah, Lingga, S., & Nurrahmah, A. (2026). Implementation of Teaching Factory in mathematics learning: A qualitative survey of students' trigonometric concept understanding and building construction reasoning literacy. *Indonesian Technology and Education Journal,* 4(2), 134-146. Doi. 10.61255/itej.v4i2.1792

## INTRODUCTION

Education has long been recognized as a fundamental pillar for developing high-quality human resources capable of responding to the rapid transformation of science, technology, and the global labor market. The emergence of digitalization, industrial automation, and Society 5.0 has shifted the expectations placed on educational institutions from merely transmitting knowledge to cultivating learners who possess critical thinking, analytical reasoning, adaptability, and problem-solving competencies relevant to increasingly complex professional environments (Amelia, 2023; Abdillah, 2024; Fati'ah & Siagian, 2024). Within this context, mathematics occupies a strategic position because it provides the conceptual and logical foundation required for interpreting quantitative information, making informed decisions, and solving authentic problems across various disciplines and occupations (Hasanah, 2023; Setiowati et al., 2024; Mutmainnah et al., 2025). Rather than functioning solely as a compulsory school subject, mathematics has become an essential competency that supports innovation, technological development, and workforce readiness in the twenty-first century. Consequently, mathematics instruction should not only emphasize procedural mastery but also facilitate meaningful learning experiences that enable students to connect mathematical concepts with practical situations encountered in both everyday life and future professional contexts.

The importance of contextual mathematics learning becomes even more evident in vocational education, where the primary objective is to prepare graduates with competencies that meet the evolving demands of industry. In Indonesia, the implementation of the *Kurikulum Merdeka* has reinforced this orientation by positioning mathematics as an adaptive subject that supports students' vocational expertise rather than as an isolated body of theoretical knowledge (Ramadhani et al., 2024; Khoiruman & Maulana, 2025). This educational direction aligns with national policies promoting stronger *link and match* between schools and the labor market through learning experiences that reflect authentic industrial practices (Kemendikbudristek, 2022; Kemendikbudristek, 2024). Accordingly, vocational students are expected to apply mathematical knowledge in solving problems related to measurement, estimation, production processes, quality control, and other technical activities relevant to their respective fields of specialization. Such expectations require mathematics instruction to be contextual, applicable, and closely connected to workplace realities so that students perceive mathematics not merely as an academic requirement but as an indispensable competency that supports their future careers.

Despite this curricular orientation, mathematics instruction in vocational high schools has not yet been fully aligned with the practical demands of students' vocational specializations. Rapid industrial development has not always been accompanied by corresponding innovations in mathematics instruction, resulting in a gap between the mathematical competencies taught in classrooms and those required in authentic workplace settings (Sutrisno, 2023). Consequently, mathematics is often perceived as an abstract and highly procedural subject, with limited relevance to the technical problems students are expected to solve in their future professions (Fedi et al., 2020; Naje'ma, 2025). This challenge is particularly evident in vocational programs where students are expected to apply mathematical concepts directly to technical activities, yet frequently experience difficulties in connecting classroom knowledge with real industrial practices. In disciplines related to building design and construction, for example, students must understand mathematical concepts such as geometry, measurement, and trigonometry to interpret technical drawings, perform accurate calculations, and support construction planning. However, many students continue to struggle to relate these concepts to authentic vocational contexts, creating barriers to the development of meaningful conceptual understanding and limiting their ability to apply mathematics in solving practical problems (Zulmaulida et al., 2021; Pramesti & Dewi, 2024; Kurniati et al., 2025). These conditions indicate that vocational mathematics instruction requires learning environments that enable students to construct mathematical understanding through contextual experiences closely connected to their fields of specialization.

To address these challenges, vocational education requires instructional approaches that effectively connect mathematical concepts with authentic industrial practices. One of the most promising approaches is the Teaching Factory (TEFA), which integrates classroom learning with real production processes, workplace standards, and industrial culture, allowing students to experience learning in contexts that closely resemble professional environments (Direktorat Pembinaan SMK, 2021; Prasetyo & Nugroho, 2022; Sutianah et al., 2024; Setiadi et al., 2025).

Through TEFA, students actively engage in planning, implementing, evaluating, and refining project-based activities that reflect actual workplace demands while simultaneously applying disciplinary knowledge to solve practical problems. Although TEFA has been widely implemented in productive vocational subjects to strengthen technical competence, collaboration, work responsibility, and career readiness (Rahmawati, 2021; Imran, 2024; Widiatna et al., 2025), its application in adaptive subjects, particularly mathematics, remains relatively limited. In vocational programs such as Building Modeling and Information Design, mathematical concepts, especially trigonometry, are fundamental for interpreting construction drawings, determining structural dimensions, calculating roof slopes, and ensuring measurement accuracy during the design process. Consequently, integrating mathematics instruction into the Teaching Factory environment offers opportunities for students to develop conceptual understanding and reasoning through authentic vocational experiences, enabling them to interpret mathematical concepts within meaningful professional contexts rather than merely memorizing formulas or procedural algorithms.

Previous studies have consistently demonstrated that contextual, project-based, and industry-oriented learning contributes positively to vocational education by improving students' competencies and strengthening the relevance of classroom learning to workplace demands. Research on Teaching Factory has primarily reported its effectiveness in enhancing technical competence, employability, collaboration, creativity, work responsibility, and students' readiness to enter professional environments (Rahmawati, 2021; Prasetyo & Nugroho, 2022; Imran, 2024; Sutianah et al., 2024; Setiadi et al., 2025; Widiatna et al., 2025). In parallel, studies in mathematics education have shown that contextual learning facilitates deeper conceptual understanding, improves visualization skills, strengthens mathematical problem-solving, and enables students to recognize the practical value of mathematical knowledge within vocational settings (Arifin, 2021; Rahayu, 2022; Wibowo, 2023; Andinasari et al., 2024; Widjajanti et al., 2025; Solikah et al., 2025). More specifically, Utomo and Muhtarom (2025) emphasized that integrating mathematics learning with Teaching Factory activities encourages meaningful participation while supporting vocational competence, whereas Muhtarom et al. (2026) demonstrated that contextual Teaching Factory instruction significantly improves vocational students' mathematical problem-solving abilities and reinforces the relationship between mathematics learning and authentic industrial practice. Furthermore, studies focusing on trigonometry have consistently reported that students achieve stronger conceptual understanding when mathematical representations, procedures, and applications are explicitly connected to real engineering and construction activities rather than presented in isolation (Suendarti & Liberna, 2021; Patmala & Yulia, 2023; Damayanti et al., 2024; Singh, 2025). Collectively, these findings indicate that authentic vocational contexts create more meaningful opportunities for students to construct mathematical understanding and apply their knowledge in solving problems encountered in professional practice.

Despite these promising findings, several limitations remain in the existing literature. Previous Teaching Factory studies have largely concentrated on productive vocational subjects, production management, soft-skill development, work readiness, and the simulation of industrial procedures, while its integration into adaptive subjects such as mathematics has received comparatively limited attention (Rohmah, 2019; Wibowo, 2020; Rahmawati, 2021; Imran, 2024). Research that connects mathematics with Teaching Factory learning has begun to demonstrate its potential for strengthening vocational competence and mathematical problem solving, yet these studies have generally focused on broad implementation models or performance outcomes rather than on the relationship between students' conceptual understanding and their reasoning within a specific vocational domain (Utomo & Muhtarom, 2025; Muhtarom et al., 2026). Likewise, studies on trigonometry have mostly examined conceptual difficulties, visualization, procedural accuracy, and problem-solving ability without sufficiently exploring how students interpret trigonometric concepts through authentic building-design tasks. This gap is particularly important in the Building Modeling and Information Design program, where students are required not only to calculate accurately but also to interpret models, connect mathematical representations with construction structures, and justify their reasoning in applied contexts. Therefore, limited empirical evidence is available regarding how Teaching Factory-based mathematics learning supports the simultaneous development of trigonometric conceptual understanding and reasoning literacy related to building construction models. The novelty of the present study lies in integrating these two cognitive competencies within an authentic Teaching Factory environment and examining how students at different levels of understanding interpret and apply trigonometric concepts during vocational project activities.

Based on this background, the present study aims to examine students' understanding of trigonometric concepts and their reasoning literacy regarding building construction models while completing project tasks through the implementation of Teaching Factory-based mathematics learning. More specifically, the study seeks to describe the distribution of students' conceptual understanding, identify their levels of reasoning literacy, and explore the reasoning characteristics demonstrated by students across high, moderate, and low proficiency categories. Theoretically, this study contributes to vocational mathematics education by extending the application of the Teaching Factory framework beyond productive subjects and positioning it as a contextual environment for examining the interaction between mathematical conceptual understanding and vocational reasoning. It also contributes to the literature on trigonometry learning by emphasizing that conceptual mastery should be analyzed together with students' ability to interpret, communicate, and apply mathematical relationships in authentic construction contexts. Practically, the findings are expected to provide mathematics teachers with a clearer basis for designing project-based lessons that connect trigonometric concepts with building-modeling activities, technical drawings, measurement tasks, and construction calculations. The study may also assist vocational schools in strengthening the integration between adaptive and productive subjects so that mathematical knowledge becomes more directly relevant to students' professional preparation. Ultimately, this research is expected to support the development of mathematics instruction that is conceptually meaningful, contextually grounded, and responsive to the competency demands of the Building Modeling and Information Design specialization.

## METHOD

This study employed a descriptive qualitative survey design to investigate students' understanding of trigonometric concepts and their reasoning literacy regarding building construction models within the implementation of Teaching Factory-based mathematics learning. A descriptive qualitative approach was selected because the study sought to provide an in-depth description of students' conceptual understanding and reasoning processes rather than to examine causal relationships or measure the effectiveness of an intervention statistically. The survey component enabled the researchers to identify the distribution of students' levels of trigonometric conceptual understanding and reasoning literacy, while qualitative exploration through interviews provided a richer interpretation of students' cognitive characteristics during the completion of vocational project tasks. The study was conducted during the 2025/2026 academic year in the Building Modeling and Information Design program at a vocational high school where Teaching Factory had been integrated into mathematics learning. This setting was selected because the specialization requires students to apply trigonometric concepts directly to authentic building-design and construction activities, thereby providing an appropriate context for examining the relationship between conceptual understanding and vocational reasoning.

The study population consisted of all tenth-grade students enrolled in the Building Modeling and Information Design specialization who had completed the trigonometry unit within the Teaching Factory learning environment. A purposive sampling technique was employed to select participants because the study required students who had experienced Teaching Factory-based mathematics instruction and had completed vocational project assignments involving the application of trigonometric concepts. A total of 40 students participated in the study and represented varying levels of conceptual understanding and reasoning literacy. Participation was voluntary, and all students were informed about the objectives and procedures of the research before data collection commenced. To obtain more comprehensive qualitative evidence, nine participants were subsequently selected for semi-structured interviews, comprising three students from each achievement category (high, moderate, and low) identified through the results of the trigonometric concept test. This participant selection strategy enabled the researchers to explore similarities and differences in students' reasoning structures and conceptual interpretations across different levels of mathematical understanding within authentic vocational learning contexts.

Three instruments were employed to collect the research data: a trigonometric concept understanding test, a building construction reasoning literacy questionnaire, and a semi-structured interview guide. The trigonometric concept understanding test consisted of open-ended essay items designed to evaluate six indicators of conceptual understanding: (1) restating trigonometric concepts, (2) classifying objects based on trigonometric properties, (3) identifying examples and non-examples of trigonometric concepts, (4) representing trigonometric concepts through multiple mathematical representations, (5) selecting and applying appropriate trigonometric procedures, and (6) applying trigonometric concepts to solve contextual problems. The building construction reasoning literacy questionnaire employed a five-point Likert scale ranging from strongly disagree to strongly agree to measure students' ability to interpret, analyze, and communicate reasoning related to building construction models within vocational project activities. Semi-structured interviews were conducted to obtain a deeper understanding of students' conceptual reasoning, interpretation strategies, and cognitive processes when solving contextual trigonometric problems. Prior to data collection, all instruments underwent expert validation by specialists in mathematics education and Building Modeling and Information Design to ensure content relevance and clarity. The reliability of the reasoning literacy questionnaire was evaluated using Cronbach's Alpha, yielding a coefficient above 0.70, which indicated acceptable internal consistency for research purposes. The overall research procedure is illustrated in Figure 1.

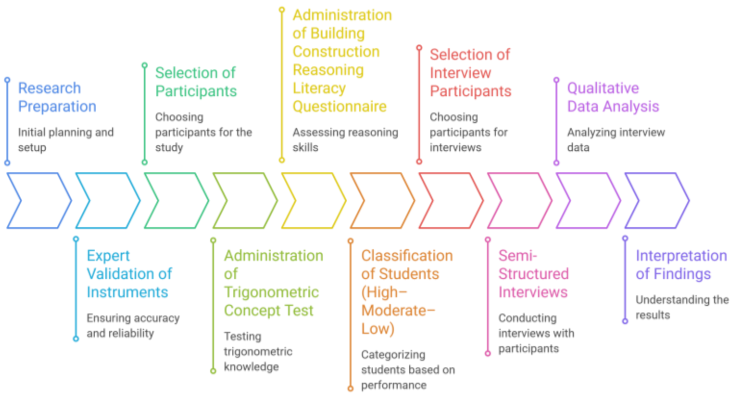


**Figure 1.** Research Procedures

Figure 1 summarizes the sequential stages implemented throughout the study, beginning with instrument preparation and validation, followed by participant selection, quantitative and qualitative data collection, participant categorization, in-depth interviews, data analysis, and the interpretation of findings. This procedure ensured that the qualitative exploration was grounded in the results of the trigonometric concept assessment and reasoning literacy questionnaire, thereby enabling a comprehensive understanding of students' conceptual and reasoning characteristics within the Teaching Factory learning environment.

Data collection was conducted over a two-month period during the 2025/2026 academic year following the sequence presented in Figure 1. The process began with the administration of the trigonometric concept understanding test to all participants in order to identify their levels of conceptual understanding. Subsequently, students completed the building construction reasoning literacy questionnaire to examine their ability to interpret and communicate reasoning related to building construction models within Teaching Factory-based project activities. Based on the results of the written test, participants were classified into high, moderate, and low conceptual understanding categories. Three students from each category were then purposively selected for semi-structured interviews to provide a more comprehensive explanation of their conceptual reasoning, interpretation strategies, and cognitive processes while solving contextual trigonometric problems. Throughout the data collection process, all written responses, questionnaire results, interview recordings, and supporting field documentation were systematically organized to facilitate subsequent analysis and ensure the completeness and consistency of the research data.

The collected data were analyzed using descriptive qualitative analysis supported by descriptive survey data. Students' responses to the trigonometric concept understanding test and the reasoning literacy questionnaire were first summarized descriptively to identify the distribution of conceptual understanding and reasoning literacy levels across all participants. The interview data were subsequently transcribed verbatim and analyzed through an iterative process involving data reduction, coding, categorization, interpretation, and conclusion drawing to identify recurring patterns in students' conceptual understanding and reasoning characteristics across the three achievement categories. The integration of written test results, questionnaire findings, and interview evidence enabled methodological triangulation, thereby strengthening the credibility and trustworthiness of the findings. Ethical principles were maintained throughout the study by informing all participants about the objectives and procedures of the research prior to data collection, obtaining their voluntary participation, ensuring the confidentiality of personal information, anonymizing participant identities through coding, and using all collected data exclusively for academic research purposes.

## RESULTS AND DISCUSSION

### Results

The findings are presented in two sections. The first section describes students' levels of trigonometric conceptual understanding based on the written test, whereas the second section presents the profile of students' reasoning literacy regarding building construction models based on the questionnaire. Together, these findings provide an overview of students' cognitive performance within the implementation of Teaching Factory-based mathematics learning before being explored further in the discussion section.

**Table 1.** Distribution of Students' Trigonometric Conceptual Understanding

| Understanding Category | Frequency | Percentage | Representative Subject |
|---|---|---|---|
| High | 16 | 40% | S38 |
| Moderate | 18 | 45% | S02 |
| Low | 6 | 15% | S06 |
| Total | 40 | 100% | |

As presented in Table 1, students demonstrated varying levels of trigonometric conceptual understanding. The largest proportion of participants was classified in the moderate category, consisting of 18 students (45%), followed by the high category with 16 students (40%), while only 6 students (15%) were categorized as having a low level of conceptual understanding. These findings indicate that most students had acquired a satisfactory understanding of fundamental trigonometric concepts, although differences in conceptual mastery remained evident across participants. The distribution also shows that nearly half of the participants had not yet reached the highest level of conceptual understanding, suggesting that variations in students' abilities persisted despite learning within the Teaching Factory environment. To facilitate further qualitative exploration, one representative participant from each category was selected for subsequent analysis based on the written test results.

Following the analysis of conceptual understanding, students' reasoning literacy regarding building construction models was examined using the questionnaire. The results are summarized in Table 2.

**Table 2.** Profile of Students' Building Construction Reasoning Literacy

| Literacy Category | Score Range | Frequency | Percentage |
|---|---|---|---|
| High | 80–100 | 10 | 25% |
| Moderate | 60–79 | 22 | 55% |
| Low | 0–59 | 8 | 20% |
| Total | | 40 | 100% |

The results presented in Table 2 reveal that the majority of students demonstrated a moderate level of reasoning literacy regarding building construction models. Specifically, 22 students (55%) achieved scores within the moderate category, whereas 10 students (25%) reached the high category and 8 students (20%) were classified in the low category. This distribution suggests that most participants were able to interpret and apply reasoning related to building construction models at an adequate level, although considerable variation remained among students. Overall, the findings indicate that students' reasoning literacy tended to follow a similar distribution to their trigonometric conceptual understanding, with the moderate category representing the largest proportion of participants. These descriptive findings provide an initial profile of students' conceptual understanding and reasoning literacy, which forms the basis for the qualitative interpretation presented in the subsequent discussion.

The results obtained from the trigonometric concept understanding test and the building construction reasoning literacy questionnaire reveal distinct variations in students' cognitive performance within the Teaching Factory learning environment. Although the majority of participants were classified in the moderate category for both measures, the presence of high- and low-performing students indicates differences in conceptual mastery and reasoning ability when addressing vocational mathematics tasks. These descriptive findings establish the empirical basis for the following discussion, in which the characteristics of students' conceptual understanding and reasoning literacy are examined in greater depth across the identified proficiency levels.

## Discussion

The predominance of students in the moderate category indicates that most participants had developed a functional understanding of trigonometric concepts, but their knowledge had not yet been fully integrated across representations, procedures, and contextual applications. This pattern suggests that students were generally able to recall basic ratios and perform routine calculations, yet they experienced greater difficulty when required to explain conceptual relationships or transfer mathematical knowledge to building-construction problems. Such a profile is consistent with the view that trigonometric understanding involves more than formula substitution because students must coordinate angles, side relationships, symbolic representations, and graphical or spatial interpretations (Weber, 2005; Suendarti & Liberna, 2021). Similar difficulties have been reported among secondary students who can complete familiar procedures but struggle to justify their reasoning or apply trigonometric concepts in unfamiliar contexts (Rahayu, 2022; Patmala & Yulia, 2023; Damayanti et al., 2024). The relatively large proportion of students in the high category nevertheless shows that meaningful conceptual development is possible when learners connect calculations with concrete vocational tasks, such as determining roof slopes and estimating structural dimensions. In contrast, the low-performing group reflects fragmented knowledge in which formulas are treated as isolated rules rather than as expressions of relationships among angles, sides, and construction measurements. The findings therefore support existing conceptual-understanding frameworks while extending them into vocational education by showing that the quality of students' trigonometric knowledge can be distinguished through their ability to interpret and use concepts within authentic building-modeling situations.

The distribution of conceptual understanding also highlights the pedagogical value and limitations of Teaching Factory-based mathematics learning. By situating trigonometric problems within building-design projects, the Teaching Factory environment provided students with concrete purposes for measurement, calculation, and spatial reasoning, thereby reducing the separation between school mathematics and professional practice. This interpretation is supported by contextual learning theory, which argues that mathematical knowledge becomes more meaningful when students construct understanding through situations that resemble its actual use (De Corte et al., 2000; Arifin, 2021; Hasanah, 2023). It also aligns with research showing that real-world problem contexts and appropriate representational supports enable students to move from procedural performance toward more connected mathematical reasoning (Geiger et al., 2018; Widjajanti et al., 2025). The findings correspond with Utomo and Muhtarom (2025), who identified the potential of Teaching Factory integration to strengthen vocationally relevant mathematics learning, and with Muhtarom et al. (2026), who reported improved mathematical problem solving through contextual Teaching Factory activities. However, the continued concentration of students in the moderate category indicates that authentic context alone does not automatically produce deep conceptual mastery; students still require explicit guidance to connect project activities with underlying trigonometric principles. Thus, the Teaching Factory should be understood not simply as an industrial simulation model, but as a pedagogical structure whose effectiveness depends on how deliberately teachers integrate conceptual explanation, mathematical representation, and reflective reasoning into vocational tasks.

The differences observed among students in the high, moderate, and low conceptual understanding categories demonstrate that successful trigonometry learning extends beyond computational accuracy to encompass the ability to interpret mathematical relationships in vocational contexts. Students with high conceptual understanding were able to connect trigonometric principles with authentic construction tasks, indicating that they had developed interconnected mathematical schemas rather than isolated procedural knowledge. Conversely, students in the moderate category tended to rely on familiar solution procedures but experienced difficulties when confronted with problems requiring deeper conceptual interpretation or multiple mathematical representations. Those in the low category encountered more fundamental obstacles, particularly in identifying trigonometric ratios, understanding relationships among triangle elements, and selecting appropriate procedures for contextual problems. These differences support previous studies emphasizing that conceptual understanding develops progressively through the integration of representations, visualization, and contextual experiences rather than through repetitive procedural practice alone (Bernard et al., 2019; Senita, 2022; Andinasari et al., 2024; Solikah et al., 2025). They also reinforce the proposition that visualization plays a central role in trigonometry because students must mentally coordinate abstract mathematical relationships with physical objects encountered in vocational learning environments (Sterling, 2014; Widjajanti et al., 2025). Consequently, improving students' conceptual understanding requires instructional designs that continuously integrate visual interpretation, mathematical reasoning, and authentic vocational experiences rather than emphasizing formula memorization as the primary learning objective.

A similar pattern emerged in students' reasoning literacy regarding building construction models, where the majority of participants were also classified in the moderate category. This finding suggests that although many students were capable of interpreting information related to construction models, they had not yet consistently demonstrated the analytical reasoning required to justify mathematical decisions within complex vocational situations. Reasoning literacy in vocational mathematics involves interpreting technical information, selecting appropriate mathematical procedures, and explaining the logical basis for decisions made during project activities. These competencies are particularly important in Building Modeling and Information Design because construction planning depends on the accurate interpretation of dimensions, angles, spatial relationships, and technical drawings (Eastman, 2011; Kilmer & Kilmer, 2021; Singh, 2025). The present findings therefore indicate that conceptual understanding and reasoning literacy should be viewed as complementary rather than independent competencies, since accurate calculations alone are insufficient without the ability to interpret their practical implications in construction work. This interpretation is consistent with studies arguing that contextual vocational learning strengthens reasoning when students actively engage with authentic engineering problems and communicate mathematical ideas within meaningful professional settings (Pedersen et al., 2012; Geiger et al., 2018). Accordingly, the Teaching Factory environment contributes not only by providing realistic learning experiences but also by creating opportunities for students to transform mathematical knowledge into vocational reasoning that reflects actual workplace practices.

The findings further suggest that trigonometric conceptual understanding and reasoning literacy developed in a mutually reinforcing manner throughout the Teaching Factory learning process. Students who demonstrated stronger conceptual understanding generally exhibited greater confidence in interpreting building construction models, selecting appropriate mathematical procedures, and explaining the rationale underlying their solutions. In contrast, students with limited conceptual understanding frequently relied on memorized formulas without fully recognizing the mathematical relationships embedded within vocational tasks, which constrained their reasoning performance. This pattern supports the argument that conceptual knowledge forms the cognitive foundation upon which higher-order reasoning is constructed, particularly when students are required to solve authentic problems rather than routine textbook exercises (Setiowati et al., 2024; Mutmainnah et al., 2025). It also corresponds with the broader perspective that vocational mathematics should cultivate interconnected competencies involving conceptual comprehension, logical reasoning, and contextual problem solving simultaneously rather than treating these dimensions as separate learning outcomes (Kurniati et al., 2025; Kurniawan et al., 2026). From a pedagogical perspective, these findings imply that mathematics instruction in vocational education should deliberately integrate conceptual explanation, practical application, and reflective reasoning so that students are able not only to perform calculations accurately but also to justify mathematical decisions within professional contexts.

The present study extends the existing literature by positioning Teaching Factory as a contextual learning environment that supports the integration of trigonometric conceptual understanding and reasoning literacy within vocational mathematics education. While previous investigations have predominantly emphasized the contribution of Teaching Factory to technical competence, employability, work readiness, and industrial simulation (Rohmah, 2019; Wibowo, 2020; Rahmawati, 2021; Prasetyo & Nugroho, 2022; Imran, 2024; Sutianah et al., 2024; Setiadi et al., 2025; Widiatna et al., 2025), comparatively little attention has been given to how the model facilitates the simultaneous development of mathematical conceptual understanding and vocational reasoning. The findings therefore contribute conceptually by demonstrating that authentic production-based learning environments provide opportunities for students to construct mathematical meaning while interpreting professional tasks requiring spatial reasoning and trigonometric analysis. This perspective complements current educational reforms that encourage stronger integration between adaptive and productive subjects within the implementation of the *Kurikulum Merdeka* and vocational education policies (Kemendikbudristek, 2022; Kemendikbudristek, 2024; Ramadhani et al., 2024; Akbar, 2025; Khoiruman & Maulana, 2025). Practically, the study highlights the importance of designing mathematics instruction that systematically embeds vocational projects, construction scenarios, and structured mathematical reflection into classroom activities rather than presenting trigonometry as an isolated theoretical topic. Such an approach has the potential to strengthen students' readiness to apply mathematical knowledge in authentic workplace situations while simultaneously supporting the broader objective of producing vocational graduates equipped with both disciplinary understanding and profession-oriented reasoning skills, as emphasized in contemporary human resource development and vocational education initiatives (Amelia, 2023; Abdillah, 2024; Fati'ah & Siagian, 2024).

## CONCLUSIONS

This study concludes that the implementation of Teaching Factory-based mathematics learning provides a meaningful context for examining students' trigonometric conceptual understanding and reasoning literacy regarding building construction models in vocational education. The findings indicate that most students demonstrated a moderate level of conceptual understanding and reasoning literacy, while students with higher conceptual understanding consistently exhibited stronger abilities to interpret construction models, justify mathematical reasoning, and apply trigonometric concepts in authentic vocational tasks. These results confirm that conceptual understanding and reasoning literacy are closely interconnected cognitive competencies that support the meaningful application of mathematics within professional contexts. The study further demonstrates that Teaching Factory offers an effective learning environment for integrating mathematical concepts with vocational practice, enabling students to construct knowledge through authentic project experiences. Therefore, mathematics instruction in vocational high schools should emphasize contextual learning that simultaneously develops conceptual understanding, mathematical reasoning, and the application of knowledge to discipline-specific problems, particularly within the Building Modeling and Information Design program.

## AUTHOR CONTRIBUTION STATEMENT

Arki Liunima conceived the study, developed the research framework, and prepared the original manuscript draft. Bambang Wijonarko designed the research instruments and conducted the data collection. Alberta Dini Catur Wibudiarty analyzed the data and interpreted the research findings. Atikah and Sohmiyati Lingga validated the research instruments, contributed to the qualitative data analysis, and critically revised the manuscript for important intellectual content. Arfatin Nurrahmah supervised the overall research process, provided methodological guidance, and reviewed and finalized the manuscript. All authors read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work, ensuring the accuracy and integrity of the research.

**REFERENCES**

Abdillah, F. (2024). Peran perguruan tinggi dalam meningkatkan kualitas sumber daya manusia di Indonesia. *Educazione: Jurnal Multidisiplin, 1*(1), 13–24.

Akbar, M. (2025). *Pengelolaan musyawarah guru mata pelajaran/guru produktif dalam implementasi Kurikulum Merdeka di Sekolah Menengah Kejuruan Negeri 2 Palopo* (Doctoral dissertation, Universitas Islam Negeri Palopo).

Amelia, U. (2023). Tantangan pembelajaran era Society 5.0 dalam perspektif manajemen pendidikan. *Al-Marsus: Jurnal Manajemen Pendidikan Islam, 1*(1), 68–82. https://doi.org/10.30983/al-marsus.v1i1.6415

Andinasari, A., Yanti, Y., & Sistyawati, R. I. (2024). Efektivitas media pembelajaran matematika konkret dan digital pada materi trigonometri terhadap hasil belajar matematika siswa. *Journal of Social and Scientific Education, 1*(3), 100–111. https://doi.org/10.58230/josse.v1i3.236

Arifin, Z. (2021). *Pembelajaran kontekstual dalam pendidikan matematika*. Remaja Rosdakarya.

Bernard, M., Sumarna, A., Rolina, R., & Akbar, P. (2019). Development of high school student worksheets using VBA for Microsoft Word trigonometry materials. *Journal of Physics: Conference Series, 1315*(1), Article 012031. https://doi.org/10.1088/1742-6596/1315/1/012031

Damayanti, I. M., Santia, I., & Hima, L. R. (2024). Analysis of students' mathematical concept understanding ability in understanding trigonometry material for Class XI senior high school. *International Journal of Research and Review, 11*(6), 706–712. https://doi.org/10.52403/ijrr.20240677

De Corte, E., Verschaffel, L., & Greer, B. (2000, November). Connecting mathematics problem solving to the real world. In *Proceedings of the International Conference on Mathematics Education into the 21st Century: Mathematics for Living* (pp. 66–73).

Direktorat Pembinaan SMK. (2021). *Panduan pelaksanaan Teaching Factory di SMK*. Kementerian Pendidikan dan Kebudayaan.

Eastman, C. M. (2011). *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers, and contractors*. John Wiley & Sons.

Fati'ah, S. N., & Siagian, I. (2024). Perencanaan sumber daya manusia dalam pengantar manajemen pendidikan untuk mengatasi tantangan dan strategi di era dinamika pendidikan. *Jurnal Ilmiah Wahana Pendidikan, 10*(21), 792–800.

Fedi, S., Blikololong, M. H. O., & Jeramat, E. (2020). Pengaruh pembelajaran tutor sebaya terhadap prestasi belajar siswa kelas VII pada pokok bahasan segi empat semester II SMPK Immaculata Ruteng tahun ajaran 2018/2019. *JIPD (Jurnal Inovasi Pendidikan Dasar), 4*(2), 91–98. https://doi.org/10.36928/jipd.v4i2.356

Geiger, V., Stillman, G., Brown, J., Galbraith, P., & Niss, M. (2018). Using mathematics to solve real world problems: The role of enablers. *Mathematics Education Research Journal, 30*(1), 7–19. https://doi.org/10.1007/s13394-017-0217-3

Hasanah, N. (2023). *Pembelajaran matematika berbasis kontekstual di sekolah kejuruan*. Deepublish.

Imran, A. (2024). Implementasi Teaching Factory dengan model evaluasi CIPP dan kesiapan kerja siswa terhadap orientasi masa depan pekerjaan siswa. *Jurnal Pendidikan Vokasi, 14*(1).

Kemendikbudristek. (2022). *Kurikulum Merdeka sebagai opsi pemulihan pembelajaran*. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

Kemendikbudristek. (2024). *Panduan pembelajaran dan asesmen Kurikulum Merdeka*. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

Khoiruman, M., & Maulana, F. (2025). Persepsi guru dan siswa terhadap implementasi Kurikulum Merdeka pada pembelajaran matematika di Madrasah Aliyah (MA). *SIGMA: Jurnal Pendidikan Matematika dan Sains, 3*(1), 1–12.

Kilmer, R., & Kilmer, W. O. (2021). *Construction drawings and details for interiors*. John Wiley & Sons.

Kurniati, R., Dahlan, T., Madubun, F. M., Afifa, R. N., Dahoklory, F. M., Dahliani, S., ... Lubis, H. (2025). *Pendidikan matematika*. Yayasan Tri Edukasi Ilmiah.

Kurniawan, H., Lintong, F. D., Judijanto, L., & Sepriano, S. (2026). *Strategi dan inovasi pendidikan kejuruan*. PT Sonpedia Publishing Indonesia.

Meditama, R. F., & Purwady, A. K. (2024). The influence of augmented reality (AR) learning on the Teaching Factory program for vocational high school students. In *International Seminar on Islamic Education & Peace* (Vol. 4, pp. 865–872).

Muhtarom, M., Utomo, H. N., & Dwijayanti, I. (2026). Enhancing vocational students' mathematical problem-solving through contextual Teaching Factory learning. *Jurnal Elemen, 12*(2), 392–408. https://doi.org/10.29408/jel.v12i2.31809

Mutmainnah, N., Izzati, N., & Jaelani, Z. A. (2025). Peran logika untuk membangun kemampuan siswa SMPN 2 Labuapi dalam berpikir kritis. *Pendas: Jurnal Ilmiah Pendidikan Dasar, 10*(1), 90–105.

Naje'ma, I. N. (2025). Persepsi siswa terhadap mata pelajaran matematika sekolah dasar. *Jurnal Terapan Pendidikan Dasar dan Menengah, 5*(2), 84–87.

Patmala, K., & Yulia, P. (2023). Analisis kemampuan pemahaman konsep matematis siswa madrasah aliyah terhadap materi trigonometri. *Venn: Journal of Sustainable Innovation on Education, Mathematics and Natural Sciences, 2*(2), 62–70. https://doi.org/10.53696/2964-867X.100

Pedersen, J. B., Andersen, S., & Majgaard, G. (2012). Design of trigonometry apps for vocational education. In *Proceedings of the IASTED International Conference on Human Computer Interaction (HCI)*. https://doi.org/10.2316/P.2012.772-020

Pramesti, S. L. D., & Dewi, H. L. (2024). *Computational thinking: Konsep dan aplikasi dalam kurikulum pembelajaran matematika*. Penerbit NEM.

Prasetyo, B., & Nugroho, A. (2022). Implementasi Teaching Factory dalam pembelajaran vokasi. *Jurnal Pendidikan Vokasi, 12*(2), 115–126.

Rahayu, S. (2022). Analisis kesulitan siswa dalam memahami konsep trigonometri pada pembelajaran matematika di SMK. *Jurnal Pendidikan Matematika, 10*(1), 55–64.

Rahmawati, D. (2021). Teaching Factory sebagai model pembelajaran berbasis industri di SMK. *Jurnal Pendidikan Kejuruan, 9*(1), 21–30.

Ramadhani, N., Siregar, J. M., & Rajaguguk, W. (2024). Tren pendidikan matematika berdasarkan perubahan kurikulum dari tahun 2006 sampai dengan 2024 tingkat SMA. *Jurnal Ilmiah Widya Pustaka Pendidikan, 12*(1), 51–61.

Rohmah, W. (2019). Pembelajaran berbasis Teaching Factory di SMK Negeri 2 Surakarta. *Jurnal Pendidikan Ilmu Sosial, 29*(2), 78–89. https://doi.org/10.23917/jpis.v29i2.9171

Senita, A. (2022). Analysis of mathematic understanding ability of senior high school students on trigonometric materials. *Journal of Mathematics Education, 3*, 47–60. https://doi.org/10.33578/jrmi.v3i1.63

Setiadi, A., Rochayati, U., Hartopo, I., & Handito, T. (2025). Production-based Teaching Factory learning model: Enhancing soft skills and simulating the industrial environment. *Indonesian Journal of Educational Development (IJED), 6*(2), 278–292. https://doi.org/10.59672/ijed.v6i2.4679

Setiowati, E., Hadi, S., Ulfa, M., Dainuri, A., Sholeh, F., Surur, M., & Munawwir, Z. (2024). Analisis kemampuan literasi matematika dalam meningkatkan kemampuan berpikir kritis siswa. *Jurnal Kajian Penelitian Pendidikan dan Kebudayaan, 2*(2), 55–68. https://doi.org/10.59031/jkppk.v2i2.321

Singh, J. (2025). *Trigonometry for engineers: A practical approach with real-world applications: Engineering-based guide for applications in machines, structures, electronics, and measurement systems*. PV Mindspire Publishing.

Solikah, N. H., Ardhani, D. C., Septi, A. D., Hidayati, J. R., & Nisak, K. (2025). Studi literatur: Pengembangan modul ajar interaktif dengan pemanfaatan aplikasi Maple pada pembelajaran trigonometri. *De Fermat: Jurnal Pendidikan Matematika, 8*(2), 615–626. https://doi.org/10.36277/defermat.v8i2.2339

Sterling, M. J. (2014). *Trigonometry for dummies*. John Wiley & Sons.

Suendarti, M., & Liberna, H. (2021). Analisis pemahaman konsep perbandingan trigonometri pada siswa SMA. *JNPM (Jurnal Nasional Pendidikan Matematika), 5*(2), 326–339. https://doi.org/10.33603/jnpm.v5i2.4917

Sutianah, C., Sobandi, B., Yamin, A. A., & Trang, P. D. K. (2024). Increasing creativity, production innovation and commercialization through the new Teaching Factory model based on life skills. *Jurnal Pendidikan Vokasi, 14*(2), 133–146. https://doi.org/10.21831/jpv.v14i2.67400

Utomo, H. N., & Muhtarom, I. D. (2025). Exploration of integrated mathematics learning with Teaching Factory learning for vocational high school pharmacy students based on design thinking. *Jurnal Gantang, 10*(2), 225–233.

Weber, K. (2005). Students' understanding of trigonometric functions. *Mathematics Education Research Journal, 17*(3), 91–112. https://doi.org/10.1007/BF03217423

Wibowo, A. (2020). Teaching Factory dan kesiapan kerja siswa SMK. *Jurnal Pendidikan Teknologi dan Kejuruan, 17*(2), 89–98.

Wibowo, A. (2023). Pembelajaran matematika berbasis proyek dalam konteks pendidikan vokasi. *Jurnal Pendidikan Matematika dan Kejuruan, 4*(1), 12–22.

Widiatna, A. D., Utami, P. P., & Kemal, I. (2025). Implementing and managing the Teaching Factory learning model at vocational schools. *Jurnal Penelitian Pendidikan IPA, 11*(5), 341–351. https://doi.org/10.29303/jppipa.v11i5.10944

Widjajanti, K., Sarosa, M., Selviana, V., & Maryanty, Y. (2025). Development of an interactive visualization application to assist vocational students in understanding trigonometry content. *Matematika dan Pembelajaran, 13*(2), 205–225.

Widodo, S. (2023). Implementasi Teaching Factory untuk meningkatkan minat belajar siswa SMK. *Jurnal Pendidikan Vokasi Indonesia, 8*(2), 67–76.