

DERIVATIVE APPLICATIONS IN MOTORCYCLE MECHANICS: AN EXPLORATION OF VOCATIONAL STUDENTS' CONTEXTUAL UNDERSTANDING

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ABSTRACT

Derivatives play a crucial role in vocational mathematics learning, particularly in understanding dynamic processes in automotive engineering contexts. However, students often experience difficulties connecting abstract derivative concepts with real mechanical phenomena encountered in workshop activities. This study aims to explore the contextual understanding of derivative applications in motorcycle mechanics among Grade XI Motorcycle Engineering (TBSM) students. This research employed a descriptive qualitative approach involving 27 Grade XI TBSM students at a vocational high school. Data were collected through classroom observations during integrated mathematics–vocational learning activities, in-depth semi-structured interviews, and analysis of students' learning documents and worksheets. The observations focused on students' engagement and interpretation of derivative concepts in authentic motorcycle mechanics contexts. Interviews were conducted to explore students' reasoning related to first and second derivatives, while document analysis was used to examine students' written representations and problem-solving strategies. Data triangulation was applied to ensure credibility and consistency of findings. The results show that students demonstrate strong contextual understanding of first derivatives, particularly in interpreting rates of change related to motorcycle speed variations. However, their understanding of second derivatives, especially in analyzing acceleration patterns and torque characteristics, remains limited. Students exhibit moderate ability in interpreting RPM graphs, with some difficulty in identifying slope changes and engine performance behavior. Practical workshop experiences, real engine performance data, and the use of diagnostic tools significantly support students' contextual mathematical reasoning. In conclusion, aligning mathematics instruction with authentic vocational practices enhances students' conceptual understanding of derivatives.

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INTRODUCTION

The development of modern automotive technology in the last two decades has experienced very rapid acceleration, especially in the motorcycle sector which is the main mode of transportation in Indonesia (Moercahyono & Pasaribu, 2023). Technological transformations such as the presence of ECU-based fuel injection systems, digital sensors (TPS, MAP, O₂ sensors), electronic control systems, and diagnostic devices such as OBD-II and dynotest require the presence of mechanics who are not only capable of carrying out repairs manually, but also have data-based analytical capabilities (Wira Sukma et al., 2019). Today's automotive technicians must be able to read engine performance graphs, analyze RPM change patterns, predict failure symptoms based on data trends, and understand the mathematical relationships between mechanical variables such as torque, power, angular velocity, and acceleration (Mylaraswamy et al., 2009). This condition makes learning mathematics, especially the concept of derivatives, a fundamental element in vocational education in the field of Motorcycle Engineering and Business (TBSM) (Tusi et al., 2019).

In mathematics education, derivatives are a fundamental concept that plays an important role in understanding dynamic changes in real-world phenomena (Mulyani & Siregar, 2025; Siregar & Siregar, 2025). The concept of derivatives allows students to analyze how one quantity changes with respect to another quantity, particularly in terms of speed, acceleration, and rate of response with respect to time (Astuti et al., 2025). In the context of motorcycle mechanics, derivatives serve not only as abstract mathematical symbols but also as analytical tools for interpreting engine performance, RPM fluctuations, acceleration behavior, and torque variations. Mastering the concept of derivatives allows vocational students to go beyond procedural calculations to a deeper understanding of technical data, which is crucial for diagnosing engine performance and understanding modern automotive systems.

In the Indonesian vocational curriculum, the integration between academic theory and workshop practice is emphasized to produce graduates who are adaptive, competitive, and in tune with industry needs (Yoto et al., 2024). The success of vocational education is greatly influenced by students' ability to connect theoretical concepts with the technical phenomena they encounter every day (Rojewski, 2009). In mathematics, the concept of derivatives is one of the core concepts that has very high relevance because it includes the analysis of the rate of change, which is the basis for understanding engine dynamics, vehicle performance, and mechanical response (Riding et al., 2025). For example, the change in RPM with time can be analyzed through the first derivative, while the acceleration of the change in RPM can be understood through the second derivative (Hitier & González-Martín, 2022). The relationship between torque and power graphs also cannot be understood without adequate mathematical insight into functions and derivatives (Has et al., 2024).

However, various studies have found that mathematics learning in vocational schools often takes place in an abstract and non-contextual manner so that students only master procedures without understanding their applied meaning (Ramadhani, 2025; Tika et al., 2024; Udzna, 2023). The separation of mathematical material from workshop practice makes it difficult for students to see the relevance of derivative concepts to actual automotive data. As a result, when students are confronted with technical graphs such as RPM curves, torque curves, fuel vs. speed graphs, or dynotest data, they struggle to interpret the mathematical meaning of the changes that occur.

Previous studies that focused on context-based mathematics learning provide an initial overview of the importance of a contextual approach (Manfreda Kolar & Hodnik, 2021). The study concluded that vocational mathematics teaching materials can increase motivation and concept retention (Pujiani et al., 2025). The Contextual Teaching and Learning (CTL) approach

that has been studied has proven to be effective in helping students understand abstract concepts through real situations (Sudarwati, 2024). In addition, the study revealed that examples of motorcycle use in everyday life help clarify the relationship between derivatives and the phenomenon of changes in speed (Hibatullah Sukendar et al., 2025).

However, these studies still have limitations because they don't specifically examine the context of motorcycle mechanics in a real workshop. Most studies only provide examples of light context, rather than concrete technical data such as dyno test measurement results graphs or injection sensor response curves. Further research has even highlighted that vocational high school students' inability to connect mathematics to technical applications is due to a lack of real-world data-based learning activities or modern diagnostic tools (Mira et al., 2024). In addition, some studies tend to focus on the effectiveness of certain learning models, without delving deeper into students' cognitive processes when linking the concept of derivatives with complex mechanical phenomena.

The research gap is further clarified by the fact that very few studies have explored how TBSM students construct a conceptual understanding of derivatives based on mechanical phenomena such as RPM fluctuations, engine acceleration, or torque variations in workshop practice. Fewer studies have examined how students interpret first and second derivatives when confronted with technical graphs, or how they reason about mathematical relationships between continuously varying data. Furthermore, few studies have documented the types of conceptual barriers, misconceptions, or thinking strategies students encounter when connecting mathematics to motorcycle mechanics.

The need for more contextual research that is closer to workshop practice is crucial, especially in the increasingly digital automotive industry. Integrating real-world technical data into mathematics learning is believed to improve vocational numeracy literacy, analytical skills, and student readiness for data-driven automotive technology. Therefore, this study aims to address this gap by conducting a direct exploration of eleventh-grade TBSM students in an authentic motorcycle mechanics context.

Based on this background and research gap, the purpose of this study is to explore students' contextual understanding of derivative applications in motorcycle mechanics, analyze how they connect technical data to mathematical concepts, and identify conceptual barriers that arise in this learning process.

METHOD

This study employed a descriptive qualitative research design aimed to explore students' contextual understanding of the application of derivatives to motorcycle mechanics. The study site was a public vocational high school (SMK) in North Sumatra, with 27 eleventh-grade TBSM students selected through purposive sampling to ensure diversity in academic ability. The qualitative design was chosen based on the need to deeply understand students' reasoning processes and how they interpret mathematical concepts in an authentic vocational learning context.

Data collection was conducted through three complementary techniques: classroom observations during integrative mathematics learning sessions within TBSM, semi-structured interviews with 12 students, and document analysis of student worksheets, RPM graphs, torque graphs, and learning artifacts produced during workshop practice. All observations followed a structured protocol to record students' verbal explanations, strategies used, and responses when working on tasks related to derivatives in the context of mechanics. The interview protocol focused on students' reasoning regarding first derivatives and second derivatives, the behavior

of RPM graphs, and torque variations. Document analysis was used to explore patterns in students' written reasoning.

Data analysis follows the interactive model of Miles and Huberman which includes the stages of data collection, data reduction, data presentation, and drawing conclusions (Ratnaningtyas et al., 2023; Rijali, 2019; Sugiyono, 2019; Waruwu, 2023; Yusanto, 2020). This analysis procedure allows for a systematic interpretation of students' conceptual patterns and the contextual factors influencing their understanding. To maintain data validity, technical triangulation (observation, interviews, document analysis) and source triangulation (students with varying ability levels) were applied. The researcher's position as the primary instrument was also acknowledged through reflective note-taking to minimize interpretive bias. Ethical aspects of the research were met by obtaining participant consent and maintaining student confidentiality.

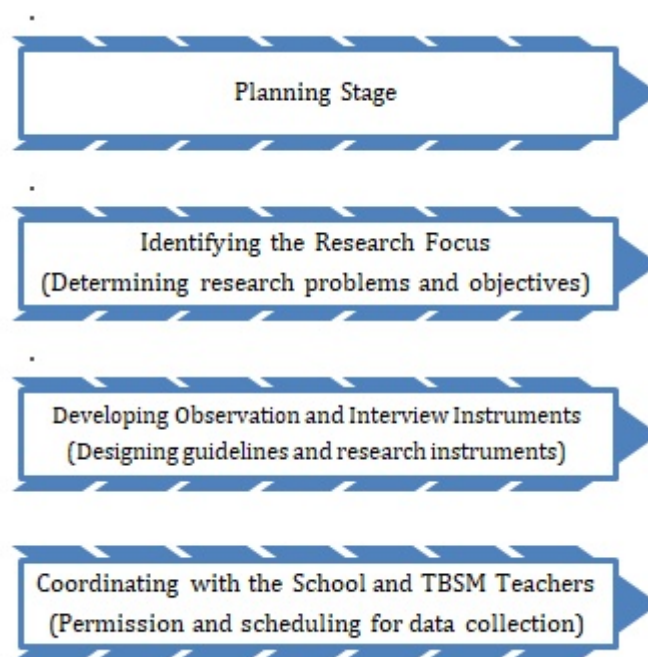


Figure 1. Flowchart of the Research Procedure

A simplified flow of the research procedure is described as follows: Planning Stage (a) Identifying the research focus, (b) Developing observation and interview instruments, (c) Coordinating with the school and TBSM teachers. Data Collection Stage (a) Classroom observations (3 meetings), (b) Student interviews (12 participants), (c) Collecting worksheets, RPM graphs, and torque analysis results. Data Analysis Stage (a) Data reduction using coding categories (derivative–velocity, derivative–acceleration, RPM interpretation, torque understanding), (b) Data presentation in tabular and matrix form. (c) Conclusion drawing and verification. Validation Stage (a) Triangulation of techniques and triangulation of sources, (b) Member checking with several students and teachers This methodological framework ensures the replication of the research and provides sufficient details for other researchers to conduct similar studies in the context of vocational learning.

RESULTS AND DISCUSSION

Results

The research revealed differences in students' understanding of the concept of derivatives in motorcycle mechanics. Initial findings indicated that the majority of students could relate the

concept of the first derivative to changes in velocity. Based on observations and interviews, 18 of 27 students were able to explain that the first derivative represents the rate of change in velocity, and provided concrete examples, such as how velocity increases when the throttle is turned. This understanding stemmed from the students' familiar experiences riding motorcycles and workshop training, allowing them to naturally associate speed fluctuations with mathematical ideas. This finding highlights that hands-on experience can strengthen the connection between abstract concepts and practical applications.

Understanding of the second derivative, or acceleration, appeared weaker. Only 12 students could explain acceleration as the change in velocity over time. Some students viewed acceleration simply as "a stronger push from the motorcycle" without being able to explain the mathematical aspects. Analysis indicated that this low ability was due to students' lack of experience interpreting acceleration graphs, as they frequently deal with speed and RPM values in workshop practice. This suggests that limited interaction with actual data makes it difficult for students to grasp the more complex concept of derivatives. Regarding reading RPM graphs, 15 students were able to explain the shape of the RPM graph, the peak engine speed point, and the stable zone. They understood that the slope of the graph reflects the rate of change in RPM. However, the other 12 students still had difficulty reading small changes in the graph and did not realize that the curve changes were related to the concept of derivatives. Field observations showed that students who frequently used tools such as OBD scanners or dynotest applications had a better understanding of graphs, indicating that modern technology contributes to increased mathematical literacy in the automotive context. This finding underscores the urgency of integrating technology in vocational education to bridge the gap between theory and practice (Santi et al., 2022).

The application of derivatives in torque was the area with the lowest level of understanding. Only 10 students could explain how torque is affected by RPM or how changes in torque can be analyzed through derivatives. Many students viewed torque solely as a calculated force, rather than a dynamic quantity. The lack of practice analyzing torque graphs during the course was a major limiting factor. Vocational high school students tended to be more familiar with static calculations than with the concept of change.

The complete distribution of student understanding is shown in the following table.

Table 1. Distribution of Student Understanding

Understanding Category	Number of Students
Relating derivative–velocity	18
Understanding acceleration (second derivative)	12
Interpretation of RPM graph	15
Application of derivatives to torque	10

The data in the table shows that the highest understanding is in the concept of derivatives as changes in velocity, and the lowest understanding is in the application of derivatives in torque. To support visual analysis, the data is visualized in the following bar graph.

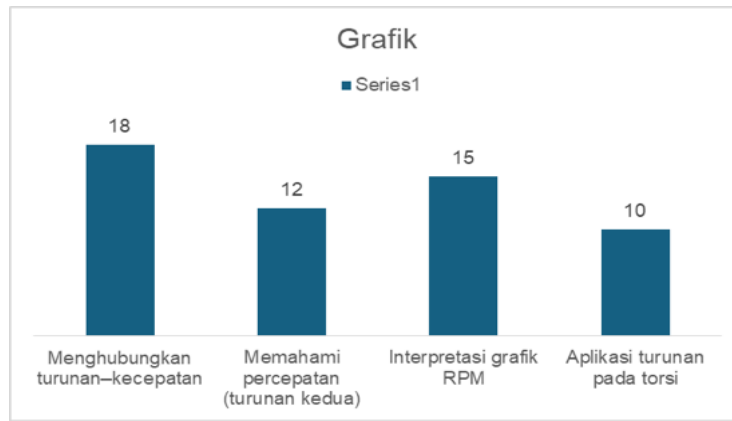


Figure 2. Student Understanding Graph

The graph shows a significant gap in understanding between categories. The most striking difference between the derivative of velocity and the application of the derivative to torque suggests that concrete experiences are easier to grasp than less obvious technical phenomena. This graph reinforces the importance of using concrete contexts in mathematics learning in vocational schools, in line with CTL theory, which emphasizes real-world situation-based learning (Putri et al., 2020). Furthermore, this variation can be explained by a hierarchy of derivative concepts: the first derivative is more intuitive because it relates to everyday experience, while the second derivative and its application to torque require a more abstract understanding. To address this gap, teachers can introduce digital simulations or step-by-step experiments, progressing from simple to complex concepts.

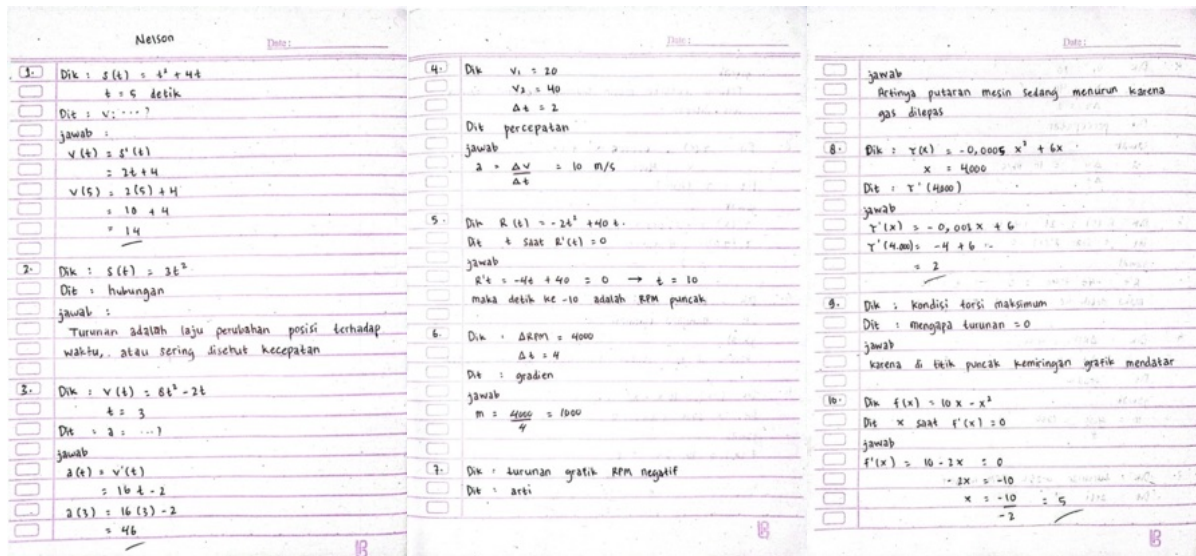


Figure 3. Photo of the initial analysis answer sheet: S1 – high ability

Nelson demonstrates a mature and integrated contextual understanding of mathematical theory and motorcycle mechanics applications. He is able to accurately perform mathematical abstractions, from reducing position to velocity to velocity to acceleration. His understanding includes the concept of stationary points for determining peak RPM and maximum power, demonstrating his mastery of the highest level of understanding in this research. Nelson works not merely procedurally but also understands the physical meaning of each calculation result as an instrument for analyzing engine performance.

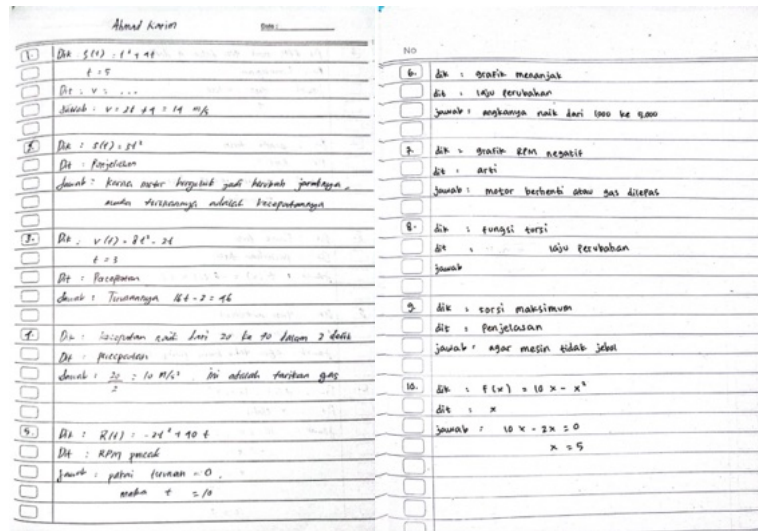


Figure 4. Photo of the initial analysis answer sheet: S2 – medium ability

Ahmad Karim represents a group of students who have a strong grasp of direct physical phenomena but begin to struggle with more abstract concepts. He excels at interpreting RPM graphs and the relationship between engine speed and speed, thanks to his practical experience using modern workshop tools. While capable of solving derivative calculations mathematically, Ahmad tends to lose analytical depth when confronted with the concepts of acceleration and torque. His understanding remains procedural, lacking a thorough physical explanation of how changes in these values affect the actual performance of a motorcycle engine in the field.

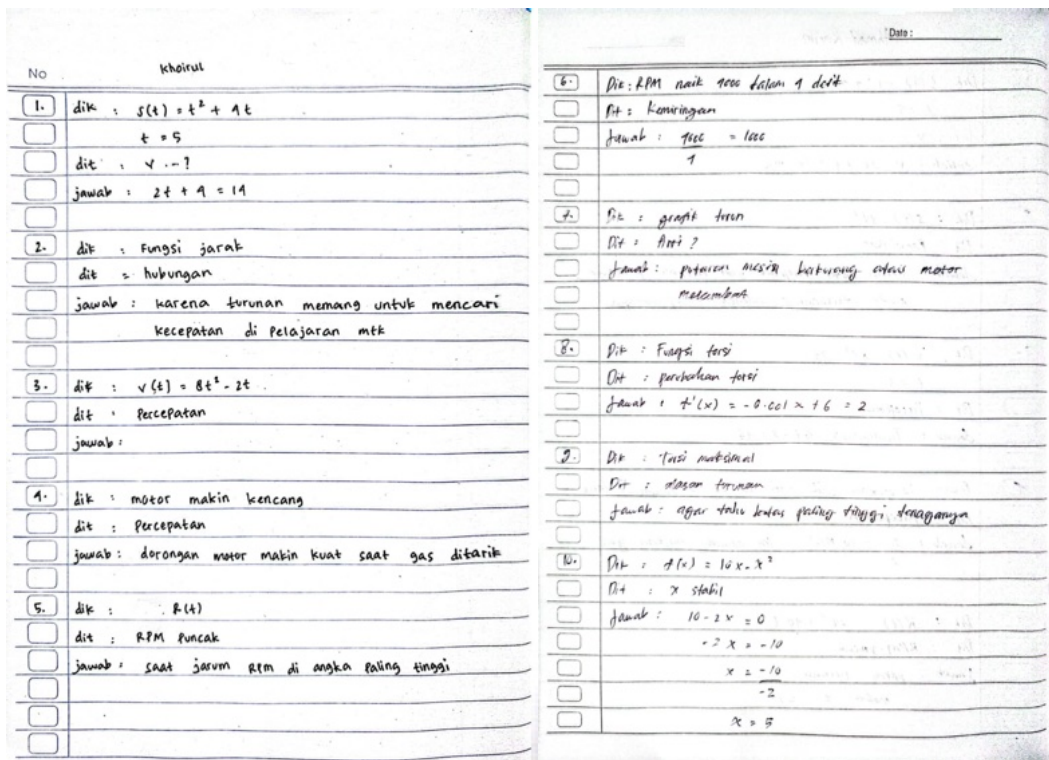


Figure 5. Photo of the initial analysis answer sheet: S3 – low ability

Khoirul exhibits the characteristics of a student with significant conceptual barriers who understand mathematics as merely a collection of symbols with no functional connection to the automotive world. His understanding is limited to first derivatives in the context of speed driven by everyday experience, but he completely fails to understand second derivatives and the

application of torque. Khoirul has difficulty interpreting complex graphs and often provides shallow descriptive answers without proper calculation processes. For him, derivatives are understood mechanically as mere arithmetic rules, so he is unable to use mathematics as an analytical tool in workshop practice.

The following is a transcript of an interview with three students:

Student Interview 1 (Initial: S1 – high ability)

P	:	When you look at the speed graph from the road test results, what do you understand about the relationship between the graph and the first derivative?
S1	:	In my opinion, the first derivative indicates how quickly the motorcycle's speed is changing. So, if the graph slopes upward and is quite steep, it means the motorcycle is accelerating rapidly. Also, at the workshop, when we tested it, when the throttle was turned deeper, the change in speed was immediately apparent from the graph. So, I relate it as "the slope of the graph = how fast the RPM or speed increases."
P	:	What about the second derivative or acceleration?
S1	:	Well, I'm still a bit confused about acceleration. I know acceleration is the change in velocity, but when I look at a graph, I can't immediately tell what the acceleration is. I usually understand it better when explained using the example of a motorcycle that "pulls hard" or "pulls slowly."
P	:	Have you ever read a torque graph from the module? What do you think it means?
S1	:	I see torque as simply "engine rpm." But if I'm asked to explain it using the concept of derivatives, I can't. Torque graphs have different shapes; they fluctuate, so I have a hard time connecting them to derivatives, like on a speed graph.

Interview with Student 2 (Initial: S2 – medium ability)

P	:	When you look at an RPM graph on an OBD scanner or dynotest app, what do you understand by the slope of the line?
S2	:	Usually, I notice that if the graph rises slowly, it means the engine rpm is increasing steadily. If it rises quickly, it means the engine is responsive. But I hadn't thought about how that actually relates to derivatives. It wasn't until it was explained in class that I realized that a sloping line indicates a change in RPM over time.
P	:	What is your understanding of the second derivative or acceleration?
S2	:	I thought acceleration was just about the bike getting faster. I didn't understand that acceleration was part of the second derivative. I only knew that if you accelerate quickly, the acceleration feels stronger, but I still couldn't visualize it on a graph.
P	:	Can you explain the change in torque in an engine as the RPM increases?
S2	:	I only know that torque is related to the engine's power at a certain RPM. But when asked if the change in torque can be analyzed using derivatives, I couldn't answer. I've never calculated or seen a torque graph in detail.

Interview with Students 3 (Initial: S3 – low ability)

P	:	What do you understand by derivatives in the context of motorcycle speed?
S3	:	Derivatives are like calculating change, but I understand them better when I say "how fast the motorcycle is accelerating." For example, if you open the throttle, the speed

		increases. But using a graph is a bit difficult for me. I can only see the line going up or down, but I don't know what that means mathematically.
P	:	When you look at the RPM graph from your workshop practice, what can you interpret?
S3	:	I can see which is high and which is low. But I can't yet explain why it increases quickly or slowly. Sometimes I just focus on the RPM number, not the shape of the graph.
P	:	What about torque? Can you explain how torque changes with RPM?
S3	:	I understand torque as "motor power for pulling." But when asked to relate it to derivatives, I don't understand. I see a torque graph that just goes up and down, but I don't know what that change means.

Based on interviews with three students, it emerged that the level of understanding of the concept of derivatives in the context of motor mechanics applications still varies and tends not to achieve a complete conceptual understanding. Students with high ability (S1) demonstrated the best understanding of the meaning of the first derivative, especially in relating the slope of the speed and RPM graphs to the rate of change of speed. However, these students still had difficulty interpreting the second derivative and when having to relate the concept of derivatives to torque graphs that have more complex up-and-down patterns.

Students with medium ability (S2) tended to understand graphs intuitively, for example, distinguishing between a graph that increases steadily and rapidly, but were not yet able to connect these observations to the principle of derivatives mathematically. The understanding of acceleration remains physical (the motor "accelerates"), not as a change in velocity. Furthermore, S2 is also unable to explain the relationship between changes in torque and the concept of derivatives.

Meanwhile, students with low ability (S3) relied more on simple verbal understanding, such as "the engine is getting faster," without being able to read or interpret graphs mathematically. S3 only looked at RPM values or the general shape of the graph without understanding the meaning of the changes represented by the slope or curve of the graph. Their understanding of torque was also limited to practical functions, not analysis of change.

Overall, these results indicate that understanding first derivatives is relatively easy to achieve, especially when linked to the context of changes in speed and RPM. However, understanding second derivatives and interpreting torque graphs remains a challenge, primarily because students tend to associate acceleration and torque physically, rather than mathematically. These findings suggest the need for a more contextual and visual learning approach, as well as scaffolding strategies that help students connect workshop experiences with mathematical representations through graphs and the concept of derivatives.

Student interviews revealed that they found it easier to understand derivatives when learning began with observable phenomena and then transformed them into mathematical forms. When analyzing a speed graph from a road test, students were able to deduce the relationship between the slope of the curve and the change in speed. However, when presented with a torque graph, most students struggled to interpret it due to the complex shape of the graph. These findings emphasize the importance of constructing knowledge based on concrete experiences.

Overall, the research results indicate that mathematics learning integrated with productive activities within the TBSM program has significant potential for improving understanding of

derived concepts, but requires the support of more visual and applicable learning tools, technology, and approaches.

Discussions

The findings of this study demonstrate that students' contextual understanding of derivative applications in motorcycle mechanics improves significantly when learning activities are directly connected to real-world workshop practices. This improvement indicates that integrating mathematical concepts with vocational contexts not only strengthens theoretical understanding but also enhances analytical and problem-solving skills. From a constructivist perspective, knowledge becomes more meaningful when learners actively relate abstract concepts to authentic experiences (MacLeod et al., 2022; O'Connor, 2022; Tan & Ng, 2021).

However, the results also reveal clear patterns of student failure, particularly in understanding second derivatives and torque-related analysis. These difficulties can be explained by cognitive barriers commonly experienced by vocational school students. Many students are accustomed to linear thinking patterns, where changes are assumed to occur proportionally and uniformly. In contrast, real engine performance data such as RPM fluctuations, acceleration curves, and torque characteristics are inherently non-linear. When students attempt to interpret non-linear mechanical data using linear reasoning, misconceptions arise, especially when analyzing concavity, acceleration trends, and changing rates of change. This mismatch between habitual cognitive schemas and the mathematical nature of mechanical systems becomes a significant obstacle to deeper derivative understanding (Amalia et al., 2024; Fayzullina et al., 2023; Parhan et al., 2024).

When linked to the research objective of exploring derivative applications through motorcycle mechanics, the findings show that vocational contexts strengthen students' ability to interpret derivatives as representations of real mechanical dynamics. Students could meaningfully connect changes in engine RPM to motorcycle speed and recognize the first derivative as a rate of change. This aligns with studies in vocational mathematics education in Germany, which emphasize that contextualized, workplace-oriented mathematics supports conceptual understanding by bridging theory and industrial practice (Fatimah, 2022; Sholikah, 2022). Similarly, research in Australian vocational education highlights that mathematics learning becomes more effective when embedded in authentic technical tasks rather than taught as isolated abstract content (Dianto et al., 2024; Taufik Qurohman et al., 2024).

An important contribution of this study is the discovery that technology plays a crucial role in supporting students' understanding. The use of diagnostic tools, real-time engine data displays, and graphical visualizations enables students to observe immediate relationships between variables such as RPM, speed, and torque. Technology helps by reducing cognitive load, allowing students to focus on interpreting patterns rather than manually processing complex data. Moreover, dynamic visual representations support conceptual change by making non-linear behavior visible and traceable over time, which is essential for understanding first and second derivatives.

Pedagogically, these findings suggest that integrating technology-rich, context-based learning can transform mathematics instruction in vocational schools. Such an approach promotes data-driven reasoning, supports metacognitive reflection, and prepares students for real workplace problem-solving. Overall, this study reinforces the importance of aligning mathematics education with vocational practices, demonstrating that contextual and technological integration enhances conceptual understanding, mathematical literacy, and job readiness in automotive engineering education.

CONCLUSION

This study concludes that eleventh-grade TBSM students' contextual understanding of derivative applications varies across conceptual categories. Students demonstrate a strong understanding of the first derivative, particularly in relation to changes in velocity and RPM fluctuations, as these concepts are closely aligned with their everyday workshop experiences. In contrast, students' understanding of acceleration, second derivatives, and torque-related applications remains limited, indicating difficulties in interpreting higher-order rates of change within non-linear mechanical systems. Practical workshop experiences, the use of modern automotive diagnostic technology, and the interpretation of engine performance graphs have been shown to positively contribute to students' contextual mathematical literacy in automotive contexts.

This study successfully addresses its main objective by revealing that vocational students' understanding of derivatives is strongly influenced by the degree to which mathematical concepts are integrated with authentic workshop practices. Access to real technical data, such as RPM graphs, torque curves, and OBD scanner outputs, significantly enhances students' ability to interpret graphs and understand rates of change mathematically. The findings also provide empirical evidence that the gap between first and second derivative understanding is largely caused by limited exposure to dynamic and visual mathematical representations. Since second derivatives and torque analysis require higher levels of abstraction, students need more systematic, technology-supported, and data-driven learning experiences.

Despite these contributions, this study has several limitations. The research was conducted with a relatively small sample from a single vocational school, which may limit the generalizability of the findings. In addition, the qualitative design focused on descriptive analysis and did not measure learning outcomes quantitatively over time. The study also examined only derivative concepts, without exploring other advanced mathematical topics relevant to vocational education.

Future research is recommended to involve larger and more diverse samples across different vocational schools and regions. Longitudinal or mixed-methods studies could provide deeper insight into how contextual and technology-based learning influences students' mathematical development over time. Further studies may also explore the integration of digital simulations, learning analytics, and other vocational fields to develop comprehensive models for applied mathematics learning in vocational education.

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REFERENCES

- Amalia, L., Makmuri, M., & Hakim, L. El. (2024). Learning Design: To Improve Mathematical Problem-Solving Skills Using a Contextual Approach. *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, 7(3), 2353–2366. <https://doi.org/10.54371/JIIP.V7I3.3455>

- Astuti, S. A. B., Siregar, R. N., & Rangkuti, R. K. (2025). Analysis of Students' Mathematical Critical Thinking in Solving Function Derivative Problems based on Gender Differences. (*JIML*) *Journal of Innovative Mathematics Learning*, 8(1), 188–199. <https://doi.org/10.22460/JIML.V8I1.27166>
- Dianto, A., Mulyani, N., Arbi, A., & Pedagogi, M. (2024). Pendekatan Pembelajaran Kognitif dalam Pendidikan Kejuruan: Membangun Keterampilan Berpikir dan Problem Solving di Era Industri 4.0. *Jurnal Penelitian Multidisiplin Bangsa*, 1(6), 441–446. <https://doi.org/10.59837/JPNMB.V1I6.82>
- Fatimah, A. T. (2022). Matematika Kejuruan Menuju Merdeka Belajar. *Unigal Repository*. <http://repository.unigal.ac.id:8080/handle/123456789/3869>
- Fayzullina, A. R., Zakirova, C. S., Dobrokhotoy, D. A., Erkiada, G., Muratova, O. A., & Grishnova, E. E. (2023). Bibliometric review of articles related to context-based learning in science education. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(9), em2330. <https://doi.org/10.29333/EJMSTE/13534>
- Has, A., Yılmaz, B., & Baleanu, D. (2024). On the Geometric and Physical Properties of Conformable Derivative. *Mathematical Sciences and Applications E-Notes*, 12(2), 60–70. <https://doi.org/10.36753/MATHENOT.1384280>
- Hibatullah Sukendar, B., Irvine Theresya, J., Dwi Saputri, S., & Hernaeny, fah. (2025). Penerapan Konsep Limit Fungsi dalam Kehidupan Sehari-Hari: Dari Kecepatan hingga Ekonomi. *Qomaruna: Journal of Multidisciplinary Studies*, 2(2), 22–36. <https://doi.org/10.62048/QJMS.V2I2.71>
- Hitier, M., & González-Martín, A. S. (2022). Derivatives and the Study of Motion at the Intersection of Calculus and Mechanics: a Praxeological Analysis of Practices at the College Level. *International Journal of Research in Undergraduate Mathematics Education* 2022 8:2, 8(2), 293–317. <https://doi.org/10.1007/S40753-022-00182-Z>
- MacLeod, A., Burm, S., & Mann, K. (2022). Constructivism: Learning theories and approaches to research. *Researching Medical Education, Second Edition*, 25–40. <https://doi.org/10.1002/9781119839446.ch3>
- Manfreda Kolar, V., & Hodnik, T. (2021). Mathematical Literacy from the Perspective of Solving Contextual Problems. *European Journal of Educational Research*, 10(1), 467–483. <https://doi.org/10.12973/eu-jer.10.1.467>
- Mira, Irmawati, Baharuddin, S. M., Grace, Jonial, Kurniawan, R., Mustafa, S. A., & Rosmiati. (2024). Analisis Permasalahan Pembelajaran Matematika di SMK Negeri 3 Majene. *Maximal Journal : Jurnal Ilmiah Bidang Sosial, Ekonomi, Budaya Dan Pendidikan*, 2(2), 251–256. <https://malaqbpublisher.com/index.php/MAKSI/article/view/372>
- Moercahyono, F. F., & Pasaribu, Y. M. (2023). Pengaruh Sepeda Motor “Moge” terhadap Tren Desain Skuter Matik di Indonesia. *Jurnal Desain Indonesia.*, 5(2), 30–57. <https://doi.org/10.52265/JDI.V5I2.326>
- Mulyani, S., & Siregar, R. N. (2025). Analysis of Students' Mathematical Understanding of Derivatives Algebraic Function on Islamic Boarding High School. (*JIML*) *Journal of Innovative Mathematics Learning*, 8(1), 173–187. <https://doi.org/10.22460/JIML.V8I1.27159>
- Mylaraswamy, D., Olson, L., & Nwadiogbu, E. (2009). Engine performance trending: practical insights. *Transactions of the Institute of Measurement and Control*, 31(3–4), 341–354. <https://doi.org/10.1177/0142331208092033>

- O'Connor, K. (2022). Constructivism, curriculum and the knowledge question: tensions and challenges for higher education. *Studies in Higher Education*, 47(2), 412–422. <https://doi.org/10.1080/03075079.2020.1750585>;PAGE:STRING:ARTICLE/CHAPTER
- Parhan, M., Syahidin, Somad, M. A., Abdulah, M., & Nugraha, R. H. (2024). Developing a Contextual Learning Model in Islamic Education to Improve Applicable Knowledge and Foster Knowledge-Based Virtues. *Jurnal Pendidikan Islam*, 10(1), 75–86. <https://doi.org/10.15575/JPI.V10I1.35205>
- Pujiani, D., Mulyati Mustika Sari, R., Nia Sania Effendi, K., Kossahdasabitah, A., Singaperbangsa Karawang Jl S Ronggowaluyo Telukjambe Timur Karawang, U. H., & Barat, J. (2025). Systematic Literature Review: Efektivitas Pembelajaran Project Based Learning pada Materi Geometri Siswa SMK. *Radian Journal: Research and Review in Mathematics Education*, 4(1), 39–46. <https://doi.org/10.35706/RADIAN.V4I1.13131>
- Putri, Y. U., Musdi, E., Permana, D., & Yerizon. (2020). *Pengembangan Perangkat Pembelajaran Matematika Berbasis Pendekatan Contextual Teaching And Learning Terhadap kemampuan Komunikasi Matematis*. 9(1), 205–212.
- Ramadhani, H. M. (2025). Efektivitas Model Problem Based Learning (PBL) Berbasis Open-Ended Dalam Meningkatkan Pemahaman Konseptual Matematika Pada Siswa SMK Pelayaran Jakarta Raya. *UIN K.H. Abdurrahman Wahid Pekalongan*. <https://perpustakaan.uingusdur.ac.id/>
- Ratnaningtyas, E. M., Ramli, Syafruddin, Saputra, E., Suliwati, D., Nugroho, B. T. A., Karimuddin, Aminy, M. H., Saputra, N., Khaidir, & Jahja, A. S. (2023). Metodologi Penelitian Kualitatif. *Yayasan Penerbit Muhammad Zaini*. <https://www.researchgate.net/publication/370561417>
- Riding, K., Yang, Y., Clark-Wilson, A., Mavrikis, M., Geraniou, · Eirini, & Crisan, · Cosette. (2025). Rethinking Affordances and Feedback in AR Environments to Foster Richer Mathematical Inquiry: Lessons from Touch the Derivative. *Digital Experiences in Mathematics Education*, 1–27. <https://doi.org/10.1007/S40751-025-00179-8>
- Rijali, A. (2019). Analisis Data Kualitatif. *Alhadharah: Jurnal Ilmu Dakwah*, 17(33), 81. <https://doi.org/10.18592/ALHADHARAH.V17I33.2374>
- Rojewski, J. W. (2009). A Conceptual Framework for Technical and Vocational Education and Training. *International Handbook of Education for the Changing World of Work*, 19–39. https://doi.org/10.1007/978-1-4020-5281-1_2
- Santi, I., Hutapea, N. M., & Murni, A. (2022). *Pengembangan Perangkat Pembelajaran Matematika Model Problem Based Learning (PBL) untuk Memfasilitasi Kemampuan Pemecahan Masalah Matematis Peserta Didik Kelas X Jurusan Otomotif SMK*. 06(02), 1584–1602.
- Sholikah, K. N. (2022). *Pengembangan Media Pembelajaran Matematika Dengan Powtoon Berbasis Kearifan Lokal Tuban Pada Materi Aplikasi Turunan Kelas XI SMK*. https://repository.unisma.ac.id/bitstream/handle/123456789/4910/S1_FKIP_PENDIDIKAN_MATEMATIKA_21701072108_KARWATI_NI'MATUS_SHOLIKAH.pdf?sequence=1
- Siregar, R., & Siregar, R. N. (2025). Analysis of Students' Mathematical Problem-Solving Ability on Senior High School – Case on Function Derivative Material. (*JIML*) *Journal of Innovative Mathematics Learning*, 8(1), 148–159. <https://doi.org/10.22460/JIML.V8I1.27134>

- Sudarwati, E. (2024). Upaya Meningkatkan Hasil Belajar Siswa dalam Pembelajaran Matematika pada Konsep Bangun Ruang Sisi Datar melalui Pendekatan CTL (Contextual Teaching and Learning). *Attractive: Innovative Education Journal*, 6(1), 498–506. <https://doi.org/10.51278/AJ.V6I1.994>
- Sugiyono. (2019). *Metode Penelitian Kuantitatif Kualitatif dan R & D* (Sutopo (ed.)). Alfabeta.
- Tan, C., & Ng, C. S. L. (2021). Constructivism in Education. *Oxford Research Encyclopedia of Education*. <https://doi.org/10.1093/ACREFORE/9780190264093.013.92>
- Taufik Qurohman, M., Wardana, A., Arif Romadhon, S., Harapan Bersama, P., & Tegal, K. (2024). Efektivitas Pendekatan Kontekstual Dalam Pengajaran Matematika Teknik: Studi Kuantitatif di Perguruan Tinggi. *Jurnal Riset Dan Inovasi Pembelajaran*, 4(2), 1198–1207. <https://doi.org/10.51574/JRIP.V4I2.1978>
- Tika, M., Matematika, P., Tanjungpura, S., & Barat, K. (2024). A Descriptive Study of the Effect of Indonesian Language on the Understanding of Mathematical Symbols in Vocational Students. *COSMOS: Jurnal Ilmu Pendidikan, Ekonomi Dan Teknologi*, 2(1), 230–248. <https://cosmos.iaisambas.ac.id/index.php/cms/article/view/228>
- Tusi, A., Nur, F. &, & Zakiah, E. (2019). Merancang tugas matematis berbasis teknik dan bisnis sepeda motor. *Unigal Repository*. <http://repository.unigal.ac.id:8080/handle/123456789/3873>
- Udzna, N. S. (2023). Efektivitas Penerapan Strategi Relating, Experiencing, Applying, Cooperating, Transferring (REACT) Dalam Meningkatkan Kemampuan Pemahaman Konsep Matematis Siswa Di SMK Negeri 1 Kedungwuni. *UIN K. H. Abdurrahman Wahid Pekalongan*. <http://perpustakaan.uingusdur.ac.id/>
- Waruwu, M. (2023). Pendekatan Penelitian Pendidikan: Metode Penelitian Kualitatif, Metode Penelitian Kuantitatif dan Metode Penelitian Kombinasi (Mixed Method). *Jurnal Pendidikan Tambusai*, 7(1), 2896–2910. <https://doi.org/10.31004/JPTAM.V7I1.6187>
- Wira Sukma, P., Hanuranto, A. T., Bogi, N., & Karna, A. (2019). Utilization of on board diagnostic-II for monitoring engine control unit sensors on automobile. *E-Proceeding of Engineering*, 6(2), 4262–4267.
- Yoto, Marsono, Suyetno, A., Mawangi, P. A. N., Romadin, A., & Paryono. (2024). The role of industry to unlock the potential of the Merdeka curriculum for vocational school. *Cogent Education*, 11(1). <https://doi.org/10.1080/2331186X.2024.2335820>
- Yusanto, Y. (2020). Ragam Pendekatan Penelitian Kualitatif. *Journal of Scientific Communication (JSC)*, 1(1). <https://doi.org/10.31506/JSC.V1I1.7764>