JOVES (Journal of Vocational Education Studies)
VOL 8, No. 1, 2025, pp. 58-76
pISSN: 2614-7483 pISSN: 2614-7475 https://doi.org/10.12928/joves.v8i1.11995

Analysis of Vocational Students' Problem-Solving Competencies in Resolving Case Studies in Statistics

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ARTICLE INFO

Article history
Received Nov 12, 2024
Revised Apr 15, 2025
Accepted Apr 17, 2025

Keywords
Problem Solving
Polya Stages
Case Study
Problem Based Learning

ABSTRACT

The rapid advancement of technology presents significant challenges, particularly in vocational education, where the aim is to produce skilled graduates ready for the workforce. This study analyzes the problem-solving competencies of vocational students when resolving case studies in Statistics courses. A descriptive qualitative approach was employed, involving 90 students divided into 30 groups as subjects. Primary data were gathered from the students' case study analyses, which were classified and analyzed according to Polya's problem-solving stages. Findings revealed that students demonstrated varying levels of initiative in understanding problems and developing solutions. Specifically, 20% of the groups fell into the substance category, 46,67% into result, and 33,33% into completion. Substance groups struggled with planning and data collection, while result groups exhibited minor errors in implementing their plans, particularly in data processing and presentation. Meanwhile, completion groups showed a comprehensive understanding and effective problem resolution. The analysis of these problem-solving capabilities provides a foundation for a deeper evaluation of instructional effectiveness and the development of targeted teaching strategies.

Introduction

Vocational education offers a unique approach in providing higher education, with its primary focus being to prepare students with applied skills necessary across various industrial sectors (Pambudi & Harjanto, 2020). Unlike universities that tend to offer a wide range of study programs, vocational education, especially those conducted by polytechnics, emphasizes practical learning. This learning is directed at developing students not only in technical expertise but also in essential soft skills required in the workplace. According to research by Asefer and Abidin (2021), the learning environment in polytechnics is designed to produce graduates who not only possess specialized skills but also have good adaptability and communication skills. Approximately 30 percent of the vocational education curriculum is theoretical, while about 70 percent is focused on direct practical experience (Sutrisno et al., 2023). Consequently, students are expected to apply their knowledge and applied skills more effectively in the workplace.

The rapid development in the era of the Fourth Industrial Revolution, characterized by the dominance of information technology, has significantly transformed the human landscape (Ivaldi et al., 2022). This era presents new challenges such as increasingly blurred boundaries and unlimited data availability driven by advancements in internet and digital technology, shaping interactions between humans and machines (Levin & Mamlok, 2021). Strategic policy formulation is crucial, especially in the context of innovating learning activities that can accommodate these significant changes in the Fourth Industrial Revolution era. To address these challenges, Problem-Based Learning (PBL) emerges as a highly relevant alternative learning method. PBL not only serves as a learning approach but also as a strategy that provides opportunities for students to develop high-level thinking skills through solving real-world problems frequently encountered in the workplace (Kek & Huijser, 2011). Additionally, PBL offers students the opportunity to not only passively receive information but also to identify, analyze, and implement learned concepts in real-life situations (Fauzi, 2016). By focusing on problem-solving, PBL creates an environment where students can link theoretical concepts with practical applications, preparing them to meet the demands of the industries.

Academic success in the learning process is reflected through the competencies acquired by students after participating in the teaching and learning process (York et al., 2019). In the context of learning Statistics, it is not sufficient to merely present curriculum-aligned material and it is crucial to imbue meaning so that students can utilize their abilities and curiosity with flexibility and without constraint. Learning in Statistics emphasizes mastery in applying theory to real-world practice. Students learn how to solve problems that occur in the real world using the perspectives and theories learned in the classroom. This approach should form the conceptual foundation in modern teaching and learning processes, as the essence of learning lies not only in mastering knowledge but also in how students can apply that knowledge to solve problems and achieve success in life (Chew & Cerbin, 2021).

One important competency that students need to master is the ability in problem solving. An essential aspect of this competency involves understanding the problem, designing a solution model, implementing the solution model, and interpreting the obtained solutions (Sholihah &

Lastariwati, 2020). Problem solving is not only relevant in the context of learning mathematics and statistics but also has broad applications in students' daily lives. This skill enables students to address complex challenges in various everyday life situations. Engaging in problem solving activities during learning also significantly contributes to the development of essential aspects of thinking skills. In the context of Statistics, problem solving activities involve the application of rules to non-routine problems, pattern discovery, generalization, and mathematical communication (Kurniawan et al., 2022). According to Kim et al. (2018), problem solving skills play a central role in dynamic knowledge and technology-based industries. These skills are considered crucial for driving innovation, growth, and sustainable development in advanced industries. Therefore, it is important to develop problem-solving skills among students at all levels of education, especially for vocational students, considering its crucial role in supporting innovation and growth in an increasingly complex industrial era.

Problem-solving in Statistics presents unique cognitive and practical challenges that distinguish it from problem-solving in other disciplines such as mathematics, physics, and engineering. In mathematics and physics, problems are often well-structured, guided by deterministic rules and formulaic procedures that lead to a single correct answer (Jonassen, 2004). Similarly, engineering problems, while applied in real-world contexts, are typically grounded in physical laws and involve systematic design processes aimed at optimization and efficiency (Jonassen et al., 2006). These domains emphasize procedural fluency, logical deduction, and precise computation. In contrast, statistical problem-solving is inherently interpretative and context-dependent (Pfannkuch, 2011). It involves reasoning with uncertainty, drawing inferences from data, and making judgments based on incomplete or variable information. Unlike deterministic disciplines, statistics does not always yield definitive answers but rather plausible conclusions supported by evidence. For vocational students, who often expect procedural clarity and definitive outcomes, this shift toward probabilistic reasoning and open-ended inquiry can be particularly challenging.

The problem based learning with a case study approach, which presents real-world problems, is an effective method in Statistics education because it allows students to apply statistical theory to solve concrete problems (Sutrisno et al., 2023). The process of solving these problems requires clear thinking processes, reflects students' understanding of the core material, and enables them to respond appropriately to the actual challenges. This research aims to analyze vocational students' problem-solving abilities in resolving case studies in Statistics courses. By understanding students' problem-solving abilities, lecturers can design more accurate evaluation strategies and provide constructive feedback. This opens up opportunities for continuous improvement in content delivery and teaching methods, with the hope of optimizing achievement of desired competencies for students. With this approach, it is expected that students will have the chance to enhance their problem-solving skills significantly. This will enable them to develop strong analytical abilities and effective solutions, preparing them to confidently tackle real-world challenges in industrial workplace.

Method

This research adopts a qualitative descriptive approach with the aim of uncovering in-depth the problem-solving competencies of students in completing case studies in the Statistics course. The statistical topics used in the case study are data collection, data processing, and data presentation for solving problems related to deposit and stock investment. The data analysis technique used in this study refers to the analysis technique introduced by Miles and Huberman (1994). The stages of data analysis consist of 1) data collection; 2) data reduction; 3) data presentation, and 4) drawing conclusions as described in the following diagram.

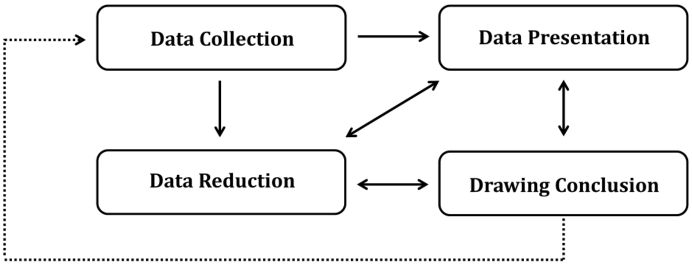

Fig 1: Procedure of research

The subjects of this study are students of the Management Accounting Study Program, Politeknik Negeri Malang. The total number of research subjects studied is 90 students from 3 classes i.e. Class A, Class B, and Class C. Students are then divided into 30 small groups, with each group consisting of 3 students, as the case study is designed to be completed in groups. The type of data used in this research is primary data obtained directly from the research subjects. The data source for this study consists of written responses (diagnostic test results) from each group. The test data that has been collected is then categorized according to the levels of problem-solving performance described by Malone et al. (2007).

First level: non commencement. At this level, students have not provided a response or shown understanding of the problem due to possibly not being able to clearly identify the problem.

Second level: approach. Students begin to make efforts to approach the given problem. They may try to identify some aspects of the problem or take initial steps towards solving the problem.

Third level: substance. Students start to grasp the core of the problem and can identify relevant information. They develop a deeper understanding of the problem and can detail key elements that need to be addressed.

Fourth level: result. At this level, students achieve partial resolution or may arrive at the correct answer. They successfully apply concepts and skills to address most aspects of the problem. Minor errors can be found in the solution at this level.

Fifth level: completion. At this level, students successfully solve the entire problem correctly and comprehensively. At this stage, they not only find a solution but also provide a thorough explanation and deep understanding of the problem-solving process they have gone through in their learning.

To systematically assess students' problem-solving competencies, this study employed a classification framework that integrates Polya's problem-solving stages with the performance levels outlined by Malone et al. There are four problem-solving stages outlined by Polya (1945) as follows:

a) Students need to understand the problem. It is important for students to wisely choose relevant data, determine what needs to be known, and detail the elements of the problem for simplification later.
b) Students plan the problem-solving process. Students are encouraged to reflect on experiences with similar issues they have faced and create problem-solving procedures. This way, they can apply lessons learned from previous experiences to address current issues.
c) Students solve the problem according to the plan. At this stage, students must implement the problem-solving procedures they have previously outlined. This involves carefully following steps to achieve the desired solution.
d) Students review the procedures and results of the solution. In this stage, students conduct in-depth analysis and evaluation of the procedures applied. These processes serve as the basis for drawing correct conclusions through the reflective phase they experienced during problem-solving.

Polya's four stages offer a structured process for analyzing how students approach and solve statistical problems. Meanwhile, Malone et al.'s classification provides gradations of student performance, from no engagement to complete and accurate problem resolution. By combining these two models, the study established five performance levels that reflect both the depth of students' cognitive engagement and the completeness of their problem-solving processes. Table 1 illustrates how this elaboration was operationalized in the classification.

Table 1. Classification criteria of problem-solving levels using Polya's stages.

Performance Level	Description	Polya Stage(s)	Observed Student Behavior
Non commencement	No response or indication of understanding the problem.	None	Students left the task blank or provided irrelevant responses with no sign of engagement.
Approach	Attempted to understand the problem, but identification was partially incorrect or unclear; no structured planning.	Stage 1: Understanding the Problem	Students tried to define the problem but misinterpreted key elements or failed to grasp the full scope.
Substance	Correctly identified and clearly stated the problem, but lacked proper planning or failed to gather all necessary data.	Stages 1-2: Understanding and Planning	Students understood the problem well but did not collect relevant data accurately or comprehensively.
Result	Devised and executed a plan based on correct understanding, but with minor errors in processing, analysis, or data presentation.	Stages 1-3: Understanding, Planning, Execution	Students applied a solution strategy with some success but had calculation or interpretation mistakes.
Completion	Completed all four stages accurately and comprehensively, including reflection and evaluation.	Stages 1–4: All Polya Stages	Students identified the problem, planned and implemented the solution accurately, and evaluated their process effectively.

The results of the classification and analysis of Polya's stages can provide valuable insights for teachers seeking to enhance their learning activities. By identifying the errors encountered by students during the problem-solving process in case studies, teachers can target specific areas for improvement, such as data identification, analysis, and presentation skills. This focused approach allows teachers to customize their instructional strategies, offering additional support that address students' needs and improve problem-solving competencies.

Result and Discussion

Levels of Problem-solving Classification

The diagnostic test results, which assessed students' responses to various problems, revealed significant insights into problem-solving levels across all groups. According to the criteria introduced by Malone et al. (2007), the classification of these responses demonstrated that every group achieved at least the third level, 'substance', which represents the minimum threshold for meaningful engagement with the problem. Notably, no groups were classified at the lower 'non-commencement' or 'approach' levels. Furthermore, some groups from each class exhibited advanced problem-solving skills, reaching the highest level, 'completion'. This distribution of problem-solving proficiency suggests a promising foundation of skills among the students, with some demonstrating more advanced capabilities. A comprehensive classification of the problem-solving levels is presented in Table 2.

Table 2. Summary of the classification of problem-solving levels for each class.

No	Name	Class A	Class B	Class C	Total	Percentage
1	Level 1: *non commencement*	-	-	-	0	0%
2	Level 2: *approach*	-	-	-	0	0%
3	Level 3: *substance*	1	2	3	6	20%
4	Level 4: *result*	6	6	2	14	46,67%
5	Level 5: *completion*	3	2	5	10	33,33%

Among the assessed groups, 20% reached the 'substance' level. At this level, students start to develop a solid understanding of the problem, moving beyond just surface-level engagement. They can identify and prioritize relevant information, showing a deeper insight into the problem's key elements. This level marks an important step forward in problem-solving skills, as students not only recognize the crucial components that need attention but also begin to clearly describe and address these elements. This capability highlights a significant milestone in students' analytical and critical thinking development.

In addition, 46,67% of the groups achieved the 'result' level. At this level, students demonstrate the ability to achieve partial resolution of the problem or even arrive at the correct answer. They effectively apply relevant concepts and skills to solve most aspects of the problem. Although there may be occasional errors, these generally do not affect their overall approach. Instead, their problem-solving direction remains largely correct, reflecting their strong understanding of the underlying principles and their ability to use them effectively. This level indicates a high degree of competence in applying learned strategies to real-world problems, marking a significant advancement in their problem-solving abilities.

Surprisingly, the 'completion' level was achieved by 33,33% of the groups assessed. At this level, students not only solve the entire problem correctly but also do so comprehensively. They demonstrate their ability to address all aspects of the problem and provide a detailed explanation of their solution. This includes a deep understanding of the problem-solving process they followed, showcasing their capability to articulate the steps taken and the reasoning behind their approach. This level reflects a high degree of mastery and suggests that these students have developed an advanced proficiency in both applying problem-solving strategies and articulating their thought processes with clarity and depth, indicating a significant advancement in their analytical and cognitive skills.

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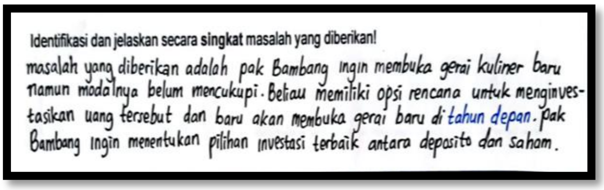
Polya's Problem-solving Stages Analysis

Here, we present the results of Polya's stages analysis of problem-solving to provide a robust framework for assessing student problem-solving abilities in educational settings. By systematically analysing each stage, teachers can identify specific areas where students may struggle, such as misinterpreting the problem or inadequately evaluating their solutions. Implementing Polya's model not only facilitates a deeper understanding of the cognitive processes involved in problem-solving but also encourages students to adopt a more structured approach to tackling mathematical and real-world challenges (Szabo et al., 2020). This method fosters metacognitive awareness, as students learn to reflect on their strategies and outcomes, ultimately enhancing their ability to approach complex problems independently. By integrating Polya's stages into the curriculum, teacher can better support the development of critical thinking and problem-solving skills essential for academic success.

Polya's stages of problem-solving begin with identifying the given problem. This initial step is crucial, as it lays the foundation for effective resolution. Clearly defining the problem ensures that students can focus their efforts on the relevant aspects and devise appropriate strategies (Ishak et al., 2021). In this context, the problem revolves around the significant capital required to open a new outlet, indicating that the current funds are insufficient and need to be invested. The options presented include fixed-term deposits and stocks, with numerous attractive bank deposit offers and various stocks from different industrial sectors showing positive and profitable trends. Generally, all groups within the categories of 'substance', 'result', and 'completion' were able to recognize and comprehend the issues presented in the provided case studies. Students successfully identified the known information and what was being asked in the problems. Figure 2 illustrates an example of the problem identification process, showcasing how students approached the problem.


Identifikasi dan jelaskan secara singkat masalah yang diberikan!
masalah yang diberikan adalah pak Bambang ingin membuka gerai kuliner baru namun modalnya belum mencukupi. Beliau memiliki opsi rencana untuk menginvestasikan uang tersebut dan baru akan membuka gerai baru di tahun depan. pak Bambang ingin menentukan pilihan investasi terbaik antara deposito dan saham.

Translation:
The given problem is that Mr. Bambang wants to open a new food outlet, but his capital is insufficient. He has a plan to invest the money and will only open the outlet next year. Mr. Bambang wants to determine the best investment option between fixed-term deposits and stocks.

Fig 2: Example of the problem identification process based on the given problem.

After successfully identifying the problem, students will develop a plan to solve it by identifying and collecting relevant data. This planning stage is important, as it not only provides a structured approach to addressing the problem but also enhances students' ability to systematically analyze

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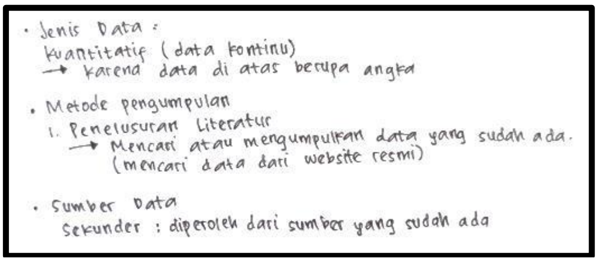
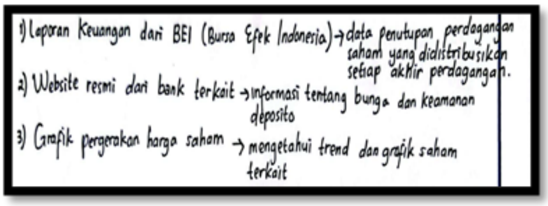
the situation and make informed decisions (Tohir et al., 2020). This identification process involves determining the types of data needed and how that data will be obtained. At this stage, several groups at the 'substance' level exhibited errors in their data identification and collection processes. Figure 3 illustrates that the data information and identification results were too general and lacked clarity, which can lead to errors in the subsequent process and influence the conclusion to be less precise.


• Jenis Data :
Kuantitatif (data kontinu)
→ karena data di atas berupa angka
• Metode pengumpulan
1. Penelusuran Literatur
→ Mencari atau mengumpulkan data yang sudah ada.
(mencari data dari website resmi)
• Sumber Data
Sekunder : diperoleh dari sumber yang sudah ada

Translation:
- Type of data
  Quantitative (continuous data)
  because the data above is in the form of numbers
- Collection method
  literature search: searching for and collecting existing data
  (searching for data from official websites)
- Data source
  secondary (obtained from existing sources)

Fig 3: Example of data identification and collection errors in the 'substance' level group.

In contrast, groups at the 'result' and 'completion' levels were able to accurately identify and collect the necessary data in a comprehensive way, as demonstrated in Figures 4. Students noted that information on bank deposit interest rates can be obtained from the official websites of the respective banks. Meanwhile, stock prices for companies can be found in the closing trade data published in financial reports accessible on the Indonesia Stock Exchange (IDX) website, or by examining stock price movement charts on search engine platforms such as Google. This understanding demonstrates the students' ability to identify reliable sources for financial data, which is essential for making informed investment decisions. By utilizing these resources, students can effectively analyze the potential benefits and risks associated with different investment options. In Figure 5, students were able to identify the types of data required based on their characteristics (quantitative or qualitative), data sources (primary or secondary), collection timing (time series or cross-sectional), and the data collection method, which included literature review.


1) Laporan Keuangan dari BEI (Bursa Efek Indonesia) → data penutupan perdagangan saham yang didistribusikan setiap akhir perdagangan.
2) Website resmi dari bank terkait → informasi tentang bunga dan keamanan deposito
3) Grafik pergerakan harga saham → mengetahui trend dan grafik saham terkait

Translation:
1. Financial reports from the Indonesia Stock Exchange (IDX): closing trade data distributed at the end of trading session.
2. Official websites of the relevant banks: information on interest rates and the security of deposit investments.
3. Stock price movement charts: to understand trends and related stock graphs.

Fig 4: Example of the data required to solve the given problem.

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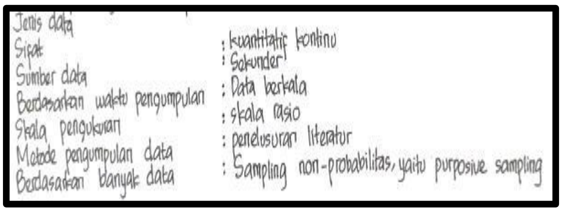
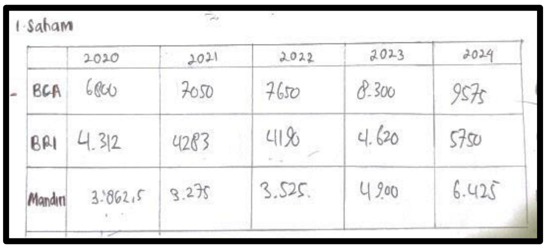


Jenis data
Sifat : kuantitatif kontinu
Sumber data : Sekunder
Berdasarkan waktu pengumpulan : Data berkala
Skala pengukuran : skala rasio
Metode pengumpulan data : penelusuran literatur
Berdasarkan banyak data : Sampling non-probabilitas, yaitu purposive sampling

Translation:	
Characteristics	*: continuous quantitative*
Data sources	*: secondary*
Collection timing	*: time series data*
Measurement scale	*: ratio scale*
Collection method	*: literature review*
Sampling method	*: non–probability sampling (purposive)*

Fig 5: Example of the results of identifying the required data based on its type.

The next stage of Polya's problem-solving process is carrying out the plan. In this phase, students focus on processing and presenting data. Data processing involves transforming raw data into a more comprehensible format, allowing students to identify patterns, relationships, and insights that might not be immediately apparent. This analytical approach not only facilitates deeper understanding but also enhances the accuracy of the conclusions drawn (Voskoglou, 2011). Groups at the 'substance' level often present incomplete data due to inaccuracies in the identification and data collection processes. For example, as shown in Figure 6a, some students only present data on banking sector stocks, despite the problem requiring an exploration of stock prices across various sectors. In contrast, groups at the 'result' level demonstrate minor errors in their data processing and presentation. An example of such an error can be seen in Figure 6b, where students use a pie chart to compare the interest earned on bank deposits with varying durations. A pie chart is more suitable for comparing deposit returns from different banks rather than comparing durations within a single bank. This highlights the importance of both accurate data collection and appropriate data representation methods in effective problem-solving.



1 Saham

	2020	2021	2022	2023	2024
BCA	6800	7050	7650	8.300	9575
BRI	4.312	4283	4180	4.620	5750
Mandiri	3.862,5	3.275	3.525.	4.900	6.425

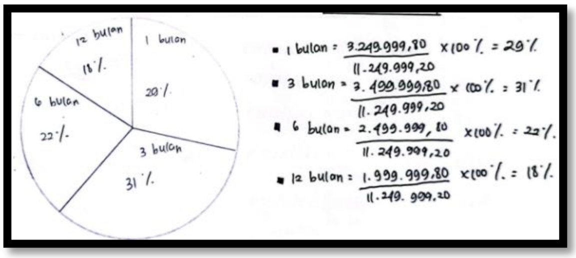
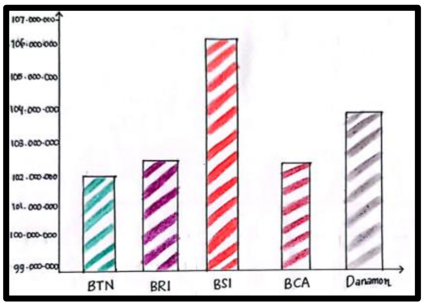


Fig 6: Examples of errors observed in 'substance' level and 'result' level groups.

On the other hand, student groups at the completion level are able to process and present data thoroughly and accurately. Figure 7a illustrates an example of data presentation that compares deposit values across several banks using a bar chart. A well-constructed and clear diagram aids in identifying the most advantageous bank deposit options. Additionally, Figure 7b displays a table estimating investment returns from stocks in various companies, taking into account the dividend values distributed. The information obtained from comparing the values of deposits and stocks serves as a critical reference for determining the best investment option. Students not only identify a solution but also offer a detailed explanation and a comprehensive understanding of the problem-solving process (Kelly et al., 2016).



nama Perusahaan	Modal	Harga	Lot	Perkiraan deviden	Total
PT Ciputra Surya Tbk.	Rp. 100.000.000	Rp. 5.200	19231	Rp. 288.462	Rp. 100.288.461,54
PT Blue Bird Tbk.	Rp. 100.000.000	Rp. 1.750	57143	Rp. 4.114.286	Rp. 104.114.285,71
PT Indofood CBP Sukses makmur Tbk	Rp 100.000.000	Rp. 11.570	8639	Rp 1.624.190	Rp. 101.624.190,66
PT Sekar laut Tbk	Rp. 100.000.000	Rp. 443	225734	Rp. 6.094.808	Rp. 106.094.808,13
PT Unilever Indonesia	Rp. 100.000.000	Rp. 3.857	25927	Rp. 1.633.394	Rp. 101.633.393,83

Fig 7: Example of data presentation that has been processed using bar charts and tables.

The final stage of Polya's problem-solving process, looking back, involves analyzing and interpreting data to draw conclusions related to the given problem. Figure 8 presents an example of a conclusion successfully crafted by a group of students based on their analysis and interpretation of the presented data. This group, categorized at the 'completion' level, concludes that Mr. Bambang should choose a deposit as the best investment option for his money. They argue that deposits are safer and more stable for short-term goals, even though stocks have the potential to yield higher returns. This conclusion exemplifies the looking back stage, where students reflect on their problem-solving process and evaluate their findings. By effectively applying this stage, they reinforce their understanding of the material and enhance their ability to make informed financial decisions (Syarifah & Nikmaturrohmah, 2021).

Berdasarkan data yang telah disajikan, Deposito dapat menjadi pilihan terbaik untuk Pak Bambang karena memiliki risiko investasi yang lebih rendah daripada saham. Deposito cenderung lebih stabil dan aman, sehingga cocok untuk tujuan jangka pendek atau sebagai cadangan dana darurat. Selain itu, tingkat return desposito biasanya lebih pasti dan dapat diandalkan, meskipun keuntungan mungkin tidak sebesar saham. Dengan kondisi modal yang belum mencukupi untuk pembukaan gerai baru. Deposito dapat memberikan keamanan dan stabilitas dalam pengelolaan dana pak Bambang.

Translation:
Based on the presented data, deposits emerge as the best option for Mr. Bambang due to their lower investment risk compared to stocks. Deposits are generally more stable and secure, making them suitable for short-term goals or as emergency funds. Additionally, the return rates on deposits are typically more certain and reliable, even though the potential profits may not match those of stocks. Given that Mr. Bambang's capital is insufficient for opening a new store, deposits offer him the security and stability needed for effective fund management.

Fig 8: Example of a conclusion drawn from the analysis of the given problem.

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Discussion

Although this study focuses on vocational students' problem-solving competencies, it is important to recognize that statistical reasoning is a skill that develops progressively over time. Statistical reasoning can be described as the cognitive process through which individuals engage with statistical concepts and derive meaning from statistical information (Garfield & Chance, 2000). This process encompasses the interpretation of data sets, graphical representations, and statistical summaries. Students typically begin with informal reasoning, such as describing data or identifying patterns, and gradually move toward more advanced thinking that involves making inferences, evaluating data quality, and applying statistical models appropriately (Makar & Ben-Zvi, 2011). This development is influenced not only by instructional methods but also by students' opportunities to engage in authentic problem contexts that require data-driven decision-making (Conway IV et al., 2019). The variation observed in this study, as reflected through Polya's problem-solving stages, may represent different points along this learning path. Students in the 'substance' group may still be in the early stages of statistical literacy, while those in the 'completion' group demonstrate more mature reasoning that integrates conceptual understanding with contextual interpretation.

Polya's problem-solving stages are widely recognized as an effective framework in mathematics education and are especially relevant for guiding students through complex problem-solving tasks. This structured framework provides a clear roadmap that helps students systematically tackle complex issues, encouraging deeper engagement and critical thinking (Vale et al., 2022). Additionally, the iterative nature of Polya's stages allows learners to reflect on their thought processes and outcomes (Carifio, 2015). By emphasizing the looking back phase, students can evaluate their strategies and results, leading to continuous improvement in their problem-solving skills (Leong et al., 2012). Moreover, Polya's approach fosters collaboration and discussion among peers, as students frequently share their processes and solutions, creating a richer learning environment (Felmer, 2023). In the context of this study, Polya's stages function not only as a theoretical foundation but also as a practical framework for classifying students' problem-solving competencies. Each group's case study analysis was examined and categorized based on the extent to which their work reflected the characteristics associated with the four stages of Polya's model. To further interpret these stages, we incorporated classification of problem-solving development levels by Malone et al. (2007). Student groups at the 'approach' level demonstrated limited engagement with the problem but made some effort to understand its context. Groups classified under the 'substance' level showed a reasonable understanding of the problem but struggled with planning and organizing data appropriately. Groups falling into the 'result' category reached a more advanced level, having devised and implemented a plan, but with observable inaccuracies or incomplete reflections. Meanwhile, 'completion' groups successfully addressed all four stages, showing both procedural fluency and strategic thinking throughout the process. This classification approach aligns well with a qualitative descriptive methodology, as it allows for in-depth interpretation of student behaviors and outputs within a structured yet adaptable framework.

While the primary focus of this study was to analyze the variation in students' problem-solving competencies, the observed differences also suggest potential influences from prior teaching strategies and learning experiences. In particular, instructional methods that emphasize student engagement and active learning, such as PBL, may play a critical role in shaping these competencies (Zhao et al., 2021; Benjamin, 2024). PBL encourages students to confront real-world problems collaboratively, develop their own approaches to solution planning, and engage in reflection throughout the process (Hmelo-Silver, 2004). This aligns closely with the stages in Polya's framework, especially in fostering deeper understanding, strategic planning, and evaluation (looking back). In contrast, more traditional methods, such as lecture-based or drill-and-practice instruction, may focus heavily on procedural fluency without promoting critical engagement or reflection. Students who are predominantly exposed to such approaches might perform well in routine exercises but struggle when faced with open-ended or context-rich statistical problems. Furthermore, cooperative learning strategies, guided inquiry, and the integration of formative feedback have also been shown to enhance students' problem-solving abilities by making their thought processes more visible and open to adjustment (Wang & Wu, 2022; Cindikia et al., 2020; Frank et al., 2018). Although this study did not explicitly measure the teaching methods used, the findings underscore the value of aligning instructional practices with cognitive frameworks such as Polya's to support problem-solving development.

Another important factor that may contribute to the variation in students' problem-solving competencies is their prior mathematical knowledge (Tambychik & Meerah, 2010). Solving statistical case studies often requires a solid foundation in basic mathematical concepts (Malangtupthong, 2022). These skills underpin key aspects of statistical reasoning, including data organization, computation of descriptive measures, and interpretation of numerical results. The subjects in this study were first-year students who had recently graduated from senior high school with diverse academic backgrounds: science, social studies, or vocational programs. Students from science streams typically have greater exposure to statistical reasoning, analytical thinking, and numerical problem-solving during high school, while those from social or vocational streams may have had less emphasis on mathematical abstraction or formal problem-solving approaches. This disparity can influence how well students comprehend statistical concepts, plan problem-solving strategies, and interpret data. Students who lack fluency in these foundational areas may find it difficult to devise coherent plans or carry out calculations accurately, as observed in groups categorized under the 'substance' and 'result' levels. Conversely, students with stronger prior mathematical knowledge are typically better equipped to navigate each phase of the problem-solving process. This could explain why groups classified under 'completion' were able to interpret problems accurately, apply appropriate methods, and reflect meaningfully on their results.

In vocational education, the relevance of Polya's stages of problem-solving becomes particularly significant as students prepare for real-world challenges that demand the practical application of theoretical knowledge. By following this structured approach, vocational students can engage with authentic scenarios, enabling them to apply their skills in meaningful contexts (Hampf & Woessmann, 2017). Emphasizing each stage ensures that students not only acquire technical competencies but also develop critical soft skills such as adaptability and collaborative problem-solving, which are essential in the workforce (Dogara et al., 2020). Furthermore, the iterative nature of Polya's model encourages students to explore various strategies, fostering resilience and innovation as they navigate complex vocational tasks (Simarmata & Hijriani, 2020). Implementing this approach in educational settings can significantly assist teachers in enhancing students' problem-solving abilities while equipping them with essential skills for their future careers. These competencies are increasingly vital in today's rapidly evolving technological landscape. Regarding the instructional method, PBL holds substantial potential for enhancing students' ability to apply statistical concepts in real-world contexts, particularly in vocational education, where practical application is a central objective (Jabarullah & Iqbal Hussain, 2019). Unlike traditional lecture-based approaches, PBL situates learning within authentic, complex problems that mirror professional situations. This method aligns closely with the nature of statistical reasoning, which involves understanding a problem, collecting and analyzing data, and drawing meaningful conclusions, as emphasized in Polya's problem-solving stages. Through repeated engagement with open-ended problems, students develop not only a deeper conceptual understanding but also greater contextual awareness, enabling them to better recognize how statistical methods are applied in real-life decision-making.

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Conclusion

Based on the analysis of students' problem-solving abilities, the findings reveal that 20% of students reached level 3 (substance), 46.67% achieved level 4 (result), and 33.33% attained level 5 (completion). The analysis according to Polya's stages indicates that groups of students at the 'substance' level tend to struggle with devising a plan to solve the given problems, which includes the processes of identifying and collecting relevant data. In contrast, those at the 'result' level exhibit several minor errors in processing and presenting data, as the part of implementing the plan, while students at the 'completion' level are able to effectively and thoroughly resolve the given problems. These findings underscore the importance of enhancing teaching strategies. Based on this research, several instructional recommendations can be proposed to enhance the effectiveness of teaching statistics in vocational education settings. First, integrating structured problem-solving models such as Polya's stages into classroom instruction can help students internalize a systematic approach to resolving real-world problems. To strengthen students' abilities in identifying and selecting relevant data, teachers should provide intensive practice and guided tasks that focus on data interpretation and problem comprehension. Additionally, to address challenges in data processing and presentation, additional practical sessions are recommended, allowing students to apply statistical methods more accurately. While PBL has shown promise in bridging theoretical concepts with vocational contexts, it is equally important to consider other instructional models that emphasize cognitive development and structured learning processes, such as guided inquiry learning, cooperative learning, or explicit modeling of problem-solving strategies. These approaches not only enhance technical understanding but also foster students' metacognitive awareness, enabling them to plan, monitor, and evaluate their problem-solving efforts effectively. Furthermore, implementing formative assessment techniques including peer feedback, self-assessment, and reflective exercises, can support continuous improvement by helping students recognize their errors and refine their approaches. However, a limitation of this study is that the case study was conducted in groups, which may result in less accurate assessments of individual problem-solving abilities. Future research could expand on this by evaluating problem-solving skills at the individual level, using the same approach in a variety of contexts that can be diversified. In addition, future research also should explore the integration of real-world business case studies to determine whether such contextualized learning experiences can further enhance vocational students' problem-solving skills and their ability to apply statistical reasoning in practical settings.

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