

## The Use Of Interactive Simulation-Based Vernier Caliper Virtual Labs For Learning Motivation

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### Abstract

*The low motivation of students to learn mathematics in vocational high schools, especially in the material of mechanical measuring instruments such as vernier calipers, is a challenge in the world of vocational education. This study aims to improve the effectiveness of the use of interactive simulation-based Virtual Labs to improve students' learning motivation. This study uses a quantitative approach, involving 42 students of class X of Mechanical Engineering Vocational High School as research subjects. The instruments used include a learning motivation questionnaire and observation sheets. The results of the study showed that students' learning motivation was in the good category, with an average value of 14.83 and high reliability (Cronbach's Alpha = 0.878). Observations showed that students showed high perseverance, interest, and independence during the learning process using the Virtual Lab. Thus, it can be concluded that the interactive simulation-based Vernier Caliper Virtual Lab is effective in improving students' learning motivation in vocational high schools.*

**Keywords:** *Virtual Lab, Vernier Calipers, Learning Motivation, Interactive Simulation.*

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## INTRODUCTION

The development of science and technology has had a significant impact on various aspects of life, including education. In the context of education, teachers are required to be able to master technology in order to create learning that is relevant to the demands of the times (Dwi, 2022). The success of education is highly dependent on the learning process in the classroom (Yhang et al., 2022). The use of technology in mathematics education can overcome challenges in learning and improve student learning outcomes (Setiawan et al., 2023). Learning activities in schools can take place well if there is reciprocal communication between teachers and students and teachers are expected to be able to guide the activities and creativity of students in learning (Novera et al., 2022).

The learning process is a dynamic interaction between teachers and students, where the teacher acts as a facilitator who encourages students to become active learners (Wahyuni & Maharani, 2023). The purpose of education is not only limited to mastering the material, but also to developing the character and competence of students (Hidayat & Maharani, 2023). However, challenges in learning mathematics are often influenced by factors such as student characteristics, school conditions, government policies, and teacher abilities. Therefore, it is important for teachers to understand the difficulties of learning mathematics in order to become effective educators (Hartono et al., 2024)

Education in the digital era requires innovation in learning methods, especially in Vocational High Schools (SMK), which must prioritize mastery of technical skills. One of the learning outcomes that students in the Mechanical Engineering program must master is the use of mechanical measuring instruments, which emphasizes accuracy, precision, and an understanding of mathematical concepts in the measurement process. Students are able to perform this task if they possess strong mathematical problem-solving skills (Putri et al., 2023). However, in practice, learning to use mechanical measuring instruments often encounters various obstacles, such as difficulty reading the main scale and vernier scale correctly, calculating

measurement tolerance limits accurately, and analyzing measurement results. These obstacles are not only caused by limited conceptual understanding but also influenced by low student motivation.

Motivation is the foundation for students to achieve maximum learning outcomes. Difficulties in learning mathematics are common, but it is precisely because of this that motivation emerges and influences their perspective when facing these difficulties (Nurrawi et al., 2023). According to Sardiman (2019), learning motivation is a key factor determining the success of the learning process. Without adequate motivation, students tend to lack enthusiasm, give up easily, and struggle to reach their optimal learning potential. Therefore, motivation also plays a key role in guiding and sustaining learning behavior.

Learning motivation is a person's inner drive to learn in accordance with their desire to achieve a goal (Syahdan Sa'id, 2021). The formation of a drive or desire to take action to achieve a goal can be used as learning motivation (Munthe & Pasaribu, 2023). The drive to complete a task can come from within or from outside. However, in practice, not all students have high learning motivation, especially in mathematics. The most important psychological characteristic of a person is motivation, which refers to the sense of enjoyment and enthusiasm with which they approach a task, in this case, learning. Students with high motivation often have a lot of energy or enthusiasm for learning.

Motivation can be defined as a psychological state that drives an individual to engage in a particular activity or behavior. The concept of motivation in learning consists of two types: intrinsic learning motivation and extrinsic learning motivation. Intrinsic learning motivation relates to an individual's inner drive to achieve personal goals or ambitions. This intrinsic drive stems from an innate desire to achieve goals, which can be achieved through the learning process. Extrinsic learning motivation, on the other hand, is influenced by external factors that encourage an individual to actively participate in the learning process. Examples of external factors that can influence student learning motivation include the desire to achieve good grades and become the top student (Mayasari et al., 2023).

Problems in mathematics learning, such as low motivation, can be addressed through innovative learning media (Fitri, 2023). One potential innovation to overcome this obstacle is the use of Virtual Labs (Virtual Laboratories) (Sa'adah et al., 2025). Teachers need to be creative in developing innovative and effective learning media to increase student motivation in the learning process (Nasution et al., 2024). With a more visual and interactive approach, Virtual Labs can also help students understand mathematical concepts related to the use of mechanical equipment in a more enjoyable way.

A Virtual Lab is a digital representation of a laboratory that allows students to conduct experiments or practice as if they were in a real laboratory, but in an interactive and safe virtual space. A Virtual Lab is a computer simulation-based learning medium that allows students to conduct experiments virtually like those in a real laboratory. A Virtual Lab is defined as an interactive environment for creating and conducting simulation experiments and a playground for experimentation (Tyas Almira et al., 2023)

The Vernier Caliper Virtual Lab is a digital learning tool that presents a simulated and interactive method for using and reading vernier calipers. Using measuring instruments like vernier calipers is often difficult for students to grasp if only explained theoretically. However, with the Virtual Lab, students can learn visually and interactively, thereby increasing their motivation.

In the context of engineering education, Virtual Labs can replace the limitations of practical equipment often encountered in vocational schools. Virtual Labs can be implemented during learning activities, both online and offline, especially when faced with constraints such as limited practical equipment. Virtual Labs can be implemented through simulation software or web-based applications equipped with tool visualizations, interactive guides, experimental data,

and automated assessments. For mathematics lessons on the application of real numbers to vernier calipers, interactive simulations help visualize measurement precision.

According to Sardiman (2019), several indicators of learning motivation can be observed in students. First, persistence in learning, demonstrated through an attitude of never giving up and continuing to try despite difficulties. In the context of virtual labs, this is reflected when students repeatedly attempt to make precise measurements or understand complex concepts. Second, tenacity in the face of difficulties, where students do not easily give up but instead seek alternative solutions or ask for help. Interactive simulations allow students to experiment with various approaches without the risk of serious consequences. Third, interest in learning, demonstrated when students actively seek additional information, ask questions, or participate in learning activities. An engaging design and relevance to the workplace are expected to spark this interest.

Fourth, deepening the learning material, where students don't just memorize but strive to deeply understand concepts and connect them to prior knowledge. The virtual caliper lab encourages exploration of the concepts of "why" and "how" a measurement is made. Fifth, independence in learning, namely the ability of students to manage their study time, seek additional learning resources, and not always rely on teacher guidance. The flexibility of the virtual lab supports this independence. Sixth, the ability to defend opinions, where students have confidence in their understanding and are able to defend arguments with a strong foundation of knowledge.

In its implementation, the interactive simulation-based vernier caliper virtual lab was designed with features such as feedback, clear visualizations, opportunities for experimentation, and direct links to vocational skills. This is expected to stimulate student learning motivation. The interactive learning environment allows students to actively engage in the learning process, significantly increasing their internal motivation to master the use of vernier calipers and solve related mathematical problems.

The use of Virtual Labs has proven effective as an alternative to mathematics practicums, especially in schools with limited facilities. This training improves teachers' digital competencies and opens up opportunities for more interactive learning (Quraisy et al., 2023). Virtual labs provide teachers and students with open opportunities for interactive and flexible learning, without the constraints of space and time (Sujadi et al., 2025). By implementing an interactive simulation-based vernier caliper Virtual Lab, this study seeks to leverage the advantages of Virtual Lab characteristics to create an optimal learning environment. This optimal learning environment is expected to not only improve material understanding but also effectively hone practical skills and motivate students in vocational high schools (SMK) majoring in Mechanical Engineering.

Based on field findings, in the mechanical measuring instrument material of vernier calipers, many students have difficulty understanding the concept due to the lack of interactive and contextual learning media. In this case, Virtual Lab presents as an innovative solution that combines visual elements, digital practice, and interactive simulations, enabling students to learn independently and interestingly. This study focuses on how Virtual Lab can influence student learning motivation in mathematics learning, especially in the material of real numbers related to the use of vernier calipers. Thus, the results of this study are expected to be an innovative solution in facing the challenges of mathematics learning in the digital era.

## RESEARCH METHODS

This study employed a quantitative approach with a pre-experimental design, specifically the one-group pretest-posttest design. According to Sugiyono (2016), quantitative research is

characterized by the use of numerical data collected through research instruments and analyzed statistically to examine specific phenomena. This approach was selected because it allows for objective measurement of the impact of Virtual Lab implementation on students' learning motivation.

The one-group pretest-posttest design was chosen following Campbell and Stanley's (1963) experimental design principles, which state that this design enables researchers to observe changes that occur after treatment within the same group, without requiring a control group. This design is particularly suitable for preliminary studies where the focus is on examining the potential effects of an intervention.

Prior to use in the study, all instruments were validated through expert judgment by two lecturers from Swadaya Gunung Jati University and two mathematics teachers. This validation process aimed to ensure that the items in the instruments aligned with the indicators to be measured, had clear wording, and were relevant to the research objectives. The validation results indicated that the instruments were suitable for use with some minor improvements. Furthermore, the instruments' reliability was statistically tested to ensure good internal consistency. With these steps, this research method was systematically designed to obtain valid, reliable data that aligns with the research objectives.

Data collection techniques were carried out using several instruments. First, an observation sheet was used to observe student activities and the implementation of the virtual lab during learning. Second, the learning motivation questionnaire was compiled based on Sardiman's (2019) model. A Likert-type questionnaire (1-4) was used to measure students' perceptions of the benefits of learning media in increasing learning motivation. Third, a mathematical problem-solving ability test was administered in the form of a pretest and posttest, with questions structured according to Polya's (1945) problem-solving stages. The descriptive questions used were related to measurements using calipers and real number operations.

The following is an observation sheet for learning motivation aspects based on learning motivation indicators according to Sardiman which will be used to observe and record during the learning process using the Virtual Lab vernier caliper.

Table 1. Observation Sheet for Learning Motivation Aspects

No	Indicator	Scale				Notes
		1	2	3	4	
1.	Perseverance in learning					
2	Persistent in the face of adversity					
3	Showing interest in learning activities					
4	Deepen the learning material					
5	Independent in learning					
6	Can defend his opinion					

Scale Description:

1 = Not observed, 2 = Rarely, 3 = Often, 4 = Consistent

The learning motivation questionnaire was used to measure students' motivation levels in learning about mechanical measuring instruments. This questionnaire was compiled based on learning motivation indicators according to Sardiman's (2019)

Table 2. Learning Motivation Questionnaire

No	Indicator	Statement	SS	S	TS	STS
1	Perseverance in learning	I still practice using the virtual lab vernier caliper even though I haven't mastered it straight away.				
2	Persistent in the face of adversity	I did not give up easily when I found difficulties in measuring using calipers in the virtual lab.				
3	Show interest in learning	When I was confused about how to read the vernier caliper scale in the virtual lab, I tried to figure it out myself.				
4	Deepening the teaching materials	I don't immediately stop learning if the measurement results in my virtual lab are wrong.				
5	Independent in learning	I am very interested in learning more about the use of vernier calipers through the virtual lab.				
6	Can defend opinions	I felt happy and enthusiastic when I participated in learning using the virtual vernier caliper lab.				
		I'm trying to understand the basic concept of a vernier caliper, not just know how to use one.				
		I ask or seek additional explanations if there are measurement concepts that I don't fully understand.				
		I feel more confident to learn vernier calipers independently with the virtual lab.				
		I am confident with my measurement results after using the vernier caliper virtual lab.				

Rating Scale Description:

SS = Strongly Agree

S = Agree

TS = Disagree

STS = Strongly Disagree

## RESULT AND DISCUSSION

### Results

Based on the results of the observation, a picture of student learning motivation was obtained through six main indicators. The assessment was carried out using a scale of 1 to 4, with the following information: 1 = Not Observed, 2 = Rarely, 3 = Often, and 4 = Consistent. Although the number of students observed was not explicitly stated, this observation reflects the general tendency in one class group.

The results of the observation showed that in the first indicator, namely perseverance in learning, students scored 4, which indicates that this behavior was observed consistently during learning. Likewise, in the third and fifth indicators, namely showing interest in learning activities and being independent in learning, each scored 4. In the interest indicator, it was noted that

students showed enthusiasm in waiting for the learning process, and in the independence indicator, students seemed enthusiastic in finding solutions. The second and fourth indicators, namely tenacity in facing difficulties and exploring learning materials, scored 3, which means that this behavior is often shown even though it is not yet completely consistent. Meanwhile, the sixth indicator, namely students' ability to defend their opinions, scored 2, with the note that some students still seemed hesitant in conveying their arguments.

Overall, if averaged, the six indicators produce a score of 3.33. This value indicates that students' learning motivation is in the "often to consistent" category. This means that most of the learning motivation indicators are already visible in the learning process, and are carried out quite stably by students. Thus, it can be concluded that in general students' learning motivation is at a good level, although there are certain aspects, such as the courage to express opinions, that still need to be improved. The learning motivation questionnaire data obtained from 42 students showed quite diverse score variations between respondents. Each student was asked to provide an assessment of 10 statements (P1–P10) which were arranged based on learning motivation indicators using a Likert scale. The total motivation score collected ranged from 10 to 30 points. This range reflects differences in motivation levels between students, ranging from those showing very low to quite high levels of motivation. Before this data was used in further analysis, such as regression testing, the validity and reliability of the questionnaire instrument were first tested to ensure that the statement items used were truly able to measure the learning motivation construct accurately and consistently. The results of this test are presented in the following table.

Table 2. Reliability Test

<b>Reliability Statistics</b>	
Cronbach's Alpha	N of Items
.878	10

Based on Table 1, the reliability test results show a Cronbach's Alpha value of 0.878 for the 10 statement items. This value is categorized as very good according to the criteria (Nunnally & Bernstein, 1994), who stated that instruments with reliability values above 0.80 have high internal consistency. This indicates that the instrument used in the study is capable of providing consistent results in measuring the constructs studied.

The Cronbach's Alpha value of 0.878 for 10 items indicates that this instrument has a very good level of reliability (good reliability) based on psychometric standards (Nunnally & Bernstein, 1994), where values above 0.80 indicate high internal consistency. Statistically, this figure reveals that 87.8% of the score variance comes from the actual measurement of the construct, while only 12.2% is due to measurement error, so that the measuring instrument is able to produce stable and reliable data. This coefficient also strengthens the findings of the previous validity test where all items correlate significantly with the total score (minimum  $r = 0.555$ ), with key items such as M3 ( $r = 0.819$ ) and M5 ( $r = 0.805$ ) as the main pillars of reliability. Overall, the instrument has met the eligibility requirements.

Thus, this research instrument can be declared reliable and suitable for use. High reliability not only demonstrates consistency between items but also ensures that the instrument is capable of producing accurate data with minimal bias. This is crucial because good instrument quality will support the overall reliability of the research results, including subsequent analysis.

Table 3. Descriptive Statistics

<b>Descriptive Statistics</b>					
	N	Minimum	Maximum	Mean	Std. Deviation
TOTAL	42	10	30	14.83	4.828
Valid N (listwise)	42				

Based on the analysis of the learning motivation questionnaire data with a Likert scale of 1-4, a minimum score of 10 was obtained, indicating that some students tended to choose the "Strongly Disagree" or "Disagree" option for several statements. On the other hand, a maximum score of 30 indicated that some students were more dominant in choosing "Agree" or "Strongly Agree." The average total score for students' learning motivation was 14.83. If converted to a Likert scale per item, the mean value was around 1.48, which indicated a tendency towards "Agree" answers. However, it should be noted that the total score is the accumulation of all items, so a more in-depth interpretation is needed by looking at the distribution of answers per statement. The standard deviation of 4.828 reflects that the variation in students' answers is quite diverse, but does not show extreme dispersion, so it can be concluded that most respondents have a relatively balanced view regarding learning motivation.

The mean score of 14.83 indicates a general tendency for respondents to fall slightly below the midpoint of the possible score range (10–30). This means that most respondents tended to provide answers in the moderate to low range. Furthermore, the standard deviation (Std. Deviation) of 4.828 indicates a significant spread of scores from the average, resulting in relatively diverse responses and not concentrated on a single value.

Thus, this descriptive data provides an initial indication that, despite the instrument's high reliability, there are significant differences in response rates among respondents. This variation is important for further analysis because it can indicate the presence of groups of respondents with different levels of construct competence, such as low, medium, and high. This information also provides a strong foundation for further analysis, both categorization and inferential analysis, to identify the factors influencing these differences in scores.

## **Discussion**

Based on observations of learning motivation indicators, it was found that students demonstrated high levels of persistence, interest, and independence, each with a score of 4. However, their ability to defend their opinions was still relatively low, with a score of 2. The average observation score of 3.33 fell into the "frequent to consistent" category, indicating that students' learning motivation was generally at a good level.

Furthermore, the results of the motivation questionnaire demonstrated very high reliability, with a Cronbach's Alpha value of 0.878. The total questionnaire score ranged from 10 to 30, with an average of 14.83. When converted to a Likert scale, this figure equates to an average score per item of 1.48, indicating that students tended to respond "agree" to statements measuring their learning motivation. The most dominant items were M3 ( $r = 0.819$ ) and M5 ( $r = 0.805$ ), which relate to persistence and independent learning exploration, respectively.

The findings of this study indicate that the use of an interactive simulation-based Vernier Caliper Virtual Lab has a significant positive impact on vocational high school students' learning motivation. This discussion explores these findings in depth by explaining them in relation to previous theory and research, and strengthening them for educational practice. Observations revealed that students demonstrated high levels of persistence, interest, and independence, which aligns with intrinsic motivation theory, where interactive learning environments foster curiosity and a natural drive to learn.

The Virtual Lab provides a safe and repeatable experimental space, allowing students to learn from mistakes without real consequences, thus encouraging their persistent efforts toward long-term mastery. However, indicators related to retention remain relatively low, indicating that while the Virtual Lab is effective in encouraging individual exploration, the virtual environment does not sufficiently encourage collaborative discussion or argumentation. Social constructivism theory emphasizes the importance of social interaction and dialogue in knowledge construction, and the lack of structured collaborative tasks in virtual environments may explain this shortcoming.

The learning motivation questionnaire demonstrated very high reliability (Cronbach's Alpha = 0.878), confirming that it consistently measures its intended construct. Strong item-total correlations for statements M3 (perseverance) and M5 (self-directed exploration) confirm that these aspects are key pillars of students' motivational experiences in virtual learning contexts.

Interactive simulations allow students to visualize abstract mathematical concepts—such as real numbers and measurement precision—in a concrete and contextualized way. This aligns with cognitive theories of multimedia learning, which suggest that people learn best when words and visuals are combined in an interactive format. The Virtual Lab's instant feedback mechanism helps students correct misconceptions immediately, reinforces correct procedures, and boosts confidence.

Vocational education requires a balance between theoretical knowledge and practical skills. Virtual Labs act as a bridge between these two domains, allowing students to apply mathematical concepts in simulated, real-world contexts. This is especially important in settings where physical equipment is limited or inaccessible, and supports the findings of Quraisy, Muzaini & Gaffar (2023) on the role of virtual labs in expanding access to practical learning in resource-constrained environments. While the results were generally positive, this study has limitations. The one-group pretest-posttest design limits the generalizability of the findings due to the lack of a control group for comparison. Future studies could employ quasi-experimental designs with a control group using traditional methods to further isolate the effects of Virtual Labs.

Furthermore, research by Tyas Almira, Febri & Ridha (2023) shows that Virtual Labs designed with interactive features can foster curiosity and enhance students' conceptual understanding. This aligns with the findings of this study, where the dominant motivational indicators were interest and independence in learning, which emerged as a result of the interactive simulation design that was engaging and relevant to the needs of vocational high school students. Therefore, this study not only corroborates previous findings but also confirms that Virtual Lab has significant potential as an innovative learning medium in vocational schools.

The low scores on the "defending an opinion" indicator also suggest the need for stronger social-interactive elements in Virtual Labs. Therefore, as an implication of these findings, it is recommended to integrate collaborative features or group discussions into virtual labs to train argumentation skills and enrich students' learning experiences more comprehensively. Peer evaluations or guided debate sessions can foster critical thinking and argumentation skills. Implications of these results suggest that Virtual Labs are not merely supplementary tools, but can be central to modern, motivation-driven pedagogy. Teachers in vocational schools should consider integrating Virtual Labs into regular instruction, especially for topics that require conceptual visualization and repeated practice.

## CONCLUSION

Based on the results of the research that has been conducted, it can be concluded that the use of the Vernier Caliper Virtual Lab based on interactive simulation has a positive effect on increasing the learning motivation of vocational high school students in mathematics subjects on real number material on mechanical measuring instruments. The results of the learning motivation questionnaire analysis showed that most students showed a positive attitude towards learning, with an average value of 14.83 and high instrument reliability ( $\alpha = 0.878$ ), which indicates that the data obtained is reliable and representative of the learning motivation construct being measured. In addition, the results of observations during the learning process strengthen this finding, where students show indicators of learning motivation such as perseverance, interest, and independence consistently.

The interactive simulation in the Virtual Lab provides a more contextual, interesting learning environment, and is in accordance with the characteristics of vocational high school students who tend to prefer direct practice-based learning. The Virtual Lab allows students to explore the concept of vernier caliper measurement visually and independently, so that they are not only passive recipients of information, but are actively involved in the learning process. This interactivity has a positive impact on building students' confidence in understanding the material, increasing curiosity, and fostering courage in solving problems.

Although most of the motivation indicators have been seen in the learning process, the observation results also show that the aspect of courage in expressing opinions still needs to be improved. Therefore, further interventions that encourage two-way communication between students and teachers, such as group discussions or presentations, can be a complementary strategy to optimize this aspect.

In general, this study provides an important contribution to the development of technology-based learning innovations in vocational schools. Virtual Labs not only act as visual aids, but also as a means to develop active, independent, and highly motivated student learning characters. For this reason, it is recommended that mathematics teachers and productive teachers in vocational schools integrate the use of Virtual Labs as part of STEM-based learning strategies or project-based learning, in order to adapt to technological developments and the needs of 21st century learning.

In addition to the conclusions drawn, this study also offers several practical recommendations. For vocational school teachers, it is recommended to integrate the use of Virtual Laboratories into classroom practice on a regular and ongoing basis. Through consistent implementation, Virtual Laboratories can serve not only as a complementary medium to conventional practices but also as an innovative learning tool that fosters students' curiosity, enhances their independence, and increases motivation to master technical subjects.

For schools, it is recommended to provide adequate technological infrastructure such as computer laboratories, stable internet access, and simulation-based learning software. The availability of these facilities is crucial to support the effective implementation of Virtual Laboratories and to ensure equal access for all students. Strong institutional support will help maximize the potential of Virtual Laboratories as part of technology-based learning innovation in vocational education.

For future researchers, it is recommended to use a quasi-experimental design with a control group to strengthen the validity of the findings and allow for more accurate comparisons between conventional and Virtual Laboratory-based learning. Furthermore, it is recommended to expand the research sample to vocational schools or different fields of study so that the results can be more broadly generalized and contribute more comprehensively to the development of Virtual Lab-based learning in education.

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