Implementing the Module and Learning Video in Turning Tapered to Enhance the Students' Competency in Mechanical Engineering Education

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ABSTRACT

The rapid advancements in technology and the demands of Industry 4.0 have underscored the need for innovative teaching approaches in Technical and Vocational Education and Training (TVET) to enhance students' practical competencies. This study evaluates the effectiveness of module-based and video learning in improving students' competencies in tapered turning within a lathe machining practice course. Employing a quasi-experimental design, the study involved 41 students from a Mechanical Engineering Education program, divided into an experimental group (19 students) and a control group (22 students). The experimental group used module-based and video learning tools, while the control group relied on traditional teaching methods. The findings revealed a statistically significant improvement in the experimental group's post-test scores compared to the control group ($t = 8.59$, $p < 0.05$), with a mean difference of 14.467. The experimental group also achieved an average normalized gain (N-Gain) score of 0.7063, categorized as "high," indicating a substantial improvement in learning outcomes. The study demonstrates that the integration of module-based and video learning enhances both cognitive understanding and practical skills, making the learning process more interactive, accessible, and aligned with industry needs. These findings highlight the potential of multimedia-based teaching tools to bridge the gap between traditional methods and modern educational requirements, contributing to the development of industry-ready graduates in the era of Industry 4.0.

Keywords: industry 4.0, lathe machining practice, module-based learning, tapered turning, TVET, video learning.

INTRODUCTION

Mechanical engineering education faces increasing pressure to produce graduates with advanced technical capabilities and adaptive, future-ready skills in the curret era of fast technological innovation and industry 4.0 change (Giang et al., 2021; Harahap & Rafika, 2020; Spöttl & Windelband, 2021). Among them, machining competencies are essential, especially in complex operations such as tapered turning, to ensure that students can meet the requirements in modern industrial sectors that emphasize efficiency, accuracy, and automation (Wagiran et al., 2023; Yao et al., 2018). However, there remains a significant gap between the expectations of industry and the practical skills acquired by students in vocational settings. This disparity emphasizes how crucial it is to reconsider teaching approaches in Technical and Vocational

Education and Training (TVET), as conventional teaching approaches frequently fail to engage students and meet their varied learning demands (Ali et al., 2020; Bachri et al., 2021). Therefore, this study is essential in exploring innovative learning tools such as instructional modules and video-based learning to enhance students' mastery of tapered turning operations, thereby improving both their cognitive understanding and hands-on performance in alignment with industrial standards (Inderanata & Sukardi, 2023; Vrchota et al., 2019).

Building on these challenges, there is a growing need to address specific technical competencies in machining, such as tapered turning, which are essential for aligning education with industrial needs (Ferraz et al., 2018; Kuper, 2020; Quintino et al., 2012). The rapid advancements in technology and the demands of Industry 4.0 have created a significant shift in educational priorities, especially in technical and vocational education(Martynov et al., 2019). As industries embrace automation and precision manufacturing, the need for a highly skilled workforce becomes more pressing (Fomunyam, 2019; Mbamba, 2023). In this context, machining skills such as tapered turning play a pivotal role in preparing students for real-world applications. This competency is crucial not only for meeting industry standards but also for fostering innovation and efficiency in manufacturing processes (Silva et al., 2015).

Despite the importance of tapered turning in modern manufacturing, students often face significant challenges in mastering this skill (Yunus et al., 2016). Traditional teaching methods, which rely heavily on verbal explanations and demonstrations, lack the interactive and visual elements needed to fully engage students (Miles, 2019). These methods often fail to address the diverse learning needs of students, especially those with varying educational backgrounds, such as vocational and general high schools. Additionally, limited access to structured resources, such as detailed instructional modules and videos, further hampers students' ability to visualize and understand complex machining techniques (Chandra et al., 2023). To overcome these challenges, there is a growing need for innovative learning tools that provide students with accessible, structured, and interactive resources. Module-based learning and instructional videos have the potential to bridge this gap by offering step-by-step guidance and visual demonstrations (van der Meij & van der Meij, 2016). These tools not only enhance students' understanding of theoretical concepts but also improve their practical competencies, making them better prepared to meet industry standards.

To address these challenges, this study introduces module-based learning and instructional videos as innovative pedagogical tools in the teaching of tapered turning. The modules are designed to provide students with detailed theoretical explanations and systematic step-by-step guidance, enabling them to understand the principles and processes involved in tapered turning. Meanwhile, the instructional videos offer visual demonstrations of the practical aspects, helping students to better visualize and replicate complex machining techniques. Together, these tools aim to enhance

both the cognitive and psychomotor competencies of students, making the learning process more interactive, accessible, and effective.

This study aims to evaluate the effectiveness of module-based and video learning in enhancing the practical competencies of students in tapered turning. Specifically, the research seeks to:

1.   Assess the extent to which these tools improve students' understanding and skill acquisition compared to conventional teaching methods.

2.   Determine the impact of these tools on students' engagement and confidence in performing tapered turning tasks.

3.   Provide empirical evidence on the potential of integrating technology-based learning in technical and vocational education.

To achieve these objectives, this study adopts an experimental research design, comparing the performance of students taught using traditional methods to those who use module-based and video learning. The findings are expected to contribute to the growing body of research in Technical and Vocational Education and Training (TVET), offering practical insights for educators and policymakers in designing more effective and industry-aligned learning strategies.

METHOD

This study employed a quantitative approach using quasi-experimental design to evaluate the effectiveness of module-based and video learning in enhancing students' competencies in tapered turning. Specifically, a pre-test post-test control group design was implemented, allowing a comparison between students taught using conventional methods and those who used the proposed learning tools. The experimental group received the intervention, which consisted of module-based and video learning, while the control group was taught using traditional teaching methods without supplementary learning media, as in Table 1. Both groups were tested before and after the intervention to measure improvements in their competencies.

Table 1. Research Design

Group	Pre-test	Intervention	Post-test
Experiment	O_1	X	O_2
Control	O_3	-	O_4

Explanation:
O_1 : pre-test of experiment group
O_2 : pre-test of control group
X   : implementation of learning module and video
-       : conventional learning without implementation of learning module and video
O_3 : post-test of experiment group
O_4 : post-test of control group

The population of this study consisted of fourth-semester students in the Mechanical Engineering Education program at Universitas Negeri Semarang during the 2023/2024 academic year. Using

purposive sampling, two classes were selected: Class 3 as the experimental group and Class 4 as the control group. A total of 41 students participated in the study, with 19 students in the experimental group and 22 in the control group.

The experimental group was provided with module-based learning materials and instructional videos covering the theoretical and practical aspects of tapered turning. These materials included detailed explanations of tapered turning principles; step-by-step video demonstrations of machining techniques; and practice problems to reinforce learning. The intervention was conducted over a four-week period, with students engaging in guided practice sessions using the modules and videos.

A performance test was used to assess students' competencies in tapered turning. The test was designed to evaluate both cognitive and psychomotor skills, with tasks including calculating the dimensions and angles for tapered turning; executing tapered turning tasks using a lathe machine; and assessing the accuracy and precision of the machined products. The test instrument was validated by two subject matter experts to ensure its reliability and validity. The experts rated the instrument as "very good" with an average score of 86%, indicating its suitability for data collection.

Data were analyzed using parametric statistical methods, including (1) Normality Test: the Shapiro-Wilk test was used to ensure that the data were normally distributed; (2) Homogeneity Test: Levene's test was conducted to verify the similarity of variances between groups; (3) Independent Samples t-Test: this was used to compare the mean scores of the experimental and control groups to determine the effectiveness of the intervention; and (4) N-Gain Score Test: the normalized gain was calculated to measure the improvement in learning outcomes in the experimental group.

RESULTS AND DISCUSSION

Results

    1. Normality and Homogeneity Test

        The normality test using the Shapiro-Wilk method showed that all data sets were normally distributed, with p-values greater than 0.05 for both pre-test and post-test scores in the experimental and control groups. The results of the normality test conducted using SPSS version 25 are shown in Tables 2 and 3, while the homogeneity test results are presented in Table 4.

Table 2. Test of Normality

	Group	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Competence	Pretest (experiment)	.131	19	.200*	.920	19	.113
	Posttest (experiment)	.126	19	.200*	.954	19	.456
	Pretest (control)	.097	22	.200*	.974	22	.804

Posttest (control)	.164	22	.128	.936	22	.161

Table 3. Normality Data Test Result

Competence value	P-value (sig)	Significance level	Result
Pretest (experiment)	0,113	0,05	Normal
Posttest (experiment)	0,804	0,05	Normal
Pretest (control)	0,456	0,05	Normal
Posttest (control)	0,161	0,05	Normal

Table 4. Test of Homogeneity

Competence	P-value (sig)	Significance level	Result
Pretest	0,053	0,05	Homogen
Posttest	0,395	0,05	Homogen

Similarly, the homogeneity test results indicated that the data variances between the groups were homogeneous, with significance values exceeding 0.05. These results confirm that the data meet the prerequisites for parametric analysis.

2. Independent Samples t-Test

The hypothesis of this study was tested using an independent sample t-test. Class 3 was designated as the experimental group, while Class 4 served as the control group. The experimental group received instruction supported by module-based and video learning during lathe practice, whereas the control group was taught using conventional methods without these additional learning tools. The t-test aimed to determine whether there was a significant difference in the competencies of the two groups. The test results are presented in Table 5.

Table 5. Independent Sample t-Test

						95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	8.59	39	0	14.467	1.684	11.06	17.873
Equal variances not assumed	8.54	37.1	0	14.467	1.694	11.034	17.899

The results of the t-test are shown in Table 5. The post-test analysis yielded a t-value (t-calculated) of 8.59, which is greater than the critical t-value (t-table) of 1.685 at a 5% significance level. The two-tailed significance value (p-value) of 0.000 is less than 0.05. Based on these results, H_0 is rejected, and H_a is accepted, indicating a statistically significant difference between the experimental and control groups.

From Table 5, the mean difference between the two groups is 14.467, with a 95% confidence interval ranging from 11.06 to 17.899. These findings highlight a substantial improvement in the competencies of students in the experimental group, who utilized module-based and video learning, compared to those in the control group. This demonstrates the effectiveness of integrating these learning tools in enhancing practical skills in tapered turning within the Mechanical Engineering Education Study Program.

3. N-Gain Score

The N-Gain test was conducted to measure the improvement in students' practical learning outcomes by comparing their pretest and posttest scores. This analysis aims to determine the extent of the enhancement achieved through the implementation of learning modules accompanied by instructional videos in the lathe machining practice course on tapered turning material. The normalized gain (N-Gain) test is a widely used method to evaluate the effectiveness of an intervention in improving average learning outcomes. The results from the experimental group are presented in Table 6.

Table 6. N-Gain Score of Experiment Group

Respondent	Experiment Group
E1	0.65
E2	0.61
E3	0.62
E4	0.85
E5	0.85
E6	0.78
E7	0.87
E8	0.94
E9	0.79
E10	0.73
E11	0.68
E12	0.84
E13	0.72
E14	0.46
E15	0.58
E16	0.54
E17	0.64
E18	0.58
E19	0.68
Average	0,7063
Minimum	0,46
Maximum	0,94

The results in Table 6 show that the experimental group, consisting of 19 students, achieved an average N-Gain score of 0.7063, which falls into the "high" category ($G \geq 0.7$). The maximum N-Gain score observed in the group was 0.94, while the minimum was 0.46. This indicates a consistent and significant improvement in learning outcomes among the students in the experimental group.

Discussion

The results of the normality and homogeneity tests confirmed that the data were normally distributed and homogenous across all groups. This validates the use of parametric statistical methods, such as the independent sample t-test, for analyzing the effectiveness of the intervention (Yusup, 2018). These findings establish a solid foundation for reliable and valid comparisons between the experimental and control groups. The confirmation of normality and homogeneity ensures that observed differences in learning outcomes are attributable to the intervention rather than random variation or unequal group characteristics. This highlights the robustness of the study design and supports the reliability of the conclusions drawn from subsequent analyses.

The independent sample t-test revealed a statistically significant improvement in the post-test scores of the experimental group compared to the control group. With a t-value of 8.59 and a significance level of $p < 0.05$, the intervention demonstrated a substantial impact on students' learning outcomes. The mean difference of 14.467, with a 95% confidence interval ranging from 11.06 to 17.899, underscores the effectiveness of the learning tools in enhancing practical competencies. The use of modules and videos allowed students to grasp complex machining concepts, such as calculating tapered angles and executing precise lathe operations. The findings align with prior research suggesting that multimedia learning tools improve both cognitive understanding and psychomotor skills in technical subjects (Fitrianingsih, 2015; Mutmainnah et al., 2021).

The results of the N-Gain test highlight the significant impact of module-based and video learning on improving students' competencies in tapered turning. With an average N-Gain score of 0.7063, the experimental group demonstrated a high level of improvement in practical learning outcomes, confirming the effectiveness of the intervention (Asri & Sumbodo, 2017). In contrast, previous studies on traditional teaching methods have shown that these approaches often yield only modest gains in practical skills due to their limited engagement and lack of interactive elements(Bachri et al., 2021; Fitrianingsih, 2015). The "high" category improvement in the experimental group reflects the ability of module-based and video learning to bridge the gap between theoretical understanding and practical application. By providing step-by-step instructions and visual demonstrations, the intervention addressed common challenges in technical education, such as difficulty in visualizing machining processes and limited access to hands-on practice. This aligns with the findings of (Makhtar et al., 2023; Mutmainnah, 2021), who highlighted that multimedia tools enhance comprehension and retention by catering to various learning styles.

The use of instructional videos also played a critical role in boosting student engagement and motivation. Traditional methods, which often rely on lectures and in-class demonstrations, may fail to capture students' interest or provide the depth of understanding needed for technical tasks. The videos, on the other hand, offered students the flexibility to revisit complex machining steps at their own pace, fostering a deeper level of engagement. This adaptability is particularly

valuable in Technical and Vocational Education and Training (TVET), where learners often come from diverse educational and skill backgrounds.

The improvement in learning outcomes also demonstrates the intervention's alignment with industry demands. Tapered turning is a critical skill in modern manufacturing, requiring precision, efficiency, and a clear understanding of machining principles. The significant increase in students' competencies ensures that they are better prepared to meet the expectations of industrial workplaces. This is crucial in the context of Industry 4.0, where high-level technical skills are essential for navigating increasingly automated and technologically advanced environments (Giang et al., 2021; Wagiran et al., 2023).

Compared to the control group, the experimental group showed a markedly higher improvement in learning outcomes. The control group, which relied solely on traditional methods, demonstrated minimal gains due to the lack of interactive and structured resources. This reinforces the need for innovative pedagogical strategies in TVET that move beyond conventional approaches. The module-based and video learning tools provided a comprehensive and student-centered learning experience, which was more effective in developing practical skills.

The significant improvement observed in the experimental group underscores the limitations of traditional teaching methods. Conventional approaches, which rely on verbal explanations and physical demonstrations, often fail to engage students or provide adequate opportunities for practice. These findings are consistent with prior research highlighting the importance of interactive and multimedia-based tools in technical education (Bachri et al., 2021; Mutmainnah, 2021; Omar et al., 2022). By contrast, the integration of module-based and video learning addressed these challenges through:

1. Enhanced Visualization: Videos provided clear, step-by-step demonstrations of tapered turning processes, helping students better understand and replicate machining techniques.
2. Structured Learning: Modules offered comprehensive theoretical guidance, bridging the gap between abstract concepts and practical applications.
3. Flexibility and Accessibility: Students could revisit the learning materials as needed, promoting self-paced learning and improved retention.

These findings have broader implications for the design and delivery of technical education. The integration of multimedia tools and structured learning modules can serve as a model for enhancing practical competencies across various technical subjects. By incorporating these tools, educators can create more engaging and effective learning environments that better prepare students for the dynamic needs of the workforce. Additionally, this approach supports the goals of TVET in producing industry-ready graduates capable of contributing to economic development in the era of Industry 4.0.

The improvement in students' competencies demonstrates the intervention's alignment with industry requirements. Tapered turning is a fundamental skill in modern manufacturing, where precision and efficiency are critical. By enhancing both theoretical understanding and practical proficiency, the intervention better prepares students for real-world industrial challenges. This is particularly relevant in the context of Industry 4.0, where the demand for highly skilled workers equipped with both technical and general competencies such as problem-solving, critical thinking, and teamwork is growing rapidly (Wagiran et al., 2023). The integration of innovative learning tools in TVET contributes to closing the gap between education and industry expectations.

The discussion reinforces the importance of innovative learning strategies in technical education. The significant improvement in the experimental group's N-Gain score highlights the value of module-based and video learning in enhancing practical competencies. These tools not only bridge the gap between theory and practice but also address key challenges in engagement, accessibility, and alignment with industry standards. The results of this study underscore the potential of such interventions to transform the landscape of TVET and ensure students' readiness for real-world industrial applications. The significant improvements observed in the experimental group highlight the potential of module-based and video learning to:

1. Enhance student engagement and motivation through interactive and visually appealing content.
2. Address the diverse learning needs of students with varying educational backgrounds and skill levels.
3. Align educational outcomes with the evolving demands of Industry 4.0.

These findings support the adoption of innovative pedagogical approaches across various technical subjects to improve both cognitive and practical competencies. By bridging the gap between traditional methods and modern educational needs, these tools can help TVET institutions produce industry-ready graduates who are equipped to contribute to economic development and technological advancement.

CONCLUSION

The integration of module-based and video learning significantly enhanced students' competencies in tapered turning, as evidenced by the high N-Gain scores and statistically significant improvements in post-test results. These findings reinforce the importance of adopting innovative teaching tools in TVET to address challenges in traditional methods and better align with industry needs. The results of this study underscore the potential of such interventions to transform technical education and ensure the readiness of students for real-world applications.

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