MJP Journal of Education and Teaching Learning
Vol.4, No.1 (2026): 29– 35
https://jurnalilmiah.co.id/index.php/MJPJETL

Swansoft Simulator Video Tutorial as Digital Media for Basic Computer Numerical Control Learning

[1] Amelia Dini Wulandari, [2] Marsono, [3] Puteri Ardista Nursisda Mawangi

[1,2,3] Departement of Mechanical Engineering Education, Faculty of Engineering, State University of Malang

*** Correspondence Author: marsono.ft@um.ac.id; + 62 857-7194-XXXX**

Article Info

Keywords:

CNC Simulator; Learning Media; N-Gain; Video Tutorial; Vocational Education

ABSTRACT

Basic CNC learning in vocational high schools faces challenges including limited practical facilities and low student procedural understanding of CNC machine programming. This study aims to analyze the effect of Swansoft CNC Simulator-based video tutorial media on improving student cognitive learning outcomes. The research employed a one-group pretest-posttest quasi-experimental design. The research subjects consisted of 10 students in grade XI of the Machining Engineering program at SMK Muhammadiyah 1 Malang City, selected through purposive sampling. Data were collected through cognitive tests (30 multiple-choice items based on Bloom's Revised Taxonomy covering C1–C5 levels) and analyzed using paired samples t-test. The results showed a statistically significant improvement in student learning outcomes ($t(9) = -2.674$, $p = 0.025$, Cohen's $d = 0.99$), with a mean score increase from 73.60 (SD = 7.20) on the pretest to 81.30 (SD = 8.25) on the posttest, yielding a mean normalized gain (N-Gain) of 0.29 (low-moderate category). These findings indicate that simulation-based video tutorial media integrating visual and auditory channels effectively enhances conceptual understanding and programming accuracy in CNC machining. This study concludes that Swansoft CNC Simulator-based video tutorial media is effective as an instructional alternative for Basic CNC courses at the vocational secondary school level.

Informasi Artikel

Kata Kunci:

CNC Simulator; Learning Media; N-Gain; Tutorial Video; Sekolah Kejuruan

ABSTRAK

Pembelajaran dasar CNC di sekolah menengah kejuruan menghadapi berbagai tantangan, termasuk keterbatasan fasilitas praktik dan rendahnya pemahaman siswa mengenai prosedur pemrograman mesin CNC. Penelitian ini bertujuan untuk menganalisis pengaruh media tutorial video berbasis Swansoft CNC Simulator terhadap peningkatan hasil belajar kognitif siswa. Penelitian ini menggunakan desain kuasi-eksperimental pretest-posttest satu kelompok. Subjek penelitian terdiri dari 10 siswa kelas XI jurusan Teknik Pemesinan di SMK Muhammadiyah 1 Kota Malang, yang dipilih melalui purposive sampling. Data dikumpulkan melalui tes kognitif (30 soal pilihan ganda berdasarkan Taksonomi Revisi Bloom yang mencakup tingkat C1–C5) dan dianalisis menggunakan uji t sampel berpasangan. Hasil menunjukkan peningkatan yang signifikan secara statistik pada hasil belajar siswa ($t(9) = -2,674$, $p = 0,025$, Cohen's $d = 0,99$), dengan peningkatan skor rata-rata dari 73,60 (SD = 7,20) pada pretest menjadi 81,30 (SD = 8,25) pada posttest, menghasilkan gain normalisasi rata-rata (N-Gain) sebesar 0,29 (kategori rendah-sedang). Temuan ini menunjukkan bahwa media tutorial video berbasis simulasi yang mengintegrasikan saluran visual dan auditori secara efektif meningkatkan pemahaman konseptual dan akurasi pemrograman dalam pemesinan CNC. Studi ini menyimpulkan bahwa media tutorial video berbasis Swansoft CNC Simulator efektif sebagai alternatif instruksional untuk mata pelajaran Dasar CNC di tingkat sekolah menengah kejuruan.

Article History

Received : 15/03/2026
Revised : 28/04/2026
Accepted : 21/07/2026

✉ ***Corresponding Author:*** (1) Marsono, (2) Departement of Mechanical Engineering Education (3) Faculty of Engineering, Malang University (4) Jl. Cakrawala No.5, Sumbersari, Kec. Lowokwaru, Malang, East Java, 65145, Indonesia, (5) Email: marsono.ft@um.ac.id

1. Introduction

Vocational education in Indonesia serves a critical function in producing industry ready graduates, yet a persistent gap remains between the competencies of graduates and the demands of modern manufacturing [1]. Central Bureau of Statistics (2025) data indicate that over 5.3 million students are enrolled across 14,456 vocational high schools nationwide; however, the quality of CNC machining competency among graduates remains a concern, as CNC technology has become the standard in contemporary industrial production. Within the Basic CNC course, students at SMK Muhammadiyah 1 Malang City currently rely on conventional teacher-demonstration methods and limited direct machine practice, resulting in insufficient exposure to CNC programming procedures and heightened risk of operational errors (Putra, 2025) [2]. Limited access to real CNC machines owing to high acquisition costs, safety risks during early-stage learning, and unfavorable student to machine ratios further restricts opportunities for independent skill development.

Prior studies have explored simulation-based and video-based approaches to address these limitations. Suyetno in his research demonstrated that CNC simulator use at Universitas Negeri Malang improved student learning outcomes with a mean score increase from 68.5 to 78.3 [3], alongside with [4] who similarly found that CNC simulators enhanced learning flexibility and outcomes at SMKN 1 Bukittinggi by enabling repeated practice and independent error correction. From the video tutorial perspective, [5] reported that video tutorial media significantly raised achievement at SMKN 1 Batusangkar, with the experimental group averaging 85.4 compared to 76.8 in the control group. Despite these promising results, no study to date has specifically examined the integrated use of Swansoft CNC Simulator combined with video tutorial media a structured, audiovisual approach that can systematically guide students through complex CNC programming procedures in a Basic CNC course at the vocational secondary school level.

The novelty of the present study lies in its focus on the combined deployment of Swansoft CNC Simulator and structured video tutorial media as an integrated instructional medium, grounded in [6] Cognitive Theory of Multimedia Learning. Swansoft Simulator replicates actual CNC machine control panels in a virtual environment, and when paired with procedural video narration, it activates both the visual and auditory cognitive channels, enabling deeper encoding of programming concepts without the risks and costs of real machine operation [7], [8].

This study therefore aims to analyze the effectiveness of Swansoft CNC Simulator-based video tutorial media on improving cognitive learning outcomes in the Basic CNC course for Grade XI Machining Engineering students at SMK Muhammadiyah 1 Malang City. The findings are intended to provide empirical evidence supporting the adoption of simulation integrated video tutorial media as a practical, technology-based alternative in vocational CNC instruction particularly for schools constrained by limited machine availability.

2. Research Method

This research used a quantitative approach with a one-group pretest-posttest quasi-experimental design. This design was chosen because the research population consisted of only one intact class group, making the formation of a separate control group unfeasible [9], [10]. This design is appropriate for measuring the effectiveness of an instructional intervention by comparing results within the same group before and after treatment [11].

The research population consisted of all grade XI students in the Machining Engineering program at SMK Muhammadiyah 1 Malang City for the 2024/2025 academic year, totaling 13 students. The sample of 10 students was selected using purposive sampling. This technique was chosen because: (1) students were already grouped into one intact class, making pure randomization impractical; (2) all students shared equivalent academic backgrounds; and (3) practical considerations related to the learning schedule and availability of facilities. The remaining three students were absent during data collection sessions and were therefore excluded.

The research was conducted over six weeks with the following stages: (1) preparation: development and validation of research instruments; (2) pretest: students were given an initial cognitive test; (3) treatment: all students used Swansoft Simulator based video tutorials over five meetings (4 lesson hours each) as the primary learning medium; (4) posttest: students were given a final cognitive test using the same instrument as the pretest.

The cognitive instrument consisted of 30 multiple-choice items measuring students' mastery of Basic CNC concepts. Items were developed based on Bloom's Revised Taxonomy [12] with the distribution of cognitive levels as presented in Table 1.

Tabel 1. Blueprint of Cognitive Learning Outcome Test

No.	Basic Competency	Item Indicator	Cognitive Level	Items (n)	Item Numbers	% Weight
1	Types and functions of CNC machines	Identify CNC machine types and their functions	C1	4	1–4	13.3%
2	G and M code functions	Explain G00, G01, G02, G03 and common M codes	C2	6	5–10	20.0%
3	CNC setup and coordinate procedures	Perform G54 setup, tool selection, and machining parameters	C3	6	11–16	20.0%
4	Basic CNC programming logic	Create programs for facing, turning, and chamfering	C3	6	17–22	20.0%
5	Identifying syntax errors in CNC programs	Detect and correct errors in given CNC codes	C4	5	23–27	16.7%
6	Evaluating CNC program efficiency	Select the most efficient program for a given output	C5	3	28–30	10.0%

Prior to use, the instrument underwent content validity review by two subject matter experts and one measurement expert. Item reliability was assessed using Cronbach's Alpha, yielding a coefficient of 0.78, which indicates acceptable reliability for research purposes [13].

Data analysis was conducted in two stages. First, descriptive statistics (mean, standard deviation) and score category distribution were computed for both pretest and posttest. Second, the normalized gain (N-Gain) was calculated for each student using the formula: N-Gain = (posttest score pretest score) / (maximum score pretest score), following Hake (1999), to measure the effectiveness of the intervention independently of initial ability levels. N-Gain categories are: high (≥0.70), moderate (0.30–0.69), and low (<0.30). Finally, a paired samples t-test was conducted with significance level $\alpha = 0.05$, and effect size was quantified using Cohen's d to assess the practical significance of the findings. The research hypothesis was H_1: there is a statistically significant improvement in student learning outcomes after the use of Swansoft CNC Simulator-based video tutorial media.

3. Result and Discussion

3.1. Individual Student Score Data

Table 2 presents the complete pretest and posttest scores of all 10 students, along with gain scores and normalized gain (N-Gain) values.

Table 2. Individual Pretest, Posttest, Gain, and N-Gain Scores

No.	Student	Pre-test	Post-test	Gain	N-Gain
1	Student 1	60	70	+10	0.25
2	Student 2	65	85	+20	0.57
3	Student 3	70	75	+5	0.17
4	Student 4	75	92	+17	0.68
5	Student 5	80	88	+8	0.40
6	Student 6	83	69	−14	−0.82*
7	Student 7	72	76	+4	0.14
8	Student 8	73	83	+10	0.37
9	Student 9	80	90	+10	0.50
10	Student 10	78	85	+7	0.32
	Mean	**73.60**	**81.30**	**+7.70**	**0.29**
	SD	7.20	8.25	—	—
	Highest	83	92	—	—
	Lowest	60	69	—	—

**Student 6 excluded from N-Gain mean calculation (negative gain); N-Gain mean computed for 9 students showing improvement.*

3.2. Score Category Distribution

Table 3 presents the distribution of student scores based on achievement categories before and after treatment.

Table 3. Score Category Distribution Before and After Treatment

Category	Range	Pre-test (n)	Pre-test (%)	Post-test (n)	Post-test (%)	Change
Very Good	≥85	0	0%	3	30%	+3 students
Good	75–84	5	50%	5	50%	Stable
Fair	65–74	4	40%	2	20%	−2 students
Poor	<65	1	10%	0	0%	−1 student
Total	—	**10**	100%	**10**	100%	—

Table 3 reveals a notable positive shift in the score distribution following the intervention. The proportion of students in the "Very Good" category increased from 0% to 30%, while the "Poor" category was completely eliminated in the posttest. The "Fair" category decreased from 40% to 20%, reflecting an upward migration of students toward higher achievement levels.

3.3. Descriptive Statistics

Table 4 provides an overview of the average student learning outcome scores before and after treatment, based on descriptive statistical analysis.

Table 4. Paired Samples Descriptive Statistics

Indicator	N	Mean	Standard Deviation	Std. Error Mean
Pre-test	10	73.60	7.199	2.276
Post-test	10	81.30	8.247	2.608

Based on Table 4, the average student learning outcome score increased after the implementation of Swansoft CNC Simulator-based video tutorial media. The pretest mean score of 73.60 (SD = 7.20) increased to 81.30 (SD = 8.25) in the posttest. The Paired Samples Correlations result shows a correlation value of 0.311 (p = 0.382), indicating a weak non-significant linear relationship between pretest and posttest scores. This condition does not affect the validity of the paired t-test, as the analysis focuses on the significance of the mean difference rather than the correlation between scores [14].

3.4. Normalized Gain (N-Gain) Analysis

To assess the effectiveness of the intervention beyond mere statistical significance, the normalized gain (N-Gain) was computed for each student. The mean N-Gain of 0.29 (for the nine students who demonstrated improvement) falls in the "low" category according to [15] classification (<0.30), approaching the boundary of the moderate category (0.30–0.69). This finding suggests that while the intervention produced a statistically significant improvement, the magnitude of learning gain was modest, which may be partially attributable to the short intervention duration (five meetings) and the small sample size. Future studies with longer treatment periods and larger samples are recommended to further evaluate the effectiveness of this media.

3.5. Paired Samples t-test and Effect Size

To determine whether the increase in learning outcomes was statistically significant, a paired samples t-test was conducted. Prior to the test, the normality of difference scores was verified using the Shapiro-Wilk test (W = 0.891, p = 0.178), confirming that the assumption of normality was met. The t-test results are presented in Table 5.

Table 5. Paired Samples t-test Results and Effect Size

Comparison	Mean Difference	t-value	df	Sig. (2-tailed)	Cohen's d
Pre-test – Post-test	−7.700	−2.674	9	0.025	0.99 (Large)

Based on Table 5, a significance value (Sig. 2-tailed) of 0.025 was obtained, which is smaller than the significance level of 0.05. Thus, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted. This means there is a statistically significant difference between learning outcomes before and after the use of Swansoft CNC Simulator-based video tutorial media.

The effect size was calculated using Cohen's d formula: $d = M_2 - M_1 / SD_{pooled}$, yielding d = 0.99, which falls in the "large" effect size category according to Cohen's (1988) benchmarks ($d \geq 0.80$) [16]. This indicates that the practical significance of the intervention is substantial: the video tutorial treatment produced a difference of approximately one standard deviation in student learning outcomes. However, the large effect size should be interpreted with caution given the small sample size (n = 10), as effect size estimates tend to be inflated in small samples [17].

3.6 Discussion

This study was designed to test the hypothesis that a statistically significant improvement exists in student cognitive learning outcomes before and after the implementation of Swansoft CNC Simulator based video tutorial media. The results of the paired samples t-test yielded $t(9) = -2.674$ with $p = 0.025$, confirming that the intervention produced a statistically significant improvement. The mean score increased from 73.60 to 81.30 (mean difference = 7.70 points), with a large effect size (Cohen's d = 0.99), providing both statistical and practical evidence of the media's effectiveness in enhancing student learning outcomes in Basic CNC instruction.

These findings are consistent with [18], who demonstrated that the integration of Swansoft Simulator into CNC practical learning significantly enhanced student learning engagement. Their study revealed that the simulator created a more dynamic and active learning environment by allowing students to operate CNC machines virtually, thereby eliminating the risks associated with direct machine operation during the early stages of learning. This aligns closely with conditions observed in the present study, where Grade XI students at SMK Muhammadiyah 1 Malang City were able to engage in guided, audiovisual supported simulation experiences that systematically strengthened their procedural understanding of CNC programming.

The present findings are also in agreement with [4], who concluded that CNC simulators effectively improved student learning outcomes in NC/CNC Machining Technology and CAM instruction at SMKN 1 Bukittinggi. That study highlighted that simulators provide substantially higher learning flexibility compared to direct machine practice, particularly with respect to the repetition of exercises and independent error correction. This characteristic is especially relevant in the current research context, where the video tutorial format allowed students to revisit specific operational procedures as needed, accommodating individual differences in learning pace and prior knowledge.

From the perspective of video-based instructional media, the results of this study are strongly supported by Marshanada et al. [5], who demonstrated that video tutorial media significantly improved student achievement at SMKN 1 Batusangkar, with the experimental group achieving a mean score of 85.4 compared to 76.8 in the control group. Their study affirmed that video tutorial media possesses distinctive advantages in conveying procedural content, as it is capable of simultaneously presenting step by step operations through both visual and auditory channels a characteristic particularly pertinent to Basic CNC instruction, which is rich in technical procedures such as zero point calibration, tool selection, and G-code programming sequences.

This outcome can be further explained through [6] Cognitive

Theory of Multimedia Learning, which posits that learning is more effective when information is delivered through an integrated combination of visual and auditory stimuli. The Swansoft CNC Simulator video tutorials employed in this study effectively engaged both channels: the animated CNC simulation sequences addressed the visual channel, while the accompanying procedural narration addressed the verbal channel. This dual-channel engagement facilitated more efficient information processing and the construction of stronger cognitive schemas among students, consistent with findings by [8] on animated video media.

The self-paced learning affordance inherent in video tutorial media further contributed to the observed learning gains. As documented by [7], a key pedagogical advantage of this format is its accessibility for independent review outside scheduled classroom hours particularly significant in vocational school contexts where students frequently encounter time constraints due to limited CNC machine availability. In the present study, the ability to replay tutorial content enabled students who required additional processing time to consolidate their understanding at their own pace, contributing to more equitable skill acquisition across the cohort.

Notwithstanding the overall pattern of improvement, one student (Student 6) experienced a score decrease from 83 on the pretest to 69 on the posttest. This anomalous result warrants careful consideration. As noted by [10], in quasi-experimental designs, confounding variables including individual health conditions, motivational fluctuations, or situational stressors on the day of assessment may independently influence test performance irrespective of the quality of the instructional intervention. It is therefore unlikely that the observed score decline in Student 6 reflects a deficit in media effectiveness. A more nuanced understanding of this case would require follow-up investigation through individual case analysis or qualitative inquiry.

Several limitations of this study must be acknowledged. First, the small sample size ($n = 10$) and single-school setting limit the generalizability of the findings. Second, the absence of a control group necessitated by the availability of only one intact class precludes definitive causal attributions; the observed gains might be partially attributable to factors such as maturation or test familiarity effects. Third, the study measured only cognitive outcomes; psychomotor performance in actual CNC operation was not assessed. Future research is recommended to employ larger samples across multiple schools, incorporate a control group where feasible, include psychomotor assessment, and conduct qualitative investigations to capture students' lived learning experiences with simulation-based media.

Taken together, the findings of this study provide compelling empirical and theoretical support for the research hypothesis. The integration of CNC simulation with structured video tutorial instruction bridges the gap between limited physical CNC equipment availability and students' need for intensive, repetitive practical training a concern similarly articulated by [19] in their study of CNC milling machine simulation in engineering education. Accordingly, Swansoft CNC Simulator-based video tutorial media is not only statistically effective but also pedagogically meaningful, rendering it a recommended instructional media alternative for Basic CNC courses within the Machining Engineering competency area at the vocational secondary school level.

4. Conclusion

This study examined the effectiveness of Swansoft CNC Simulator-based video tutorial media on cognitive learning outcomes of Grade XI Machining Engineering students at SMK Muhammadiyah 1 Malang City. The findings lead to the following conclusions. First, the use of Swansoft CNC Simulator-based video tutorial media produced a statistically significant improvement in student cognitive learning outcomes ($t(9) = -2.674$, $p = 0.025 < 0.05$, Cohen's $d = 0.99$). The mean score increased from 73.60 to 81.30, representing a mean gain of 7.70 points. Second, the mean normalized gain (N-Gain = 0.29) falls in the low-to-moderate category, suggesting that while the intervention was statistically significant with large practical effect, the overall magnitude of learning gain was modest likely influenced by the limited duration of the intervention and the small sample size. Third, the score distribution shifted positively: the proportion of students in the "Very Good" category increased from 0% to 30%, while the "Poor" category was eliminated, indicating a broader improvement across the cohort. Fourth, the video tutorial format integrating animated CNC simulation with procedural narration effectively supported dual-channel information processing consistent with Mayer's Cognitive Theory of Multimedia Learning, facilitating conceptual understanding that traditional lecture-based methods could not provide. Based on these findings, Swansoft CNC Simulator-based video tutorial media is recommended as a viable and effective instructional media alternative for Basic CNC courses in Machining Engineering programs at the vocational secondary school level. Future research should expand the sample, incorporate a control group, and include psychomotor assessment to provide a more comprehensive evaluation of media effectiveness.

Acknowledgements

The researchers would like to express gratitude to SMK Muhammadiyah 1 Malang City for providing permission and support in conducting this research. Gratitude are also extended to the Teaching Assistance Supervising Lecturer who guided the preparation of this scientific article, as well as the Basic CNC subject teacher and all Grade XI Machining Engineering students who actively participated in this research.

References

[1] Suharno, N. A. Pambudi, and B. Harjanto, "Vocational education in Indonesia: History, development, opportunities, and challenges [Pendidikan vokasi di Indonesia: Sejarah, perkembangan, peluang, dan

tantangan]," *Child. Youth Serv. Rev.*, vol. 115, p. 105092, 2020, doi: 10.1016/j.childyouth.2020.105092.
[2] P. A. N. Putra, "Keterbatasan akses dan infrastruktur dalam keberlangsungan pendidikan vokasional [Limitations of access and infrastructure in the sustainability of vocational education]," *Humanit. J. Hum. Sos. Dan Bisnis*, vol. 3, no. 5, pp. 1202–1207, 2025.
[3] A. Suyetno, "Pengaruh penggunaan simulator CNC terhadap hasil belajar mata kuliah CNC selama masa pandemi COVID-19 di Jurusan Teknik Mesin Universitas Negeri Malang [The effect of using CNC simulator on CNC course learning outcomes during the COVID-19 pandemic in the Mechanical Engineering Department, State University of Malang]," *J. Tek. Mesin Dan Pembelajaran*, vol. 5, no. 1, pp. 7–16, 2022, doi: 10.17977/um054v5i1p7-16.
[4] D. Ardianto, Y. A, N. Helmi, and E. Indrawan, "Efektivitas penggunaan CNC Simulator untuk meningkatkan hasil belajar pada pembelajaran teknik pemesinan NC/CNC dan CAM kelas XI SMKN 1 Bukittinggi [The effectiveness of using CNC Simulator to improve learning outcomes in NC/CNC and CAM machining learning for grade XI at SMKN 1 Bukittinggi]," *J. Vokasi Mek. Vomek*, vol. 3, no. 4, pp. 62–67, 2021, doi: 10.24036/vomek.v3i4.246.
[5] N. Marshanada, E. Elida, K. Kasmita, and E. Anggraini, "Media video tutorial sebagai inovasi pembelajaran pastry: Dampaknya terhadap hasil belajar siswa di SMKN 1 Batusangkar [Video tutorial media as an innovation in pastry learning: Its impact on student learning outcomes at SMKN 1 Batusangkar]," *J. Sos. Hum. Dan Pendidik.*, vol. 4, no. 1, pp. 87–96, 2025, doi: 10.55606/inovasi.v4i1.4190.
[6] R. E. Mayer, *Multimedia learning (2nd ed.) [Pembelajaran multimedia (edisi ke-2)]*. Cambridge University Press, 2009.
[7] B. A. I. Williyana, Y. N. Kholisho, and A. Fathoni, "Pengembangan media pembelajaran berbasis video tutorial interaktif pada mata pelajaran [Development of interactive tutorial video-based learning media in subjects]," *Edumatic J. Pendidik. Inform.*, vol. 2, no. 2, pp. 52–58, 2018, doi: 10.29408/edumatic.v2i2.869.
[8] R. Arianti and I. Wicaksono, "Efektivitas media video animasi materi pemanasan global terhadap aktivitas dan hasil belajar siswa [The effectiveness of animated video media on global warming material toward student activity and learning outcomes]," *J. Pendidik. Fis.*, vol. 5, pp. 1–10, 2020.
[9] D. T. Campbell and J. C. Stanley, *Experimental and quasi-experimental designs for research [Desain eksperimental dan kuasi-eksperimental untuk penelitian]*. Ravenio Books, 2015.
[10] J. R. Fraenkel, N. E. Wallen, and H. H. Hyun, *How to design and evaluate research in education (8th ed.) [Cara merancang dan mengevaluasi penelitian dalam pendidikan (edisi ke-8)]*. McGraw-Hill, 2012.
[11] J. W. Creswell and J. D. Creswell, *Research design: Qualitative, quantitative, and mixed methods approaches (6th ed.) [Desain penelitian: Pendekatan kualitatif, kuantitatif, dan metode campuran (edisi ke-6)]*. SAGE Publications, 2023.
[12] L. W. Anderson and D. R. Krathwohl, *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives [Taksonomi untuk pembelajaran, pengajaran, dan penilaian: Revisi taksonomi Bloom dalam tujuan pendidikan]*. Longman, 2001.
[13] S. Arikunto, *Dasar-dasar evaluasi pendidikan (Edisi 3) [Fundamentals of educational evaluation (3rd edition)]*. Bumi Aksara, 2021.
[14] A. Field, *Discovering statistics using IBM SPSS Statistics (5th ed.) [Memahami statistik menggunakan IBM SPSS Statistics (edisi ke-5)]*. SAGE Publications, 2018.
[15] R. R. Hake, "Analyzing change/gain scores [Menganalisis skor perubahan/peningkatan]." [Online]. Available: https://physics.indiana.edu/~sdi/AnalyzingChange-Gain.pdf
[16] J. Cohen, *Statistical power analysis for the behavioral sciences (2nd ed.) [Analisis kekuatan statistik untuk ilmu perilaku (edisi ke-2)]*. Lawrence Erlbaum Associates, 1988.
[17] D. Lakens, "Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs [Menghitung dan melaporkan ukuran efek untuk mendukung akumulasi ilmu: Panduan praktis untuk uji-t dan ANOVA]," *Front. Psychol.*, vol. 4, p. 863, 2013, doi: 10.3389/fpsyg.2013.00863.
[18] H. Abizar, Moh. Fawaid, S. Nurhaji, and A. R. Pambudi, "Efektivitas pembelajaran praktik CNC menggunakan Swansoft Simulator pada keaktifan belajar siswa [The effectiveness of CNC practical learning using Swansoft Simulator on students' learning activeness]," *Taman Vokasi*, vol. 8, no. 1, p. 36, 2020, doi: 10.30738/jtv.v8i1.7619.
[19] E. L. Valvo, R. Licari, and A. Adornetto, "CNC milling machine simulation in engineering education [Simulasi mesin milling CNC dalam pendidikan teknik]," *Int. J. Online Biomed. Eng. IJOE*, vol. 8, no. 2, pp. 33–38, 2012, doi: 10.3991/ijoe.v8i2.2047.