

IMPLEMENTATION OF PROJECT-BASED LEARNING MODEL ON LEARNING OUTCOMES IN DRAWING HEXAGONS AT SMK MUHAMMADIYAH 2 SEMARANG.

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ABSTRACT

This study examines the effect of the Project-Based Learning (PjBL) model on students' learning outcomes in technical drawing, specifically hexagon construction, at SMK Muhammadiyah 2 Semarang. A quantitative experimental method with a pretest-posttest control group design was employed, involving two intact classes selected through cluster random sampling. The PjBL model was implemented through stages of problem identification, project planning, execution, and presentation. Data were collected using a psychomotor performance test assessed with a validated rubric. Instrument validity was measured using Aiken's V and Content Validity Index (CVI), while reliability was determined using the Intraclass Correlation Coefficient (ICC). Data analysis included normality and homogeneity tests, followed by an independent samples t-test and effect size analysis using Cohen's d. The results showed no significant difference in pretest scores ($p = 0,842 > 0,05$), indicating equivalent initial abilities. However, posttest results revealed a significant difference ($p = 0,0001 < 0,05$), with the experimental class achieving a higher mean score (82,32) than the control class (73,60). The effect size ($d = 1,78$) indicates a very large effect. These findings demonstrate that PjBL is highly effective in improving students' psychomotor learning outcomes in technical drawing.

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INTRODUCTION

Vocational education plays a crucial role in preparing a skilled workforce that meets industrial demands. Vocational High Schools (SMK), particularly in mechanical engineering programs, are expected to produce graduates who not only understand theoretical concepts but also demonstrate strong practical competencies. In this context, technical drawing becomes a fundamental skill, as it serves as a universal medium of communication in design and manufacturing processes (Azizah Hasan, 2024; Fadilah et al., 2019; Suri & Nuryanto, 2023). The mastery of technical drawing requires a combination of conceptual understanding, accuracy, and psychomotor skills (Amirullah et al., 2025; Baharudin et al., 2025). One essential component within this subject is a hexagon construction, which is widely

applied in mechanical elements such as bolts and nuts (Fuat et al., 2025). Consequently, students must be able to construct hexagons accurately through proper geometric procedures (Putri et al., 2024; Supriadi et al., 2023).

Despite its importance, empirical conditions indicate that students' competence in hexagon drawing remains relatively low. Preliminary observations at SMK Muhammadiyah 2 Semarang show that only 46% of students achieved the minimum mastery criterion ($KKM \geq 75$). This finding suggests that students encounter difficulties not only in understanding geometric concepts but also in applying procedural steps with precision. Such conditions reflect a gap between expected competencies and actual learning outcomes, particularly in the psychomotor domain, which is essential in vocational education (Ariyanto et al., 2019; Ramadani et al., 2024).

This problem is closely associated with the instructional approaches commonly used in the classroom. Technical drawing instruction is still largely dominated by conventional methods, such as lectures and individual exercises, which tend to position students as passive recipients of information. As a consequence, learning becomes less engaging and does not provide sufficient opportunities for students to actively construct knowledge or develop procedural skills. Previous studies have consistently shown that such approaches are less effective in improving spatial understanding and technical drawing performance Fitri et al., 2025; Nurhamidah & Nurachadijat, 2023). Therefore, there is a need for an instructional model that emphasizes active learning and integrates conceptual understanding with practical application.

In response to this need, Project-Based Learning (PjBL) offers a promising alternative. PjBL emphasizes learning through meaningful projects that require students to actively engage in problem solving processes (Krajcik & Blumenfeld, 2005; Thomas, 2000). In the context of hexagons using appropriate tools and techniques, and presenting the final product. Through this process, students are not only required to understand geometric concepts but also to apply them in a systematic and precise manner. Previous research has demonstrated that PjBL can improve students' engagement, technical competence, and conceptual understanding in vocational education settings (Amri et al., 2025; Nur Cahyo & Marsono, 2024).

However, although the effectiveness of PjBL has been widely reported, most existing studies tend to focus on general technical competencies or broad geometry learning. Research that specifically examines the application of PjBL in technical drawing tasks requiring high procedural accuracy such as hexagon construction remains limited. In addition, few studies have employed a rigorous experimental design to compare the effectiveness of PjBL with conventional methods, particularly in measuring psychomotor learning outcomes. This gap indicates the need for a more focused and methodologically robust investigation.

Based on these considerations, this study offers a distinct contribution by focusing on the application of PjBL in hexagon construction tasks, integrating conceptual understanding with psychomotor performance, and employing a quantitative experimental approach using a pretest-posttest control group design. Accordingly, this study aims to examine the implementation of the project based learning model on students' learning outcomes in technical drawing, specifically in hexagon construction, and to evaluate its effectiveness compared to conventional teaching methods at SMK Muhammadiyah 2 Semarang.

METHOD

This study employs a quantitative approach using an experimental method aimed at determining the effect of a specific treatment on other variables under controlled conditions (Sugiyono, 2017). The design applied is the Pretest-Posttest Group Design involving two groups, namely the experimental class and the control class. The experimental class is treated using the Project Based Learning (PjBL) model, while the control class is taught using conventional methods. Measurements are conducted through a pretest to determine initial ability and a posttest to determine final ability, so that the effect of the treatment is analyzed based on differences in learning outcomes between the two groups.

The study is conducted in the second semester of the 2025/2026 academic year at SMK Muhammadiyah 2 Semarang, with the population consisting of all students in classes X TO 3 and X TO 4. The sampling technique used

is intact group sampling, as the selected samples are intact class rather than individual students. Each class consists of 25 students, assigned as the experimental and control groups.

The variables in this study consist of the independent variable, namely the Project Based Learning model, the dependent variable, namely learning outcomes in drawing hexagons, and control variables including learning materials, instructional time, teacher, and test instruments. The implementation of the PjBL model is conducted over four meetings, each lasting 2 x 45 minutes. The learning syntax in each meeting includes: (1) determining project questions, (2) designing project plans, (3) arranging schedules. (4) monitoring project progress, (5) testing results, and (6) evaluating learning experiences.

Data collection techniques include documentation, tests, observation, and interviews (Asdar, 2018). The main instrument is a job sheet-based test used to measure psychomotor learning outcomes, assessed using a rubric focusing on drawing accuracy and measurement precision. The assessment rubric includes several indicators: (1) drawing preparation, (2) tool usage accuracy, (3) conformity of hexagon construction steps, (4) measurement precision, and (5) neatness of the final result. Each is scored on a scale of 1-4, where 1 indicates very poor performance and 4 indicates very poor performance.

Instrument validity is tested using content validity through expert judgment with the Aiken index (Aiken, 1980), while reliability is measured using the Intraclass Correlation Coefficient (ICC) with the assistance of SPSS (Ismunarti et al., 2020). In addition, learning media are analyzed using the Content Validity Index (CVI) (Polit & Beck, 2006) and percent agreement to determine inter-rater agreement (Khumaedi et al., 2021).

Data analysis is carried out in initial and final stages. The initial analysis uses an independent samples t-test to determine the equivalence of initial abilities between the experimental and control groups. The final analysis includes measuring psychomotor learning outcomes using a ratio scale, descriptive percentage analysis, and prerequisite tests consisting of normality and homogeneity tests before conducting a t-test to examine differences in mean learning outcomes (Arikunto, 2013).

In addition, learning improvement is calculated using the percentage increase between pretest and posttest scores, which is then categorized into levels ranging from low to very high (Khumaedi et al., 2021). To strengthen the interpretation of treatment effect size is calculated using Cohen's d, which is obtained from the difference between the mean scores of the experimental and control groups divided by the pooled standard deviation. The effect size is interpreted as small ($d < 0,5$), medium ($0,5 \leq d < 0,8$), or large ($d \geq 0,8$).

The results of these analyses are used to determine the effectiveness of the Project Based Learning model in improving students' ability to draw hexagons.

RESULT AND DISCUSSION

Validity and Reliability Results

The validity of the test instrument in this study was analyzed using content validity with the Aiken's v. assessment was carried out by 3 validators, namely lecturers who are experts in technical drawings and subject teachers.

Table 1. Aiken's v validity results

Yes	Assessment aspects	V	Criteria
1	Image shape accuracy	0,89	Valid
2	Measurement accuracy	0,89	Valid
3	Line precision	0,78	Valid
4	Image neatness	0,83	Valid
5	Suitability of the procedure	0,94	Valid

Based on the calculation results, all instruments have an Aiken's v value ≥ 0.75 , it can therefore be concluded that the test instrument used in the study is valid and suitable for measuring student learning outcomes.

Table 2. icc test results

Types of ICC	ICC Value	Criteria
Single measures	0,728	Good
Average measures	0,842	Excellent

Based on the results of the analysis, an ICC (average measures) value of **0,842**. This shows that the level of agreement between validators in assessing test instruments is very high, so that the instrument is declared reliable and can be used in research. Based on the results of the validity and realism test of the test instrument, the test instrument used in this study has met the valid and reliable criteria, so it is suitable to be used to measure the results of students' learning.

Based on the criteria used in this study, the media is declared valid if the I-CVI value ≥ 0.80 .

Table 3. Results of Media Validity Analysis Based on Media Aspects

Statement	Expert Judgment		Total fit	I-CVI
1	5	5	2	1
2	5	5	2	1
3	5	5	2	1
4	5	5	2	1
5	5	5	2	1
6	5	4	1	0,5
7	5	5	2	1
8	5	5	2	1
9	5	5	2	1
10	4	4	0	0
11	5	5	2	1
12	5	5	2	1
13	5	5	1	1
14	4	4	0	0
15	5	5	2	1
Total	73	72	I-CVI Ratio	0,8125

Table 4. The results of the media validity analysis are based on the material aspect

Statement	Expert Judgment		Total fit	I-CVI
Statement	Expert Judgment		Total fit	I-CVI
1	5	5	2	1
2	5	5	2	1
3	5	5	2	1
4	5	5	2	1
5	5	5	2	1
6	4	4	0	0
7	5	5	2	1
8	5	5	2	1
9	5	5	2	1
10	5	5	2	1
11	4	5	1	0,5
12	5	5	2	1
13	5	5	2	1
Total	63	64	I-CVI Ratio	0,885

Remarks: the value of 5 is assumed to be the ordinal scale comtoction which means appropriate, and the value 4 is assumed to be the ordinal scale dichotomization which means inappropriate.

The table above shows that the average value of I-CVI obtained based on the assessment on the media aspect is 0.812, and the assessment on the material aspect is 0.885. This means that from the results of expert assessments both in the media and material aspects, the media is declared valid because is greater than 0,8.

Learning Outcomes in the Realm of Psychomotor

Table 5. Pretest Results

Classes	N	Average	Highest Score	Lowest Score
Experiments	25	55,12	64	46
Controls	25	55,92	63	47

Based on the table above, the average pretest scores of the experimental and control classes are relatively the same. This shows that the initial ability of students in both classes is in equal condition.

Table 6. Posttest Results

Classes	N	Average	Highest Score	Lowest Score
Experiments	25	82,32	92	72
Controls	25	73,60	83	66

It was seen that the average value of the experimental class was higher as compared to the control class.

Analysis Prerequisites Test

Table 7. Normality Test

Classes	Sig.	Remarks
Pretest Experiment	0,200	Normal
Control Pretest	0,200	Normal
Posttest Experiment	0,087	Normal
Posttest Control	0,105	Normal

Based on the table above, all data have a significant value of more than 0.05 so it can be concluded that the data is normally distributed.

Table 8. Homogeneity Test

Classes	Sig.	Remarks
Pretest	0,312	Homogeneous
Posttest	0,228	Homogeneous

Based on these results, it can be concluded that the data has a homogeneous variance.

Hypothesis Test

The hypothesis test was carried out using a two-party t-test.

Table 9. Pretest Hypothesis Test Results

Sig. (2-tailed)	Remarks
0,842	Not signifying

Since the Sig. value > 0.05, H₀ is accepted. There were no significant differences in the initial abilities of students in the experimental and control classes. This shows that both classes have equal initial conditions before being given treatment.

Table 10. Posttest Hypothesis Test Results

Sig. (2-tailed)	Remarks
0,001	Significant

With the Sig. value falling below 0,05, we reject H₀ and accept H_a. This confirms a significant difference in learning outcomes between students in the experimental class and those in the control class. Since the experimental

class's average score exceeds that of the control class, it's safe to conclude that Project-Based Learning positively influences improvements in hexagon drawing performance.

Effect Size Analysis (Cohen's d)

To strengthen the interpretation of the hypothesis testing results, the size was calculated using Cohen's d to determine the magnitude of the influence of the Project Based Learning (PjBL) model on students' learning outcomes.

$$d = \frac{\bar{X}_1 - \bar{X}_2}{S_p}$$

$$S_p = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}}$$

The calculation resulted in Cohen's d = 1.78, which falls into the very large category

Table 11. Effect size results

Variable	Mean experiment	Mean control	Cohen's d	category
Learning outcomes	82,32	73,60	1,78	Very large

This indicates that PjBL has a very strong practical effect on improving students' learning outcomes.

Analysis of Learning Outcomes Improvement

Increments are calculated using the increment percentage formula

Experimental Classes

$$\frac{82,32 - 55,12}{55,12} \times 100\% \approx 49.3\%$$

Category : Medium

Control Class

$$\frac{73,60 - 54,92}{54,92} \times 100\% \approx 34.0\%$$

Category : Medium

Study results revealed that the experimental class experienced greater improvements compared to the control class.

Analysis confirmed that students' starting abilities in both the experimental and control groups were evenly matched, as shown by pretest scores and t-test results with no significant differences. Post-intervention, however, posttest outcomes displayed a clear significant gap, where the experimental class posted higher average scores than the control class. On top of that, learning gains were more substantial in the experimental group. All this leads to the conclusion that the teaching method used in the experimental class outperformed the one in the control class when it comes to boosting student learning outcomes.

The results of the study indicate that the implementation of Project Based Learning (PjBL) can improve learning outcomes in drawing hexagons. This is because PjBL is student-centered and encourages active involvement in the learning process, resulting in deeper conceptual understanding. Furthermore, through hands-on practice and problem-solving, PjBL helps develop psychomotor skills, accuracy, and procedural understanding. The integration of theory and practice in project activities also strengthens students' conceptual understanding and supports the improvement of technical skills and critical thinking.

CONCLUSION

This study confirms that the implementation of the Project Based Learning (PjBL) model significantly improves students' psychomotor learning outcomes in drawing hexagons. The results indicate that both experimental and control groups had equivalent initial abilities, as evidenced by non-significant pretest differences. However, after the intervention, the experimental group demonstrated significantly higher posttest scores and greater learning gains compared to the control group. These findings are consistent with the learning process observed, in which PjBL facilitated active engagement, structured project execution, and deeper procedural understanding.

The findings imply that PjBL is an effective instructional model for vocational education, particularly in technical drawing, as it integrates conceptual knowledge with hands-on practice and enhances accuracy, creativity, and skill mastery.

Nevertheless, the study is limited by the relatively small sample size and short duration of implementation. Future research is recommended to involve broader samples, longer interventions, and expanded variables, including cognitive and affective domains, as well as the integration of digital learning media to strengthen the effectiveness and generalizability of PjBL.

REFERENCES

- Aiken, L. R. (1980). Content Validity and Reliability of Single Items or Questionnaires. *Educational and Psychological Measurement*, 40(4), 955–959. <https://doi.org/10.1177/001316448004000419>
- Amirullah, M., Aswar, & Rahayu, H. (2025). Level Employability Skills Siswa di Sekolah Menengah Kejuruan ditinjau Dari Aspek Kognitif, Afektif, dan Psikomotorik. *Indonesian Journal of School Counseling: Theory, Application, and Development*, 5(1), 32. <https://doi.org/10.26858/ijosc.v5i1.71896>
- Amri, M. A. S., Yadi, F., Ramadhan, A. A., Meldianto, E., Ridho, M. A., & Hardiyansyah, A. (2025). Peningkatan STEM-SKILLS Melalui Project Based Learning pada Materi Roda Gigi. *Jurnal Pendidikan Teknik Mesin*, 12(1), 81–92. <https://doi.org/10.36706/jptm.v12i1.78>
- Arikunto. 2017. *Prosedur Penelitian Suatu Pendekatan Praktik*. Jakarta: PT Rineka Cipta.
- Ariyanto, S. R., Munoto, M., & Muhaji, M. (2019). Development of Psychomotor Domain Assessment Instrument on Brake System Competence in SMKN 1 Jetis Mojokerto. *International Journal for Educational and Vocational Studies*, 1(6). <https://doi.org/10.29103/ijevs.v1i6.1648>
- Asdar. (2018). *Metode Penelitian Pendidikan: Suatu Pendekatan Praktik (Edisi Pertama)*. Azkiya Publishing.
- Azizah Hasan, N. (2024). PENGARUH PEMBELAJARAN PJBL TERHADAP HASIL BELAJAR GAMBAR TEKNIK SISWA KELAS X TKR II SMK N 2 KUPANG. In *Seminar Nasional Pendidikan Teknik Mesin (SENAPTIM): x, No. x*.
- Baharudin, R., Abbas, M. H., Rosli, A. D., Zanal, A., Abd Rahman, M. F., & Che Ani, A. I. (2025). The Correlation Between Students' Cognitive and Psychomotor Performance in an Embedded Systems Course in Electrical Engineering. *Asian Journal of Vocational Education and Humanities*, (6), 56–65. <https://doi.org/10.53797/ajvah.v6i1.8.2025>
- Fadilah, E., Maryono, D., & Wihidayat, E. S. (2019). Implementation of Project-Based Learning Models in 2D and 3D Animation Techniques to Improve Psychomotor Skills and Student Creativity of Class XI Multimedia SMK Negeri 3 Surakarta. *Journal of Informatics and Vocational Education*, 2(1). <https://doi.org/10.20961/joive.v2i1.35748>
- Fitri, H. M., Khaerunnisa, P., Setiawan, E., & Wardoyo, S. (2025). Peningkatan Keterampilan Pra-Vokasional Siswa SMK melalui Project-Based Learning (PjBL): Studi Literatur. *Jurnal Pendidikan Dan Pembelajaran Indonesia (JPPI)*, 5(1), 307–318. <https://doi.org/10.53299/jppi.v5i1.996>
- Fuat, F., Senja, M., & Labh, A. (2025). Exploring Mathematical Creativity in the Crafting of Hex Flange Nuts: Drawing Regular Hexagons. *Journal of Teaching and Learning Mathematics*, 2(2), 122–142. <https://doi.org/10.22219/jtln.v2i2.29600>
- Ismunarti, D. H., Zainuri, M., Sugianto, D. N., & Saputra, S. W. (2020). Pengujian Reliabilitas Instrumen Terhadap Variabel Kontinu Untuk Pengukuran Konsentrasi Klorofil-A Perairan. *Buletin Oseanografi Marina*, 9(1), 1–8. <https://doi.org/10.14710/buloma.v9i1.23924>
- Khumaedi, M., Widjanarko, D., Setiadi, R., & Setiyawan, A. (2021). Evaluating the Impact of Audio-Visual Media on Learning Outcomes of Drawing Orthographic Projections. *International Journal of Education and Practice*, 9(3), 613–624. <https://doi.org/10.18488/journal.61.2021.93.613.624>
- Krajcik, J. S., & Blumenfeld, P. C. (2005). Project-Based Learning. In *The Cambridge Handbook of the Learning Sciences* (pp. 317–334). Cambridge University Press. <https://doi.org/10.1017/CBO9780511816833.020>

- Nur Cahyo, B., & Marsono. (2024). Pengembangan Lembar Kerja Peserta Didik (LKPD) Materi Gambar Teknik Manufaktur Berbasis Project Based Learning (PJBL) di SMK Negeri 6 Malang. *Jurnal Teknik Mesin Dan Pembelajaran*, 7(2), 72–88. <https://doi.org/10.17977/um054v7i1p72-88>
- Nurhamidah, S., & Nurachadijat, K. (2023). Project Based Learning dalam Meningkatkan Kemandirian Belajar Siswa. *Jurnal Inovasi, Evaluasi, Dan Pengembangan Pembelajaran (JIEPP)*, 3(2), 42–50. <http://journal.ainarapress.org/index.php/jiepp>
- Polit, D. F., & Beck, C. T. (2006). The Content Validity Index: Are You Sure You Know What's Being Reported? Critique and Recommendations. *Research in Nursing & Health*, 29(5), 489–497. <https://doi.org/10.1002/nur.20147>
- Putri, N., Syahri, B., Refdinal, Adri, J., & Media, A. (2024). Penerapan Pembelajaran Berbasis Proyek dalam Meningkatkan Hasil Belajar Siswa Gambar Teknik Manufaktur. *VOMEK*, 6(1), 51–56.
- Ramadani, A. H., Ekohariadi, Anifah, L., Nugroho, Y. S., & Safitri, R. (2024). Development of Performance Assessment Instruments for Measuring Drawing Skills in Vocational Students Competence in Mechanical Engineering Expertise. *IJORER: International Journal of Recent Educational Research*, 5(2), 268–279. <https://doi.org/10.46245/ijorer.v5i2.551>
- Sugiyono. (2017). *Metode Penelitian Pendidikan: Pendekatan Kuantitatif, Kualitatif, dan R&D*. Alfabeta.
- Supriadi, Eka Putra, M., Maulana, F., Rizky, R., & Fatwa, I. (2023). Peningkatan Hasil Belajar Mahasiswa Menggunakan Model Perkuliahan Problem Based Intruction (PBI) Mata Kuliah Gambar Teknik. *Jurnal Pendidikan Teknik Mesin*, 10(1), 22–30.
- Suri, H. M., & Nuryanto, A. (2023). Implementation of the SMK Manufacturing Engineering Drawing Learning Model in Sleman. *European Journal of Education and Pedagogy*, 4(6), 93–96. <https://doi.org/10.24018/ejedu.2023.4.6.725>
- Thomas, J. W. (2000). *A Review of Research on Project-Based Learning*. <http://www.autodesk.com/foundation>