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ORIGINAL

Development of a Team-Based Experimental Learning (TeBEL) Model to Enhance Higher-Order Thinking Skills in Industrial Product Problem-Solving

Desarrollo de un modelo de aprendizaje experimental basado en el trabajo en equipo (TeBEL) para mejorar las habilidades de pensamiento de orden superior en la resolución de problemas relacionados con productos industriales

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ABSTRACT

The gap between theoretical learning in higher education and the real needs of the manufacturing industry remains a significant challenge in engineering education, particularly in mastering Tool Design competencies. Students generally understand the concepts theoretically, but their analytical, evaluative, and creative abilities for solving industrial design problems are not yet fully developed. This study aims to develop and test the effectiveness of the Team-Based Experimental Learning (TeBEL) learning model in improving students' Higher-Order Thinking Skills (HOTS) through a collaborative and experiential approach. The research method employs a Research and Development (R&D) approach, utilising a 4D model (Define, Design, Develop, and Disseminate). A total of eight validators, comprising academics and industry practitioners, assessed the construct validity, content, and feasibility of the model's implementation, with an average score of 4,8, categorising it as very valid. The effectiveness test involved a control class using conventional methods and an experimental class implementing TeBEL. The results of the Shapiro-Wilk normality test showed a significance value of 0,921 in the control class and 0,175 in the experimental class (both > 0,05), while the Levene test produced a value of 0,610 (> 0,05), so the data were declared homogeneous and met the requirements for parametric testing. The independent t-test showed a significant difference between the two classes (Sig. 0,000 < 0,05), where the experimental class experienced a higher increase in learning outcomes with an average N-Gain of 0,59 (medium-high category) compared to the control class of 0,31. These findings confirm that the TeBEL model is effective in bridging the gap between theory and practice, improving students' analytical, evaluative, and creative abilities, and strengthening the application of collaborative and experiential learning in engineering education. This model has the potential to be replicated in various engineering courses, improving graduates' readiness to face the challenges of the modern manufacturing industry.

Keywords: Cutting Tool; High Order Thinking; Skills; Team-Based Experiment Learning; Tool Design.

RESUMEN

La brecha entre el aprendizaje teórico en la educación superior y las necesidades reales de la industria manufacturera sigue siendo un desafío importante en la formación en ingeniería, en particular en el dominio de las competencias de diseño de herramientas. Si bien los estudiantes generalmente comprenden los conceptos teóricamente, aún no dominan por completo sus habilidades analíticas, de evaluación y creativas para resolver problemas de diseño industrial. Este estudio tiene como objetivo desarrollar y probar la efectividad del modelo de aprendizaje experimental basado en equipos (TeBEL) para mejorar las habilidades de pensamiento de orden superior (HOTS) de los estudiantes mediante un enfoque colaborativo y experimental. La metodología de investigación emplea un enfoque de Investigación y Desarrollo (I+D) con un modelo 4D (Definir, Diseñar, Desarrollar y Difundir). Ocho validadores, entre académicos y profesionales de la industria, evaluaron la validez de constructo, el contenido y la viabilidad de la implementación del modelo, obteniendo una puntuación promedio de 4,8, lo que lo categoriza como muy válido. La prueba de efectividad incluyó un grupo de control que utilizó métodos convencionales y un grupo experimental que implementó TeBEL. Los resultados de la prueba de normalidad de Shapiro-Wilk mostraron un valor de significancia de 0,921 en el grupo de control y de 0,175 en el grupo experimental (ambos > 0,05), mientras que la prueba de Levene arrojó un valor de 0,610 (> 0,05), por lo que los datos se consideraron homogéneos y cumplieron con los requisitos para las pruebas paramétricas. La prueba t de Student para muestras independientes mostró una diferencia significativa entre los dos grupos (p < 0,05), donde el grupo experimental experimentó un mayor incremento en los resultados de aprendizaje, con una ganancia N promedio de 0,59 (categoría media-alta), en comparación con el grupo de control, cuyo valor fue de 0,31. Estos hallazgos confirman que el modelo TeBEL es eficaz para cerrar la brecha entre la teoría y la práctica, mejorando las habilidades analíticas, evaluativas y creativas de los estudiantes, y fortaleciendo la aplicación del aprendizaje colaborativo y experiencial en la educación en ingeniería. Este modelo tiene el potencial de ser replicado en diversos cursos de ingeniería para mejorar la preparación de los egresados para afrontar los desafíos de la industria manufacturera moderna.

Palabras clave: Herramienta de Corte; Pensamiento de Alto Nivel; Habilidades; Aprendizaje Experimental Basado en el Trabajo en Equipo; Diseño de Herramientas.

INTRODUCTION

The Industrial Revolution 4.0 has brought fundamental changes to production systems and work patterns in the manufacturing industry. Automation processes, artificial intelligence integration, and production chain digitisation require a workforce that not only masters technical skills but also possesses higher-order thinking skills (HOTS) such as analysis, evaluation, and creativity in dealing with complex problems.[1,2] HOTS plays a crucial role in data-driven decision-making, process optimisation, design innovation, and enhancing product efficiency and quality.[3,4] Workers with critical and analytical thinking skills can identify the root causes of technical problems, evaluate the feasibility of solutions, and design innovations that are adaptive to technological changes.[5,6]

Conversely, weak higher-order thinking skills have a direct impact on industrial performance, such as poor troubleshooting skills, errors in determining production parameters, and delays in product innovation.[3] Empirical studies demonstrate that problem-solving and critical thinking skills significantly contribute to the productivity and sustainability of the manufacturing industry.[1,4] Therefore, the development of HOTS is a strategic necessity for the industrial world to ensure that the workforce can adapt to technological transformations and contribute to increasing global competitiveness.

Higher education institutions play a strategic role in preparing competent human resources who are adaptable to the needs of modern manufacturing industries. However, various studies show a gap between the academic abilities of engineering students and the competency requirements of industry.[2] Graduates still exhibit limitations in their analytical and problem-solving abilities when confronted with real technical problems, particularly in the design and evaluation of production tools. In courses such as Tool Design, students often struggle to apply theoretical concepts of metal cutting, material selection, and cutting tool design that meet industry needs. Production efficiency is greatly influenced by the quality of design and use of cutting tools, where parameter errors can increase production costs by 20–30 %.[7,8,9]

Limitations in analytical and problem-solving skills suggest that engineering education, which is still dominated by a conventional theory-oriented approach, has not effectively fostered higher-order thinking skills (HOTS) in students. Students tend to learn concepts textually without challenging and reflective experimental experiences. In fact, Experiential Learning has been proven to improve conceptual understanding and critical thinking skills through a cycle of experience-based learning, reflection, and application.[10,11] On the other hand, Team-Based Learning (TBL) is effective in building collaboration, communication, and team responsibility, all of which are crucial in engineering education.[12,13,14]

Most previous studies on Team-Based Learning (TBL) and Experimental Learning (EL) have demonstrated that both approaches hold great potential for enhancing student engagement, performance, and skill mastery in various fields, including physics, medicine, engineering, and mathematics. Several studies conclude that

TBL can encourage collaboration, individual responsibility, and active learning that strengthens conceptual understanding.[15,16] While EL has been proven effective in fostering practical skills and problem-solving through direct experience in laboratories or real projects.[10,17] However, research results also indicate several weaknesses, including low integration between theory and industrial practice, a lack of emphasis on Higher-Order Thinking Skills (HOTS) such as analysis, evaluation, and creation, and the absence of a model that explicitly combines the strengths of TBL and EL in the context of manufacturing engineering education. This study aims to develop and test the effectiveness of the Team-Based Experiment Learning (TeBEL) model in improving Higher Order Thinking Skills (HOTS) of engineering students in the Tool Design course. The novelty of this research lies in the simultaneous integration of Team-Based Learning and Experiential Learning approaches into a single conceptual framework that combines team collaboration, hands-on experimentation, and systematic reflection in the context of industrial design problem solving. The TeBEL model offers a new approach that not only emphasises conceptual understanding but also encourages students to develop analytical, evaluative, and creative skills through authentic learning experiences. Theoretically, this research enriches social constructivism-based learning theory by showing that the synergy between collaboration and experimental experience can significantly improve engineering students' HOTS. Practically, the research results contribute to the development of innovative learning strategies that are relevant to the needs of modern manufacturing industries, supporting graduates' readiness to face the era of smart manufacturing and digital transformation in the world of work.

METHOD

Research Design and Analysis Approach

Research Design

This study employs a research and development (R&D) approach, utilising a 4D development model (Define, Design, Develop, and Disseminate).[18] This model was chosen because it enables the systematic development and validation of learning models tailored to real-world needs in the industrial sector. This model also offers a holistic approach to innovative learning design, ensuring that each stage of development is grounded in empirical data and rigorous evaluation.

Figure 1. The 4D Development Approach for the TeBEL Model

The Define stage focuses on identifying learning needs in the Tool Design course by analysing the gap between students' academic competencies and the demands of the manufacturing industry through literature studies, classroom observations, and interviews with lecturers and industry practitioners. The Design stage then directs the development of a Team-Based Experimental Learning (TeBEL) model, based on experimentation and team collaboration, which integrates real-world industry projects and creates learning tools such as modules, team worksheets, and Higher-Order Thinking Skills (HOTS) evaluation instruments.

The development stage focused on model validation and testing, using an experimental method with a pretest-posttest control group design. This experimental design met the researchers' needs, as both the control class and the experimental class were tested posttest. The aim was to objectively measure the effectiveness of the developed learning model in improving students' higher-order thinking skills. Two classes were randomly selected as comparators and did not refer to any recommendations. The experimental design during model testing is presented in table 1.

Table 1. Model testing experiment design

Group/Class	Pretest	Treatment	Posttest
Experiment	O_1	X (Team-Based Experimental Learning)	O_2
Control	O_3	Y (Existing Learning Model)	O_4

The control class and the experimental class are two different groups of students, but both have the same learning outcomes in accordance with the standards set by lecturers and researchers. The main difference between the two classes lies in the learning model applied during the lecture process. The control class employs conventional learning methods, as commonly used in the Tool Design course. In contrast, the experimental class utilises the Team-Based Experimental Learning (TeBEL) model developed in this study. The Tool Design course was chosen as the research context because it possesses complex and applicable characteristics, including the ability to design, analyse, and optimise cutting tools based on technical parameters of the manufacturing industry. Additionally, this course requires the integration of theoretical knowledge and practical skills in the use of CAD/CAM-based design software, as well as an understanding of the machining process. These characteristics make Tool Design highly relevant for testing the effectiveness of the TeBEL model, which is designed to enhance higher-order thinking skills (HOTS) through team collaboration, experimentation, and project-based problem-solving. The differences in the application of these two learning models were then observed through observation, tests, and evaluations to assess the extent to which the TeBEL model could improve students' analytical, evaluative, and creative competencies in solving industrial cutting tool design problems.

The Disseminate stage focuses on disseminating the results of development through implementation in related study programs and scientific publications, thereby expanding the application of the TeBEL model in engineering education and ensuring its continued impact on improving the quality of learning relevant to the needs of the manufacturing industry.

Research subjects

The subjects of this study were students enrolled in the Mechanical Engineering Education Study Program at the Faculty of Engineering, Yogyakarta State University, who were taking the Tool Design course. This study employed an experimental design with a pre-test and posttest control group, involving two groups: the experimental class and the control class. Each class consisted of 16 students, resulting in a total of 32 research subjects. This sample size was selected based on the available class conditions (intact courses). It was still considered adequate for a two-group pretest-posttest design in educational research, considering that many experimental studies in engineering education use classes of 15–20 participants to detect medium to significant learning effects.[19,20] The study focused on the Team-Based Experimental Learning Model (TeBEL), which was developed to enhance students' higher-order thinking skills (HOTS) in solving problems related to the design and selection of cutting tools in the manufacturing industry. The control class employed conventional learning methods that have been applied in the Cutting Tool Design course. In contrast, the experimental class utilised the TeBEL learning model to compare its effectiveness in enhancing students' higher-order thinking skills.

Data Collection Techniques

This study used a research and development (R&D) approach with a 4D model. The TeBEL model was validated through expert judgment by eight validators representing academics and industry practitioners, namely lecturers teaching Tool Design in Mechanical Engineering at UNY, experts in mechanical engineering education, product design experts, learning evaluation experts, CAD/CAM industry practitioners, industrial tooling engineers, manufacturing production supervisors, and industrial CNC trainers. The experts' assessments covered aspects of model syntax, the relevance of experimental activities, and the integration of theory and practice. The validation results showed a high level of agreement with an inter-rater reliability value of Kappa = 0,8, indicating excellent consistency in assessment.

After being declared feasible, the model was tested for effectiveness using a pretest-posttest control group design. The HOTS test instrument consisted of 12 essay questions developed based on the indicators of analysis, evaluation, and creation, as outlined by Anderson and Krathwohl.[21] Technical education experts assessed content validity. Examples of instrument items included: analysing the factors causing tool wear (analysis), evaluating the effectiveness of two cutting tool designs (evaluation), and designing alternative cutting tools based on process requirements (creation).

Tests were administered before and after the treatment to measure the improvement in students' HOTS. All data collection was conducted during one semester of the 2024/2025 academic year, taking into account research ethics and obtaining participant consent.

Data Analysis Techniques

Data analysis in this study was conducted quantitatively through two main stages: model validation analysis and effectiveness analysis of the TeBEL (Team-Based Experiment Learning) model. In the validation stage, the assessment data from eight validators were analysed descriptively and quantitatively by calculating the average score for each aspect to determine the model's feasibility. Inter-rater reliability was tested using the Intraclass Correlation Coefficient (ICC) based on Kappa values.

During the effectiveness test stage, the pretest and posttest data were analysed using both descriptive and inferential statistics. Descriptive analysis was used to describe the mean values, standard deviations, and range of students' HOTS scores. Normality and homogeneity tests were conducted to ensure that the data met the parametric assumptions. The difference in the increase in HOTS abilities between the experimental and control classes was analysed using a t-test (independent sample t-test) with a significance level of 0,05. The effectiveness of the model was calculated using the N-Gain Score.

RESULTS

The Team-Based Experimental Learning (TeBEL) model was developed through a systematic process, beginning with the preparation and construction of the model, followed by the development and implementation of learning tools, and culminating in testing the model's effectiveness in the classroom. Each stage was designed based on an analysis of the learning needs of Tool Design, which requires higher-order thinking skills, collaborative abilities, and the relevance of design concepts to the needs of the manufacturing industry. The development procedure was carried out in a structured manner to ensure that the TeBEL model not only improves the quality of learning in the classroom but also supports students' readiness to face the challenges of product design and cutting tool design, aligning with industry needs.

Model syntax construction

The Team-Based Experimental Learning (TeBEL) learning model was developed by adopting a project-based and teamwork approach to improve students' Higher-Order Thinking Skills (HOTS). The TeBEL learning syntax consists of seven main stages. This syntax is systematically designed to integrate analysis, collaboration, and reflection activities in Tool Design learning that is relevant to the needs of the manufacturing industry. The following are the seven syntaxes of the TeBEL learning model.

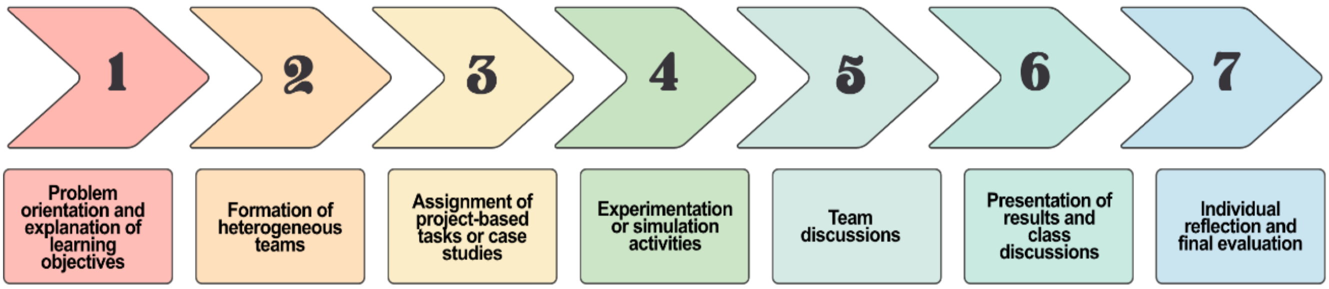

Figure 2. Syntax of the TeBEL Learning Model

Problem orientation and explanation of learning objectives

The initial stages of the Team-Based Experimental Learning (TeBEL) model begin with problem orientation activities and an explanation of learning objectives. At this stage, lecturers present real problems often encountered in the manufacturing industry, such as errors in selecting cutting parameters in the cutter design process. Students are encouraged to understand how minor mistakes in choosing the cutting angle, spindle speed, or type of material can affect production efficiency and results. At this stage, students are guided to develop a critical awareness of the importance of Higher-Order Thinking Skills (HOTS) in solving complex technical problems, while also understanding the connection between the theory learned in class and real-world applications in industry.

Formation of heterogeneous teams

The second stage involves forming a heterogeneous team comprising four to six students with diverse academic backgrounds, practical experience, and interests. The primary objective of this stage is to foster complementary collaboration, where each team member has a distinct role that contributes to the project's success. For example, a student who excels in design theory will complement a teammate who is experienced in workshop practice or Ansys simulation. Through this interaction, students learn to work in teams, develop practical communication skills, and cultivate leadership skills, as well as a sense of shared responsibility in solving industrial problems.

Assignment of project-based tasks or case studies

The third stage focuses on project-based assignments or case studies that require students to apply cutting tool design concepts in situations that resemble real-world industrial conditions. Lecturers provide cutter design scenarios for specific types of materials, with time constraints, production costs, and cutting quality targets. Through this project, students are trained to analyse technical data, evaluate various design alternatives, and create innovative solutions that consider the efficiency and sustainability of the production process. This stage serves as a bridge between academic theory and practical application within the manufacturing industry.

Experimentation or simulation activities

During the experimentation or simulation stage, students test their designs using Ansys laboratory-scale software. This activity provides students with the opportunity to test technical hypotheses, such as the effect of varying cutting angles on cutter wear or the quality of the cut surface. Additionally, students record experimental data, analyse variables that affect tool performance, and evaluate the effectiveness of the design based on the results obtained. Through these activities, students not only learn theoretically but also gain empirical experience that strengthens their skills in analysis, data interpretation, and the application of industrial design principles.

Team discussions

The fifth stage is a team discussion conducted after the experiment or simulation is complete. In this stage, students discuss and analyse the experimental data, compare their findings with the theories they have learned, and formulate the best design solutions based on strong technical arguments. This discussion process trains students to think analytically and evaluatively, consider various points of view, and integrate the contributions of each team member. Thus, this stage becomes a forum for strengthening scientific communication skills, logical reasoning, and cooperation in the context of solving real problems.

Presentation of results and class discussions

The sixth stage involves presenting the results and facilitating class discussions. Each team presents the results of their cutter design along with the technical arguments underlying their design decisions. This activity is followed by cross-team discussions that allow students to provide criticism, suggestions, and constructive feedback on the work of other groups. Through this stage, students develop critical thinking skills, scientific communication skills, and confidence in presenting technical ideas professionally. Lecturers act as facilitators, guiding the discussion to ensure it remains focused on aspects of analysis and design innovation.

Individual reflection and final evaluation

The final stage in TeBEL syntax is individual reflection and final evaluation. Students are asked to write personal reflections on the learning process, obstacles encountered, problem-solving strategies, and new knowledge gained during the project. Lecturers then conduct evaluations using HOTS instruments that cover aspects of analysis, evaluation, and creation to assess improvements in students' higher-order thinking skills. The review is undertaken both formatively and summatively, allowing for comprehensive monitoring of learning outcomes. This reflection stage is essential for fostering students' metacognitive awareness and strengthening meaningful learning that is oriented towards improving competence and readiness to face the challenges of the manufacturing industry.

Assessment Between Model Raters

Table 2. Inter-Rater Reliability Assessment

Validator	Construct	Content	Implementation	Evaluation & Sustainability
Tool Design Lecturer	5	5	4	5
Mechanical Engineering Education Expert	5	5	5	5
Product Design Expert	4	5	4	5
Learning Evaluation Expert	5	5	5	5
Industrial CAD/CAM Expert	4	4	4	5
Industrial Tooling Engineer	4	4	4	4
Manufacturing Production Supervisor	4	4	4	4
Industrial CNC Trainer	5	5	4	5

An inter-validator assessment was conducted using a 5-point Likert scale to evaluate the feasibility of the TeBEL Model in terms of construct validity, content validity, implementation, and potential sustainability. Eight validators were involved, consisting of lecturers in Tool Design, mechanical engineering education experts, product design experts, learning evaluation experts, CAD/CAM practitioners, tooling engineers, manufacturing production supervisors, and industrial CNC instructors. The selection of validators took into account a minimum of five years of professional experience, ensuring that the assessments provided could be academically justified.

As shown in table 2, all validators awarded high scores in almost all aspects, indicating that the model's syntax, guidance clarity, and appropriateness to the cutting tool design needs were considered good. The distribution of scores among validators is visualised in figure 3, which demonstrates the consistency of the assessments despite the experts' diverse backgrounds.

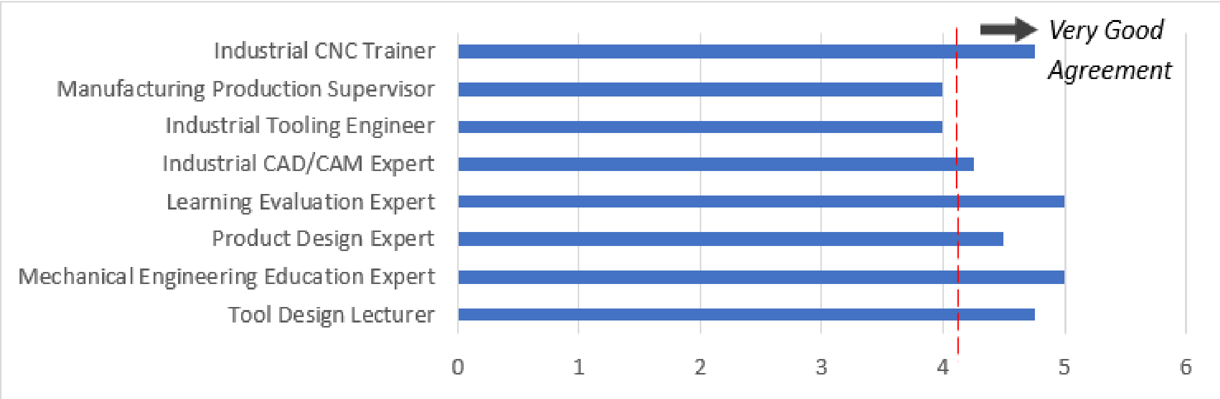

Figure 3. Inter-Rater Assessment

In general, the validators agreed that the TeBEL Model is relevant to the characteristics of modern tool design learning. However, validators from the field of educational technology and learning evaluation noted that the use of interactive digital media and the development of performance assessment instruments need to be strengthened to support long-term implementation.

To ensure quantitative inter-rater consistency, a reliability test was conducted using the Intraclass Correlation Coefficient (ICC) in SPSS. Table 3 presents the results of the ICC analysis.

Table 3. Intraclass Correlation of Antar Rater

	Intraclass Correlation	95 % Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	0,582[a]	0,232	0,876	6,565	7	21	0,000
Average Measures	0,848[c]	0,548	0,966	6,565	7	21	0,000

Based on the results of the inter-rater reliability analysis in table 3, it was found that the validity of the Team-Based Experimental Learning (TeBEL) model was categorised as very good. Based on the Cohen's Kappa value of 0,848, this value exceeded the limit of 0,8, indicating a high level of agreement among validators regarding the quality of the developed model. Eight validators, consisting of academic experts and industry practitioners, provided consistent assessments of the aspects of syntactic systematics, the feasibility of learning tools, the clarity of model usage guidelines, and the potential for sustainable implementation. The analysis results also showed a significance level of 0,000 with a quality measure below 0,05, indicating that there were no significant differences between evaluators in providing evaluations. Thus, the TeBEL model is declared valid and reliable for application in engineering education, particularly in the Tool Design course, to enhance students' higher-order thinking skills.

The above research review shows that expert validators have constructively tested the Team-Based Experimental Learning model. Improvements to each substance in the model were made based on direct suggestions and review notes, ensuring the quality and completeness of the model were validated and ready for implementation in actual classroom conditions.

The Effectiveness of Team-Based Experimental Learning Models in Tool Design Learning

During the implementation stage of the Team-Based Experimental Learning (TeBEL) model, students were assigned a project to design a cutting tool planner that optimises the material cutting process in the

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manufacturing industry. This project was chosen because cutting tools are a key component in the machining process, directly affecting the accuracy, efficiency, and quality of production results. This makes it a learning context highly relevant to industry needs. In addition, the design of a cutting tool planner requires integrative skills in theoretical, analytical, and practical aspects, making it an effective medium for training students' Higher-Order Thinking Skills (HOTS).

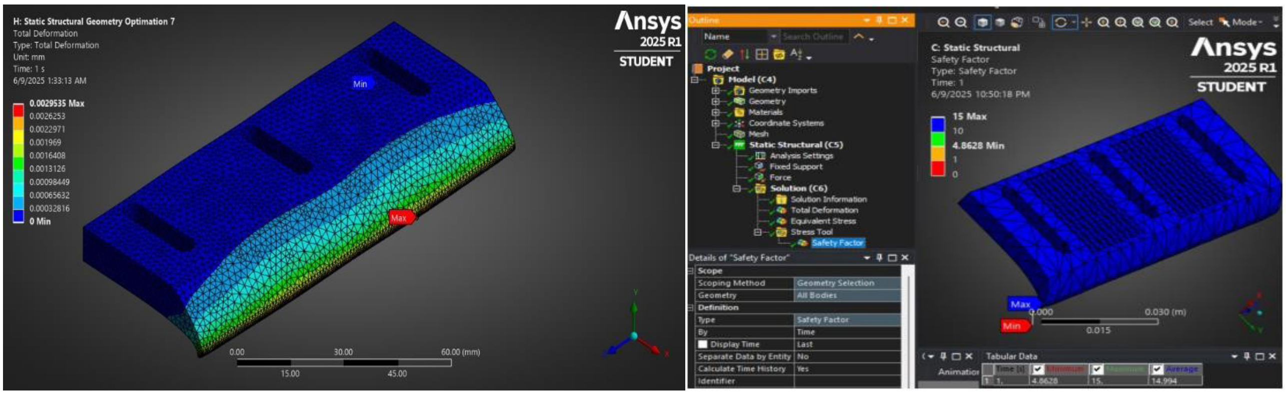

Figure 4. Ansys Simulation of Cutting Tool Design

In its implementation (figure 4), this project integrates design capabilities using CAD software with strength and deformation analysis using ANSYS 2025 R1, as shown in the simulation results image. The static structural test results show a varying distribution of total deformation on the cutting tool surface, with a maximum value of 0,0029535 mm, indicating critical areas for cutting loads. Through this analysis, students can identify weak zones, evaluate structural designs, and make geometric improvements to increase tool rigidity and efficiency. Thus, this project not only provides an authentic experiment-based learning experience but also proves the effectiveness of the TeBEL model in developing students' analytical, evaluative, and creative abilities in line with the demands of the manufacturing industry.

The research results, as shown in the graph, indicate that the average pretest scores between the class using the Team-Based Experimental Learning (TeBEL) model and the control class were at a relatively similar level, around 55, which suggests that the students' initial abilities were equivalent before the treatment was administered. This pretest included analysis, evaluation, and creation questions that assessed students' higher-order thinking skills (HOTS) in the context of cutting tool design, such as analysing cutting parameters, evaluating cutting tool designs, and creating alternative designs based on technical constraints. After implementing the learning model, a posttest with a similar structure and level of difficulty was conducted to measure the improvement in abilities after the learning intervention. The results showed a significant improvement in the TeBEL class, with a posttest average of over 80, while the control class only scored around 68. This difference proves that the TeBEL model is more effective in improving students' abilities than conventional methods. The TeBEL-based learning approach, which emphasises team collaboration, experimentation, and industry-based case projects, has proven to be capable of developing students' analytical, evaluative, and creative skills more deeply, thereby improving conceptual understanding and problem-solving skills in the context of Tool Design relevant to the needs of the manufacturing industry.

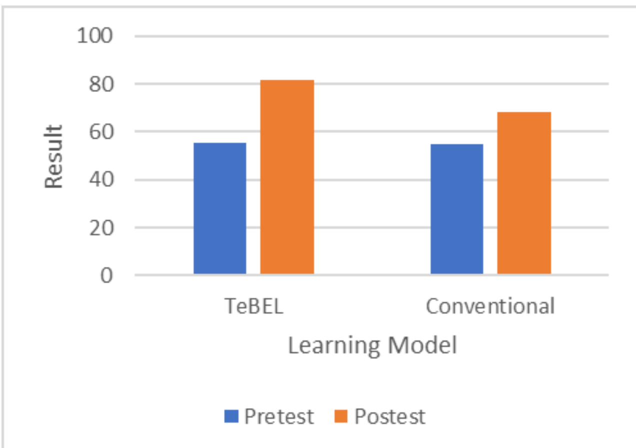

Figure 5. Learning Outcomes of the Pretest and Posttest of the 2 Learning Models Applied

The effectiveness test in this study involved two classes, namely the control class and the experimental class. The control class was a group that used conventional learning methods as commonly applied by lecturers in the Tool Design course. Based on the observation results, learning in the control class tended to be instructional and lecturer-centred, where students followed the steps in the worksheet procedurally without much interaction or analytical discussion. Meanwhile, the experimental class employed the Team-Based Experimental Learning (TeBEL) model, which emphasises team collaboration, experimental activities, and the completion of projects based on real-world industrial cases. Each team of students participated in designing and analysing cutting tools, considering technical parameters and manufacturing process efficiency. All students in both classes received the same material, specifically modelling and designing cutting tools of high complexity. Before testing the effectiveness, the students' learning outcome data were analysed using the Shapiro-Wilk normality test to ensure that the data distribution was normal, as well as an independent t-test to test the homogeneity of variance between groups.

Table 4. Normality Test using Shapiro-Wilk

Groups		Shapiro-Wilk		
		Statistic	**df**	**Sig.**
Result	Group C	0,976	16	0,921
	Group E	0,921	16	0,175

Based on the results of table 4 of the normality test using the Shapiro-Wilk, the Sig. The value for the control class was 0,921, and the significance level was 0,175. The value for the experimental class was 0,175. Since both Sig. Values are greater than 0,05, in accordance with the decision-making basis in the Shapiro-Wilk test, it can be concluded that the student learning outcome data in the control class and experimental class are normally distributed. These results indicate that the data from both groups are suitable for further analysis using parametric tests, allowing for an independent t-test to be performed to identify differences in learning effectiveness between classes using the Team-Based Experimental Learning (TeBEL) model and those using conventional learning methods.

Table 5. Independent Samples Test on Two Test Methods

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95 % Confidence Interval of the Difference**	
									Lower	**Upper**
Result	Equal variances assumed	0,266	0,610	-9,260	30	0,000	-13,2500	1,4309	-16,1722	-10,3278
	Equal variances not assumed			-9,260	28,973	0,000	-13,2500	1,4309	-16,1766	-10,3234

Based on the tabulation results using SPSS in the independent t-test (table 5), the data of both classes were declared homogeneous. This homogeneity can be seen from the significance value of Levene's test, which shows a Sig. value of 0,610, which is greater than the significance level of 0,05. This means that the student learning outcome data in the control class and the experimental class have homogeneous variance, or the same variance. Thus, there is no significant difference in the initial data distribution between the two classes, allowing the parametric test to proceed. The results of the independent sample t-test show a Sig. (2-tailed) value of 0,000, which is less than 0,05. This value indicates a significant difference between the learning outcomes of students in the control class and the experimental class, where the experimental class, which applied the Team-Based Experimental Learning (TeBEL) model, showed higher learning outcomes than the control class that used conventional methods.

The scores obtained indicate that the two research classes will yield different results based on the learning method employed. The differences produced by each class must be aligned based on the mean and standard deviation values. Descriptive data based on the tabulation of the learning outcomes of students in the control class and the experimental class are presented in table 6 below.

Table 6. TeBEL Model Test Results

Class	Average Pretest	Average Posttest	Highest Score	Lowest Score	Standard Deviation	N-Gain	Category
Experiment (TeBEL)	55,2	81,6	92	68	6,8	0,59	Moderate-High
Control (Conventional)	54,7	68,4	84	55	10,2	0,31	Low-Moderate

Referring to table 6, the experimental class experienced an average increase of 26,4 points, accompanied by an increasingly homogeneous data distribution (standard deviation of 6,8). The highest score in this class reached 92, while the lowest score was 68, indicating that the majority of students were able to exceed the minimum competency threshold set. A total of 75 % of students fell into the excellent category, with scores above 80. This shows that the TeBEL model was effective in accommodating variations in students' initial abilities and bringing most participants to a higher cognitive level.

In the control class, the average increase was only 13,7 points with a highest score of 84 and a lowest score of 55. The standard deviation of 10,2 indicates a relatively wide spread of scores, signifying significant and uneven variation in student learning outcomes. Only about 31 % of students managed to achieve scores above 80. This data suggests that conventional methods are less effective in comprehensively improving HOTS.

DISCUSSION

The results of the study indicate that the implementation of the Team-Based Experimental Learning (TeBEL) model significantly improved students' HOTS skills in the Tool Design course. The increase in the average score from 55,2 to 81,6 with an N-Gain of 0,59 (medium-high category), compared to the control class, which only increased from 54,7 to 68,4 with an N-Gain of 0,31, indicates that TeBEL can provide a more collaborative, interactive, and cognitively challenging learning environment than conventional learning. These findings reinforce the view that team-based learning and experimental activities are effective in increasing students' cognitive engagement.

This improvement can be attributed to the core characteristics of TeBEL, which integrate the principles of Team-Based Learning (TBL) and Experiential Learning (EL). The heterogeneous group work structure and hands-on experiments provide students with opportunities to construct knowledge through a learning-by-doing process. This mechanism aligns with social constructivism theory, which explains that team interactions enable students to construct meaning through complex negotiation and exchange of ideas.(22,23) Meanwhile, the Experiential Learning theory emphasises that concrete experience, reflection, conceptualisation, and active experimentation are the foundations of meaningful learning.(10,22,23) The combination of these two approaches explains why the analysis and evaluation indicators in HOTS, according to Anderson and Krathwohl, increased more significantly in the experimental class.(21)

Qualitatively, student responses corroborated the quantitative findings. Students found the learning more challenging and realistic as they analysed design failures, evaluated test data, and collaboratively formulated technical solutions. These activities enabled students to view problems from multiple perspectives, thereby deepening their conceptual understanding and enhancing their critical thinking skills. This aligns with research on experiential learning, which shows that project environments and reflection can increase engagement and HOTS in engineering students.(11,24,25)

The findings of this study also support previous studies, which show that team-based learning can improve critical thinking skills and foster collective responsibility.(26,27) In the context of engineering education, project-based experiments offer students the opportunity to test theories in real-world situations and refine designs based on the results of these tests.(12) This approach is particularly relevant in the context of Tool Design, where the analysis of technical parameters, material selection and cutting tool geometry requires a high level of analytical and evaluative skills.(8,28) Considering that optimal cutting tool design has a significant impact on the production efficiency of the manufacturing industry, HOTS capabilities are a key competency for prospective engineers.(7)

Additionally, the implementation of TeBEL has been demonstrated to support the development of students' metacognitive awareness—the ability to monitor and evaluate their own thinking processes during learning. Metacognition is a crucial component in the development of sustainable HOTS.(29,30) Through cycles of exploration, team reflection, and recontextualization of experimental results into new designs, students develop reflective thinking strategies and more effective problem-solving skills. This mechanism aligns with the concept of experiential labs, which have been proven to improve HOTS and technological literacy in engineering students.(11)

While the results of this study demonstrate strong effectiveness, several limitations exist. The primary limitation is the relatively small sample size, which is drawn from only one course and one institution; therefore, the generalizability of the findings should be approached with caution. Future research is recommended to apply TeBEL to various engineering fields, involve a larger and more diverse sample, and incorporate digital technology or industrial simulation support to enhance the model's relevance in the Industry 4.0 era.

CONCLUSIONS

This study concludes that the application of the Team-Based Experimental Learning (TeBEL) model significantly improves student learning outcomes, particularly in the mastery of Higher-Order Thinking Skills (HOTS), which encompass analytical, evaluative, and creative abilities, as demonstrated in the Tool Design course. This model encourages students to actively collaborate through project-based and experimental learning stages, from problem orientation to individual reflection. The effectiveness test results indicate that the experimental class, which applied TeBEL, achieved higher learning outcomes than the control class that used conventional methods. These findings confirm that a team-based and experimental approach can bridge the gap between theory and practice in engineering education, while increasing student engagement and learning responsibility. Practically, the TeBEL model has the potential to become an innovative learning strategy that can be adopted in various engineering courses. Its application contributes to improving the relevance of the curriculum to industry needs, as well as strengthening the competencies of graduates who are adaptive, creative, and collaborative in the modern manufacturing era.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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