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ORIGINAL

Breaking Grounds in Civil Engineering Education: The Potential of Building Information Modelling Software as Catalyst for Improved Interior Design Learning

Innovando en la enseñanza de la ingeniería civil: el potencial del software de modelado de información de construcción como catalizador para mejorar el aprendizaje del diseño de interiores

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ABSTRACT

The Industrial Revolution 4.0 in the 21st century has necessitated a shift in learning experiences and self-development to adapt to evolving learning mindsets and digital literacy demands. Teachers are encouraged to reduce administrative workloads that are not aligned with the digital age and focus on adopting digital-based learning models and media that suit modern student needs. This study aimed to implement and analyze the impact of case-based projects integrated with Building Information Modeling (BIM) software on civil engineering students' understanding of interior building design. This mixed-methods research utilized a sequential explanatory design. A sample of 60 civil engineering students was selected through random sampling. Quantitative data were analyzed using path analysis, while qualitative data were examined through data reduction, data display, and conclusion drawing/verification analysis. The findings indicate that the case-based project approach, integrated with BIM software, was effectively applied and positively impacted students' skills in learning BIM. Students showed improved abilities to analyze, explore, and synthesize information through hands-on experience with real-world case-based projects. This study contributes a novel educational model by integrating technology with learning methods through case-based projects in BIM software. This innovation supports students in enhancing their analytical and problem-solving skills and aligns with the requirements of the Industrial Revolution 4.0.

Keywords: Building Information Modeling Software; Case-Based Project Method; Building Interior Design Learning.

RESUMEN

La Revolución Industrial 4.0 en el siglo XXI ha hecho necesario un cambio en las experiencias de aprendizaje y el desarrollo personal para adaptarse a las cambiantes mentalidades de aprendizaje y las demandas de alfabetización digital. Se anima a los profesores a reducir las cargas de trabajo administrativo que no están alineadas con la era digital y a centrarse en la adopción de modelos y medios de aprendizaje basados en lo digital que se adapten a las necesidades de los estudiantes modernos. Este estudio tuvo como objetivo implementar y analizar el impacto de los proyectos basados en casos integrados con el software Building Information Modeling (BIM) en la comprensión de los estudiantes de ingeniería civil sobre el diseño de interiores de edificios. Esta investigación de métodos mixtos utilizó un diseño explicativo secuencial. Se seleccionó una muestra de 60 estudiantes de ingeniería civil mediante un muestreo aleatorio. Los datos cuantitativos se analizaron mediante el análisis de trayectorias, mientras que los datos cualitativos se

examinaron mediante la reducción de datos, la visualización de datos y el análisis de extracción/verificación de conclusiones. Los hallazgos indican que el enfoque del proyecto basado en casos, integrado con el software BIM, se aplicó de manera efectiva e influyó positivamente en las habilidades de los estudiantes en el aprendizaje de BIM. Los estudiantes mostraron mejores habilidades para analizar, explorar y sintetizar información a través de la experiencia práctica con proyectos basados en casos del mundo real. Este estudio aporta un nuevo modelo educativo al integrar la tecnología con los métodos de aprendizaje a través de proyectos basados en casos en software BIM. Esta innovación ayuda a los estudiantes a mejorar sus habilidades analíticas y de resolución de problemas y se alinea con los requisitos de la Revolución Industrial 4.0.

Palabras clave: Software de Modelado de Información de Construcción; Método de Proyectos Basados en Casos; Aprendizaje de Diseño de Interiores de Edificios.

INTRODUCTION

In the era of industrial revolution 4.0 there are many changes in the way of teaching and learning such as the content of teaching, the role of teachers and learners.[1] Professional teachers must be aware of and adapt to this development, in addition to the Industrial Revolution 4.0 is a condition in the 21st century which requires learning experience and maturity in dealing with changes in learning mindsets, having digital literacy, continuing to learn new things, taking advantage of opportunities for development for better teaching.[2] Teachers can also consider integrating more current technologies in teaching methodologies.[3,4] Then according to Huda et al.[5], a software engineering expert, identified five future skills that teachers must teach their students to adapt to the millennial civilization. Teachers should no longer immerse themselves in the thicket of administrative paper, which is not a solution to the dynamics of paperless learners. Teachers must be able to present the future to students in the present and must be able to focus on providing challenges, inspirational examples so that they work hard.[6,7]

To assist the learning process in facing the changing era of the industrial revolution 4.0, it is necessary for teachers to choose the right learning model that can be applied in accordance with current changes.[8] Learning models can be used by teachers as plans or patterns to form curriculum, design learning materials and guide learning.[9] Therefore, teachers can choose appropriate and efficient learning models to achieve their educational goals. In addition, it is also necessary to master 4.0 competencies in vocations such as data literacy, technological literacy and human literacy.[10,11]

Problems that occur based on the characteristics of Building Interior Design subjects require the need for student hard skills to be creative and innovative in producing Planning Drawings and being able to solve problems if the results made are not in accordance with industry standards, requiring learning models that require products, requiring procedural and systematic thinking that is poured into Drawing techniques.[12,13] The learning model that is considered relevant to be applied to Building Interior Design subjects is the case-based Project Based Learning (PjBL) learning strategy,[14,15] where the model emphasizes the core of learning activities through projects. In addition, Building Information Modeling (BIM) is one of the software that is suitable as a compliment to this case-based project method.

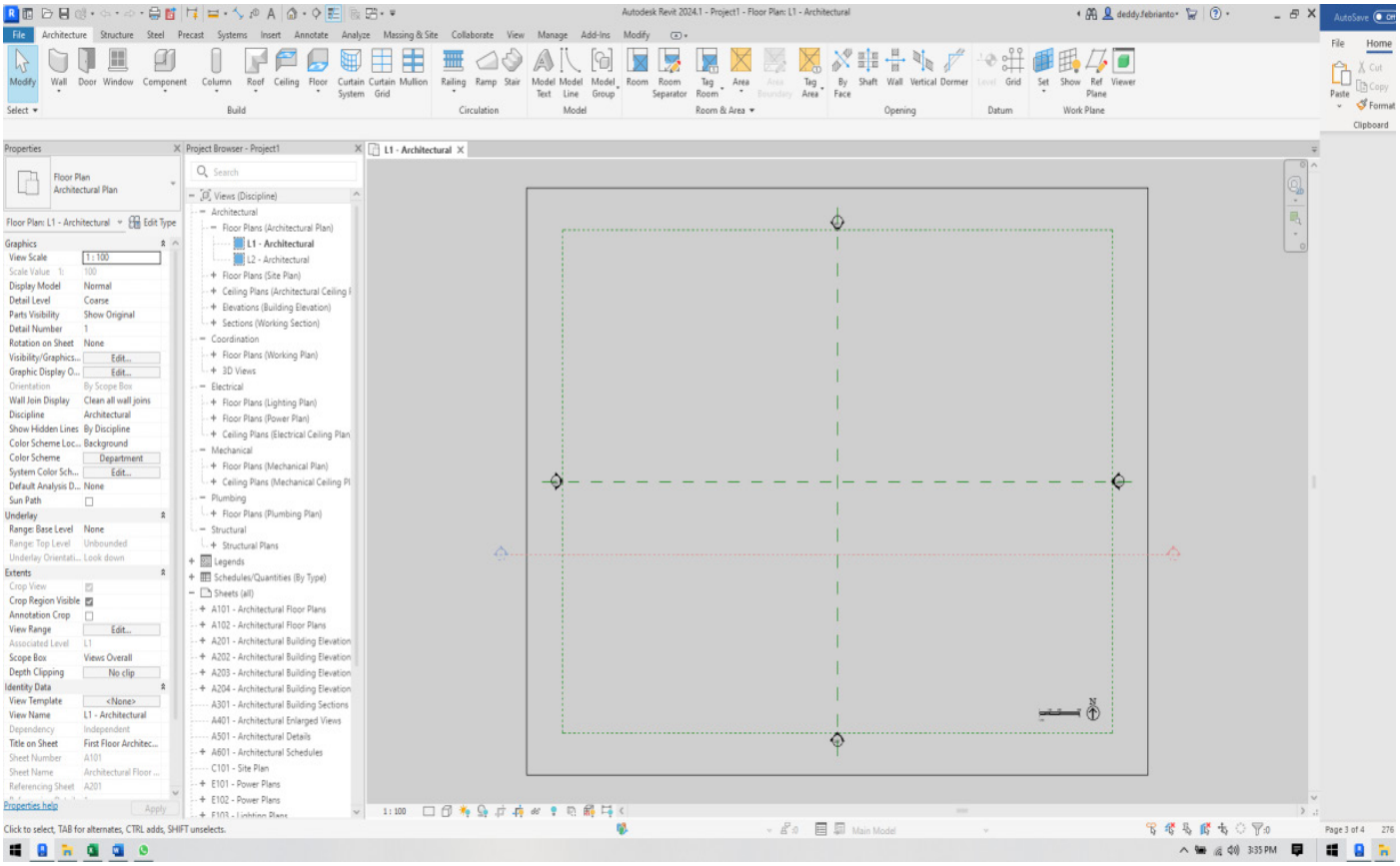
The case-based project method integrated with BIM was chosen because this method can involve students directly in problem-solving activities, and provide opportunities for students to work autonomously to construct their own learning and culminate in producing realistic value student work products using projects (activities) as the core of learning.[16] The novelty of this method is that students can explore, assess, interpret, and synthesize information to obtain various learning outcomes (knowledge, skills, and attitudes), and provide opportunities for students to work autonomously to construct their own learning and culminate in producing realistic value student work products that use projects as learning process activities to achieve attitude, knowledge and skills competencies where the learning emphasis lies in student activities to produce products by applying research skills, analyzing, making, and presenting learning products based on real experiences. So that the purpose of this study is to evaluate the effectiveness of a case-based project method integrated with Building Information Modeling (BIM) software in enhancing students' learning outcomes in Building Interior Design.

Building Information Modeling (BIM) Software

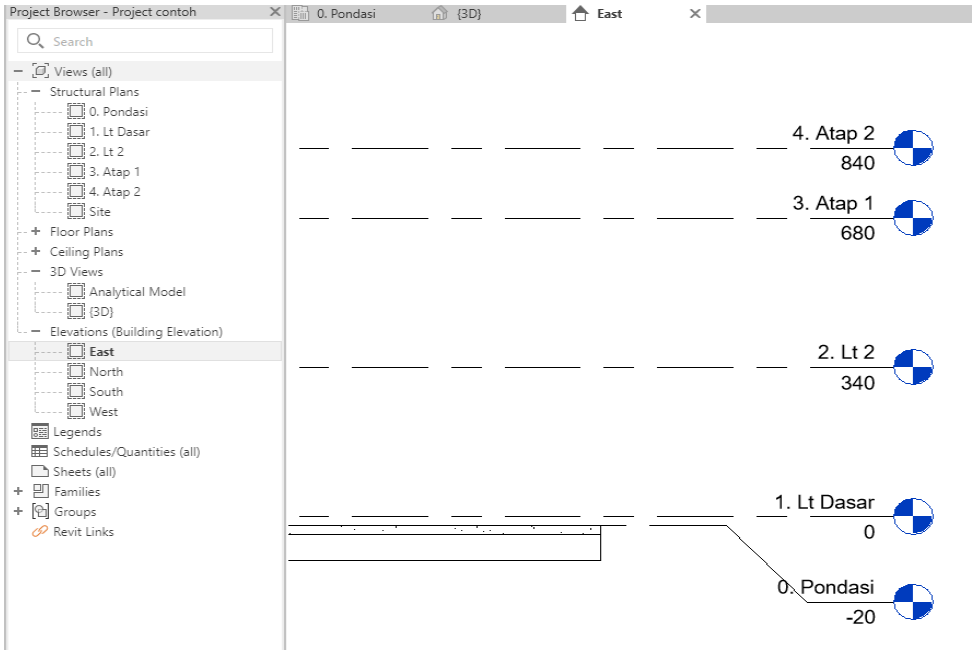
Building Information Modeling (BIM) is a collaborative approach to planning, designing, constructing, and managing buildings and infrastructure. BIM uses specialized software to create detailed 3D models of construction projects. These models include not only visual elements, but also related data such as material specifications, cost estimates, project schedules, and other information relevant to the project lifecycle.[17] The application of BIM concepts through software brings fundamental changes in the way construction

projects are planned, managed, and executed. By utilizing data more efficiently, projects can be executed more accurately, efficiently, and coordinated, resulting in higher quality buildings that satisfy project owners and building occupants.[18]

BIM software enables real-time visualization of construction projects. This helps stakeholders to see and understand the project better before, during, and after construction. These visualizations can also be used for presentations to clients or project owners. By enabling better collaboration, reducing design errors, and enabling more efficient planning, BIM software helps save project time and costs significantly. Design changes and cost calculations can be made quickly and accurately.[19]



(a)



(b)

Figure 1. Building Information Modeling Autodesk Revit Interface (a) and Setting Level (b)

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The BIM software used in this research is Autodesk Revit, Autodesk Revit is one of the most popular Building Information Modeling (BIM) software in the world. Developed by Autodesk, Revit is specifically designed to help construction professionals plan, design, build and manage construction projects efficiently. Revit generates construction documentation automatically based on 3D models. This includes technical drawings, plan drawings, cross sections, and elevations.[19] This automated documentation ensures consistency and accuracy between the model and construction drawings. Autodesk Revit is widely used in the construction industry for large and complex projects such as commercial buildings, housing, shopping centers, and infrastructure. Its use has changed the way construction projects are planned, managed, and executed, enabling greater efficiency and higher quality in the construction of such projects.[20]

Case-Based Project Method

The case-based project method is a discussion-based participatory learning to solve cases or problems. The implementation of this method will sharpen and improve critical thinking skills to solve problems, communication skills, collaboration, and creativity.[21] In the learning process, it is not only the students who learn but also the lecturers and one thing that we must pay attention to is the learning resources. The case method is a discussion-based participatory learning to solve cases or problems.

At the Case Method level, the main issue is the Teaching & Learning method of delivering a subject. It uses real scenarios in the form of case studies.[22] Case Method is able to connect knowledge and action.[23] It was first introduced at Harvard Law and Business School almost a hundred years ago. Given the fact that it proved effective as a Teaching & Learning tool, it was later applied in other educational fields such as medicine, management, nursing, computer science, information systems and telecommunications.[24,25]

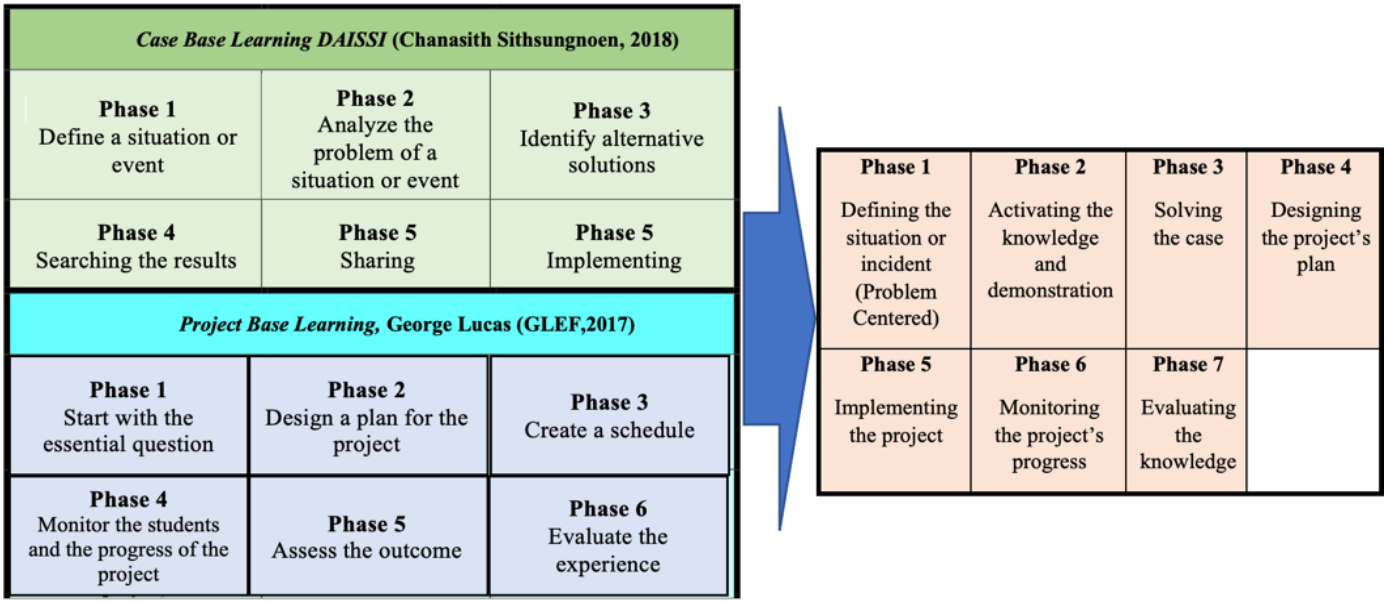

Figure 2. Case-Based Project Method

The application of Case-Based Project Method in providing learning experience will greatly affect the students' acceptance of knowledge and skills. Thus, one of the factors that determine the success of learning is the "involvement" of students "mentally" in the learning process through the opportunity to "experience" certain conditions / situations as they occur (experiential learning). This involvement will make the learning process interesting and relevant for students.[26]

METHOD

Research Type

This type of research is a mix method that uses a sequential explanatory design approach. In this study, quantitative data plays a role in obtaining measurable data that is descriptive, comparative, and associative. Qualitative data plays a role in proving, deepening and expanding the quantitative data obtained.[27] In this study, quantitative data serves to see how much influence Autodesk Rivet Software and Case-Project Method have on building interior design, while qualitative data is to analyze in depth about the influence.

Research Procedures

A series of stages conceptually there are 10 stages that must be taken, but according to the needs of developing a learning model in this study, the research modifies the stage procedure according to what the

researchers will carry out, which concerns the entire process in the research from beginning to end, which is clarified in the following flow.

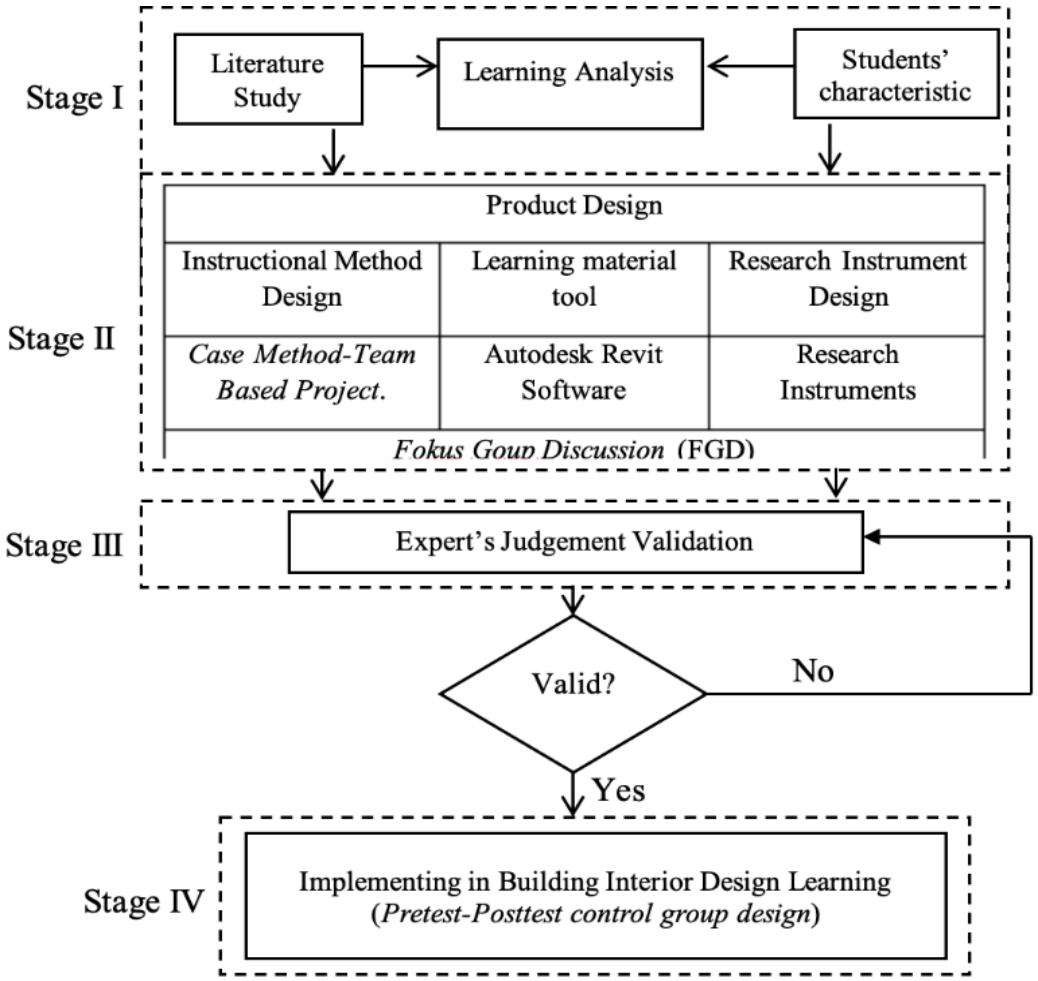

Figure 3. Research Procedures

Research Participants

The population in this study were all students majoring in Civil and Building Engineering who took Interior Building Design learning in West Sumatra Province. The sampling technique used is "Simple Random Sampling", in which all populations have the same opportunity to be sampled because they have the same characteristics. After the preliminary study, 70 students were selected as the sample of this research.

Data Collection Techniques

The data collection techniques used in this research included in-depth interviews, questionnaires, and case-based projects. In-depth interviews were conducted to gather qualitative data on students' experiences and perceptions. Quantitative data were collected through questionnaires, which measured variables such as problem-solving abilities, creative thinking, brainstorming skills, cognitive abilities, and psychomotor skills. Additionally, a case-based project was implemented to assess students' levels of problem-solving, creative thinking, and cognitive and psychomotor abilities following the application of the case-based project method integrated with Building Information Modeling (BIM). The results of the pilot study demonstrated that the questionnaires and case-based project assessments were valid and reliable for use in the data collection process.

Data Analysis Techniques

There are two data analyses used in this study, namely parametric analysis (Table 1) to analyze quantitative data. Meanwhile, qualitative data were analyzed using data reduction, data display and conclusion drawing/ verification analysis. Qualitative data analysis activities are carried out interactively and continuously through each stage of research until completion and data saturation. Parametric analysis aims to estimate the relationship between Autodesk Rivet Software and Case-Project Method with Building Interior Design learning.

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Table 1. Parametric Test for Quantitative Analysis

Variable	Analysis Technique
Expert Validity Test	Aiken's V Coefficient
Utility Test	Presentation of Achievement Level
Group Comparison	Independent Sample T-test
Hypothesis Test	Z-Score

RESULTS AND DISCUSSION

Case-Based Project Integrated Building Information Modeling Development

This research aims to see the impact of case-based project method integrated with Building Information Modeling on learning Interior Building Design. Based on the initial analysis that has been done, it is found that students already have their own mindset in trying to solve complex and abstract problems and can imagine many alternative solutions to problems along with possible consequences or results. At this stage students no longer receive information as it is but will process the information and adapt it to their own thinking. And based on the results of the initial analysis of learning, it is also found that this subject is an important productive subject, and students are required to be able to master the concepts in the lesson.

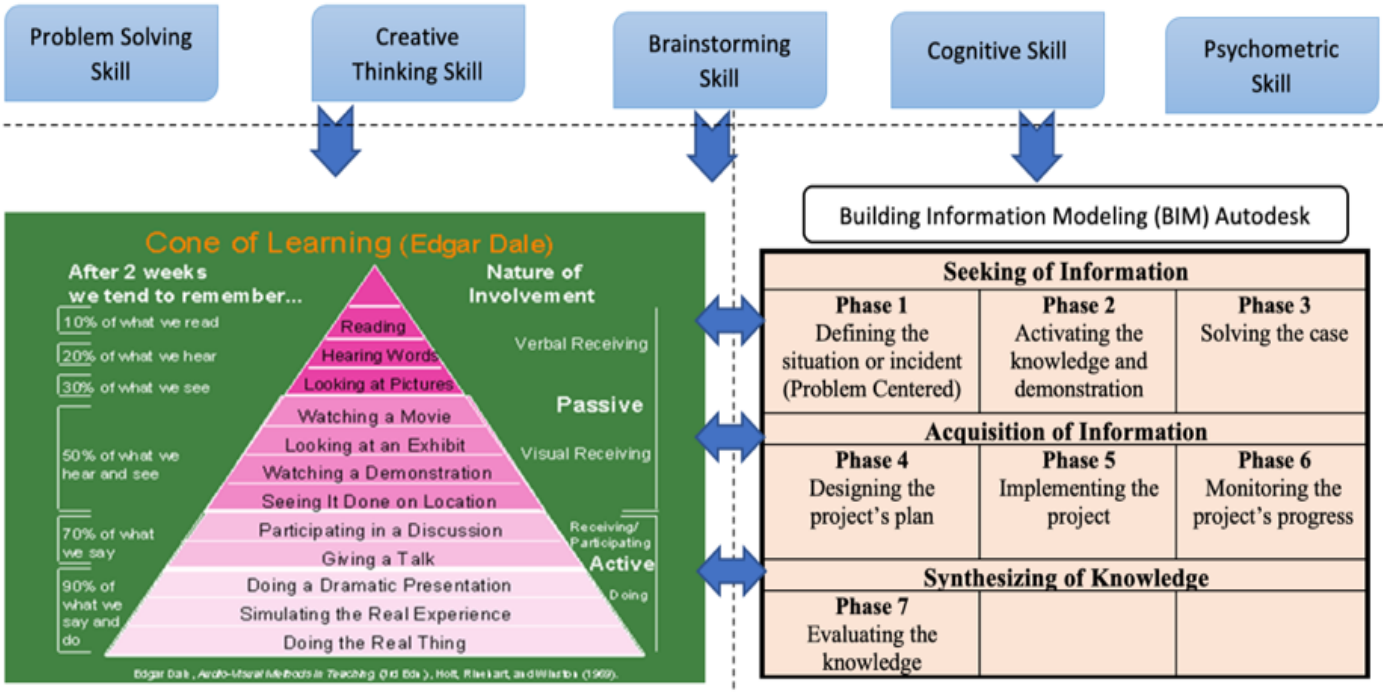

Figure 4. Framework of Case-Project Method and Building Information Modeling Integration

Based on the rationality of this initial analysis, the development design of the Case-Based Project learning model integrated with Building Information Modeling focused on learning Building Interior Design (figure 3), because the effective way that can help students understand this Building Interior Design learning is by applying interesting learning through innovative learning methods. This can be seen from the validity test results of Case-Based Project integrated with Building Information Modeling.

Table 2. Expert Validation of Case-Based Project Integrated Building Information Modeling

Assessment Indicators	Mean			Aiken's V Coefficient	Category
	V1	V2	V3		
Rationale of Model	4,5	4	4,5	0,81	Valid
Supporting Theory	4,6	5	4,6	0,808	Valid
Characteristics of Model	4,5	4	4,5	0,751	Valid
Syntax of Model	4,5	4,8	4,7	0,74	Valid
Social System	5	4,6	4,6	0,892	Valid
Principle and Reaction	4,6	4,6	5	0,716	Valid
Supporting System	4,67	4,8	4,8	0,78	Valid
Instructional and Accompanying Impact	5	4,6	4,5	0,735	Valid
Learning Implementation	4,6	4,8	4,8	0,730	Valid

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Table 2 shows the results of the validity test of the Case-Based Project Integrated Building Information Modeling model. The results of Aiken's calculation range from 0 to 1 and the more the number of validation results approaches the number 1 can be interpreted as having a high enough coefficient can be interpreted as having a high enough valid coefficient. Based on the results of data processing, it is found that Aiken's V coefficient for the rationale of the model, Supporting Theory, Characteristics of Model, Syntax of Model, Social System, Principle and Reaction, Supporting System, Instructional and Accompanying Impact, Learning Implementation is almost close to 1, so it can be concluded that Case-Based Project Integrated Building Information Modeling is declared in the valid category. Based on the suggestions given by the validators, revisions were made so that Case-Based Project Integrated Building Information Modeling was obtained which was feasible to be tested as a learning model in learning interior design.

Table 3. Expert Validation of Building Interior Design Learning Material

Assessment Indicators	Mean			Aiken's V Coefficient	Category
	V1	V2	V3		
Lesson Plan's Components	5	4	5	0,73	Valid
Learning Outcomes	4,8	5	4,6	0,829	Valid
Indicators for Competency Achievement	4,3	5	5	0,706	Valid
Learning Material Complexity	5	4	5	0,703	Valid
Learning Method Selection	4,6	5	4,8	0,714	Valid
Learning Activities Type	5	4,5	5	0,708	Valid
Learning Outcomes Assessment	4,5	5	5	0,706	Valid
Implemented	3,8	5	4,7	0,881	Valid
Composition of Learning Steps	4,5	4,8	5	0,721	Valid
Ways to Motivate Students	5	4,6	5	0,853	Valid
Manage the Classroom	4,5	4,8	4,5	0,883	Valid
Assessment Procedures	4,5	4,8	5	0,714	Valid

Table 3 shows the results of the validity test of learning devices from validators from aspects namely; 1) Syllabus Component Instructions 2) SAP Component 3) Language from the aspects of Lesson Plan's Components, Learning Outcomes, Indicators For Competency Achievement, Learning Material Complexity, Learning Method Selection, Learning Activities Type, Learning Outcomes Assessment, Implemented, Composition of Learning Steps, Ways to Motivate Students, Manage the Classroom and Assessment Procedures are Valid with Aiken's V value close to 1. The results of Aiken's calculation range from 0 to 1 and the more the number of validation results approaches 1, it can be interpreted as having a high valid coefficient. Based on the suggestions given by the validators, revisions were made so that the learning tools consisting of lecturer guides in the learning process, lesson plans and assessment rubrics were valid and suitable for testing.

Table 4. The Utility of Case-Based Project Integrated Building Information Modeling

Group	Aspects	Achievement Level (%)	Total	Category
Small Group (10 students)	Students' Interest	86 - 100	8	Strongly
		76 - 85	2	Utility
	Process	86 - 100	9	Strongly
		76 - 85	1	Utility
	Activeness	86 - 100	7	Strongly
		76 - 85	3	Utility
	Independence	86 - 100	5	Strongly
		76 - 85	5	Utility
Large Group (60 students)	Students' Interest	86 - 100	54	Strongly
		76 - 85	6	Utility
	Process	86 - 100	51	Strongly
		76 - 85	9	Utility
	Activeness	86 - 100	48	Strongly
		76 - 85	12	Utility
	Independence	86 - 100	50	Strongly
		76 - 85	10	Utility

Based on table 4, the Case-Based Project Integrated Building Information Modeling utility test is based on

small groups and large groups of students with an average percentage obtained above 76 %, which is included in the utility and very utility criteria. Thus, it can be concluded that the application of Case-Based Project Integrated Building Information Modeling is utility in learning interior design.

The Interior Building Design course covers various concepts and skills required to plan and design building interiors with a focus on aesthetics, functionality, and occupant safety. The Building Interior Design course not only teaches interior design techniques, but also develops creativity, critical thinking, collaboration, and communication skills. It provides students with a strong foundation to enter the world of interior design with the necessary skills to succeed in this dynamic industry.

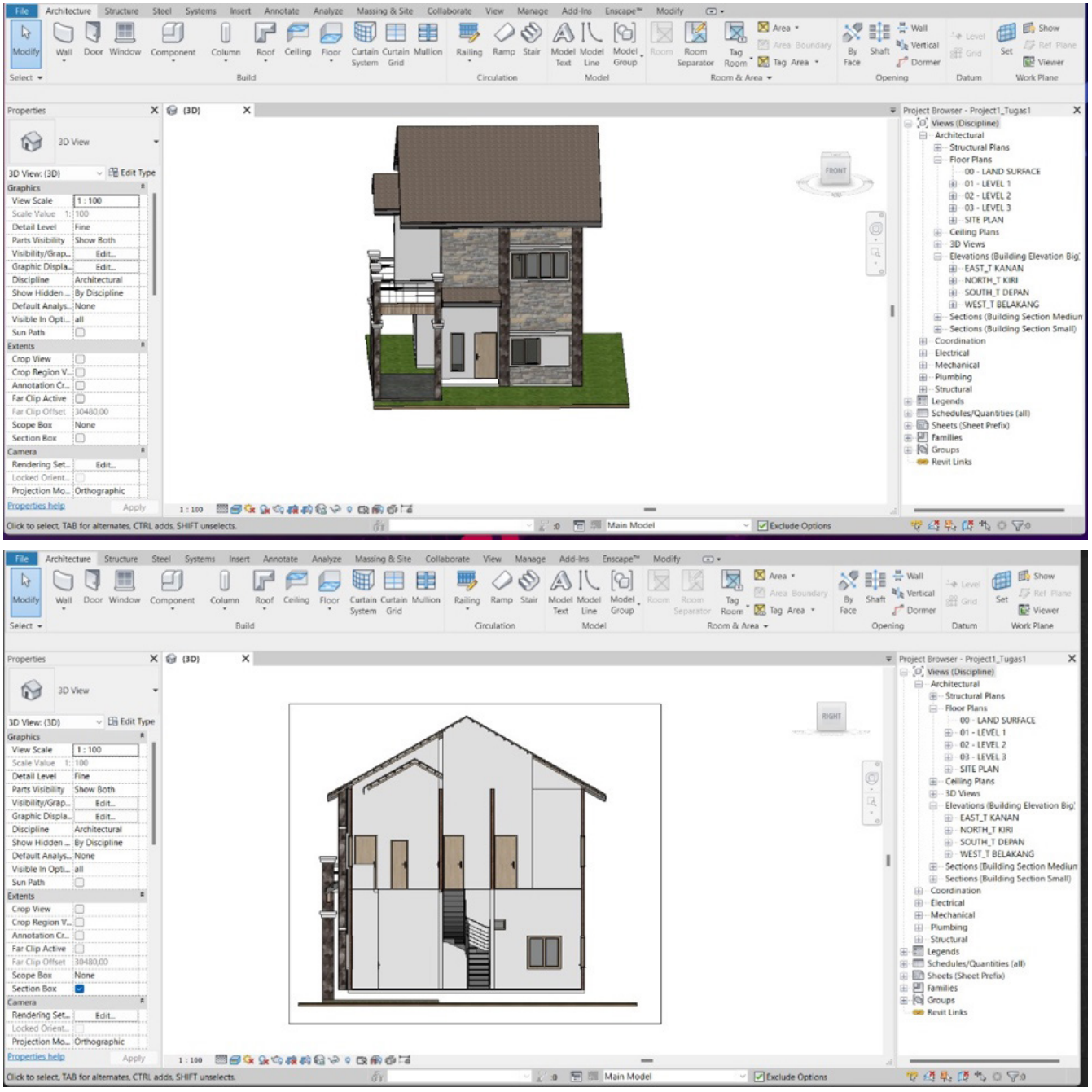

Figure 5. Framework of Case-Project Method and Building Information Modeling Integration

The integration of Autodesk Revit software with the Case-Project method in learning interior building design brings significant benefits to students. By combining the power of BIM (Building Information Modeling) technology from Revit and the practical and contextual approach from the Case-Project method, students can gain a deeper understanding of interior design and its implementation process in real projects, as well as improve efficiency and quality in the teaching and learning process.

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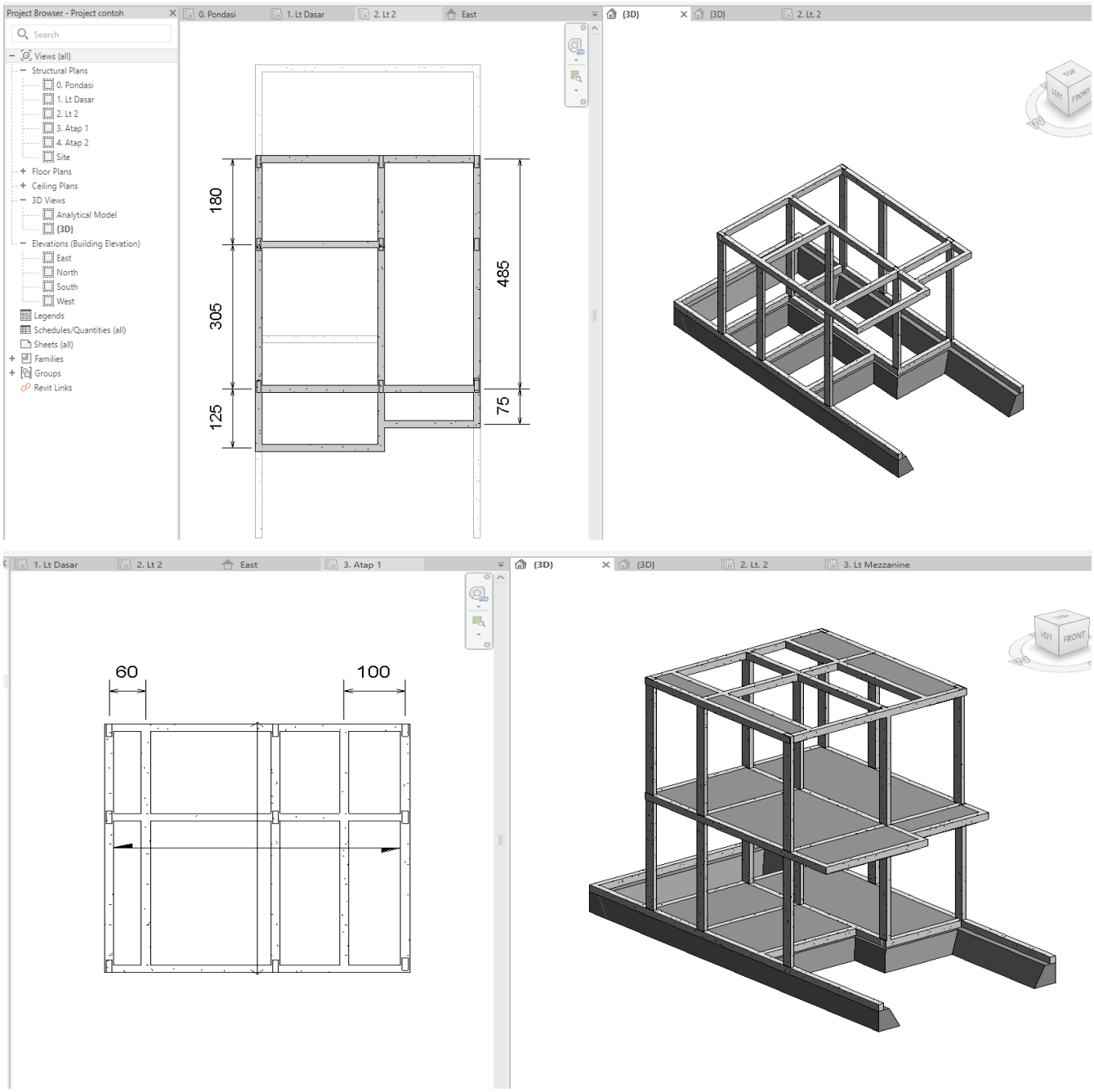

Figure 6. Columns Slot

The Case-Based Project Integrated Building Information Modeling (BIM) learning model has several advantages that can improve learning effectiveness and student preparation for the construction and engineering industry. As with the research conducted by Ibrahim et al.[28] in applying BIM in developing Technical Skills related to BIM software, 3D modeling, structural analysis, etc., which are highly sought after in the construction industry. By working on BIM projects, students can understand the construction process from start to finish, including planning, design, construction, and project management. This gives them a deep insight into the construction industry.[29] The model uses real case studies related to actual construction projects. Thus, students can understand the real-world context in which their knowledge will be used. This allows students to develop strong problem-solving skills.[30] They have to face actual challenges that may arise in construction projects and find effective solutions.[31] The Case-Based Project Integrated Building Information Modeling learning model provides a comprehensive learning experience and prepares students with skills and knowledge relevant to the modern construction industry.

Empirical Effect on Building Interior Design Learning

The integration of Autodesk Revit and the Case-Project method in learning interior building design not

only improves the quality of design but also prepares students with the practical skills required in the modern interior design industry. As well as students understanding the practical context and challenges, they face in the industry every day. This integration also provides an in-depth and relevant learning experience, preparing students with skills that are highly valued in the interior design job market. The participants in this study were 70 students majoring in civil engineering who took the building interior design course, whose data normality can be seen in figure 7.

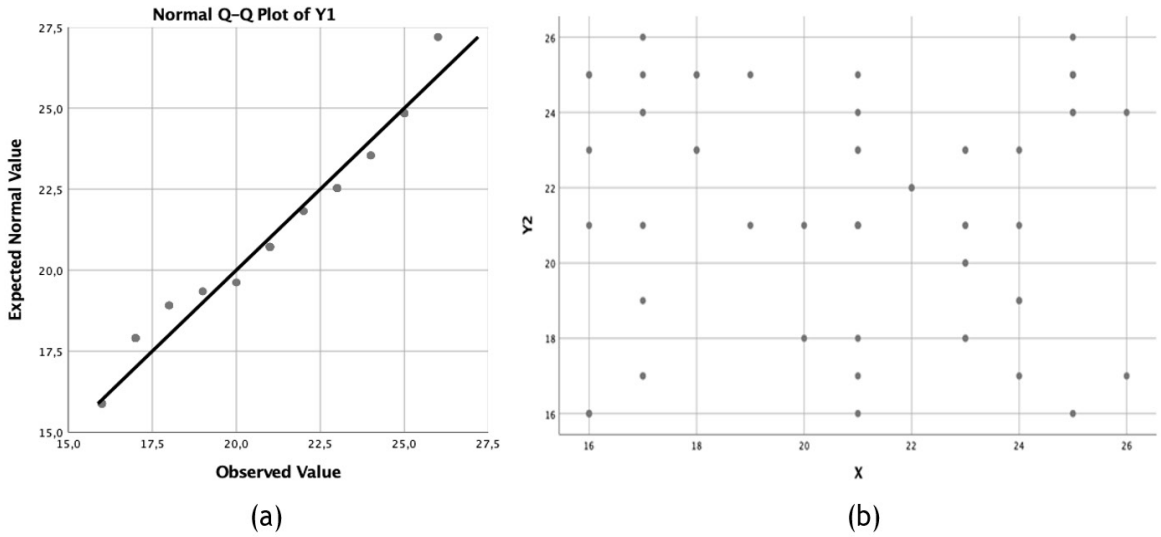

Figure 7. The Normality QQ Plots (a) and Linearity Scatter Plot (b) of Students' Skill in Interior Design Building Learning

Figure 7a displays the results of data normality distribution of Problem-Solving Skill (P > 0,05, Z = 1,101), Creative thinking skill (P > 0,05, Z = 1,815), Brainstorming skill (P > 0,05, Z = 1,716), Cognitive skill (P > 0,05, Z = 1,166) and Psychomotor Skill (P > 0,05, Z = 1,708) showing that the data of these four variables are normal. Figure 7b illustrates the scatter plot between the independent variable and the dependent variable. As well as the linearity value of data from X1-Y1 is 0,015 (p-value < 0,05), the linearity value of data from X1-Y2 is 0,001 (p-value < 0,05), the linearity value of data from X1-Y3 is 0,016 (p-value < 0,05), the linearity value of data from X1-Y4 is 0,029 (p-value < 0,05), the linearity value of data from X1-Y5 is 0,008 (p-value < 0,05). So, it can be assumed that linearity has been fulfilled because the p-value <0,05 and the observation points are evenly distributed around the horizontal line and do not form a certain pattern.

Table 5. Posttest Comparison

Trial	Variables	Group	N	Mean	t	p-value	Median
Limited	Problem Solving Skill	Control	5	62,6	5,15	0,000	67
		Treated	5	83			80,8
	Creative thinking skills	Control	5	67,6	9,02	0,001	66
		Treated	5	89,5			88
	Brainstorming skills	Control	5	61,5	6,61	0,000	62,9
		Treated	5	80,1			80,7
	Cognitive skill	Control	5	61,6	8,10	0,000	60,7
		Treated	5	82,0			80,4
	Psychomotor Skill	Control	5	65	6,12	0,003	61
		Treated	5	88			81
Expanded	Problem Solving Skill	Control	30	69,2	7,78	0,000	65,1
		Treated	30	87			86,1
	Creative thinking skills	Control	30	67	11,92	0,005	61
		Treated	30	80,4			80,2
	Brainstorming skills	Control	30	69	7,61	0,001	62,1
		Treated	30	82			81,6
	Cognitive skill	Control	30	66,03	7,86	0,001	67
		Treated	30	82			82
	Psychomotor Skill	Control	30	72,4	8,18	0,002	71,1
		Treated	30	88			87,6

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Table 5 shows the comparison of posttest between groups in the limited trial and extended trial samples. The results show that in the limited trial there is a significant difference between the control and treatment groups on problem solving skill (t = 5,15; p<0,05), creative thinking skill (t = 9,02; p<0,05), brainstorming skill (t = 6,61; p<0,05), cognitive skill (t = 8,10; p<0,05) and psychomotor skill (t = 6,12; p<0,05). While in the extended trial, there were also significant differences between the control and treatment groups in problem solving skill (t = 7,78; p<0,05), creative thinking skill (t = 11,92; p<0,05), brainstorming skill (t = 7,61; p<0,05), cognitive skill (t = 7,86; p<0,05) and psychomotor skill (t = 8,18; p<0,05). In addition, the mean value also shows that the treatment class has a higher mean than the control class. So, it can be assumed that the treatment class that uses Case-Based Project Integrated Building Information Modeling has better results than the control group that does not use Case-Based Project Integrated Building Information Modeling.

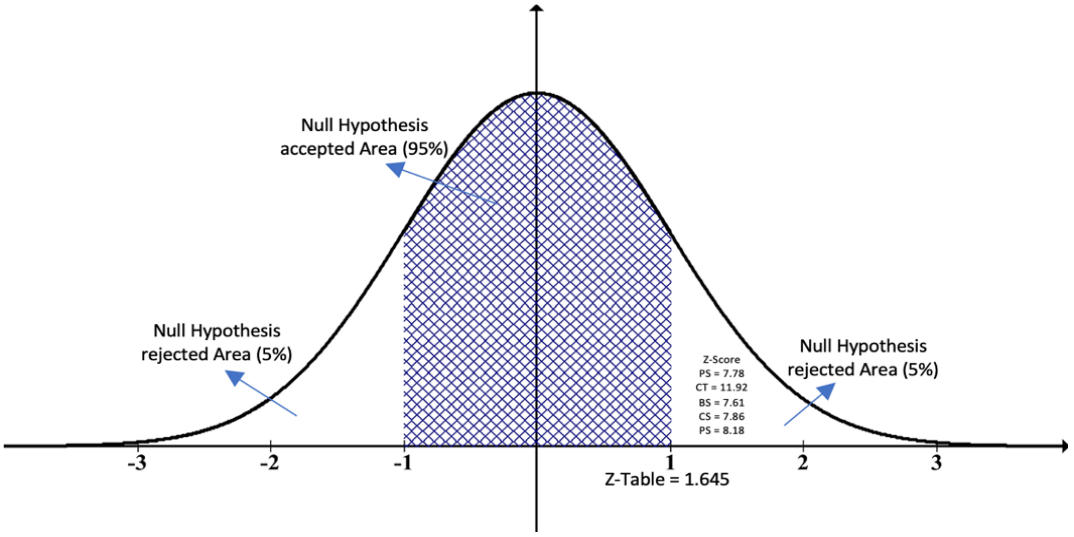

Figure 8. Normal Curve of Expended Trial's Z Score

Comparing z-count and z-table to determine whether the null hypothesis is accepted or rejected. It is found that the z-count value of Problem-solving skill (7,78), Creative thinking skill (11,92), Brainstorming skill (7,61), Cognitive skill (7,86) and Psychomotor skill (8,18) is greater than z-table (1,645). So, it can be concluded that z-table > z-count, then the null hypothesis is rejected. Thus, the ability of student absorption in learning interior building design using Case-Based Project Integrated Building Information Modeling is at least or equal to 76 % of the maximum value.

Case-Based Project Integrated Building Information Modeling is an approach that involves analyzing and applying solutions based on real cases that happened before. This approach allows students to use experiences from previous cases to solve problems or develop new solutions. This is in line with research conducted by Fernandes[32] which explains Case-Based Project allows students to learn from real situations or concrete cases. It helps students understand theoretical concepts in a practical context, making learning more meaningful and relevant to them. Through Case-Based Project Integrated Building Information Modeling, students are invited to analyze complex situations, identify problems, and formulate solutions based on a deep understanding of the case.[33] This hones their analytical and problem-solving skills. Students are often encouraged to work together in groups, which can promote teamwork, discussion, and exchange of ideas between students, which can enhance their collective understanding.[34] It can also improve students' verbal and written communication skills.[35]

The application of Case-Based Project (CBP) Integrated Building Information Modeling (BIM) method has a positive impact on learning interior design. This is in line with constructivism theory, which emphasizes the importance of active learning, where students construct their own knowledge through experience and interaction with their environment.[36] In the context of CBP BIM, students can build an understanding of building interior design through a project-based experience involving the use of BIM technology to create accurate and functional building models. In addition, cognitive load theory proposes that learning is more effective when information is presented in a size that matches students' cognitive capacity.[37,38] In CBP BIM, BIM technology allows students to access building interior design information in a visual format that they can easily understand, reducing their cognitive load and allowing them to concentrate on design concepts and principles.[39]

CONCLUSIONS

This research shows that the Integrated Autodesk Rivet Software and Case-Project Method has a positive

influence on learning building interior design. The existence of a project in the form of a case given to students makes students' brainstorming skills improve. The results also show that the Integrated Autodesk Rivet Software and Case-Project Method has a positive influence in improving students' abilities in learning interior building design. This research will contribute to science in adding references to innovative learning methods in vocational education. This research will also have implications for curriculum developers and decision makers related to vocational education. This study only looks at the impact of Integrated Autodesk Rivet Software and Case-Project Method on students' problem solving, creative thinking, brainstorming, cognitive and psychomotor skills in Building Interior Design Learning and has not looked at other higher order thinking skills, this can be a suggestion for future researchers who want to conduct similar research.

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