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Improving students' data analysis skills through guided project-based learning: A case report from a technical university

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Abstract: Business intelligence and big data analysis have garnered significant academic and practical attention. However, many educational institutions lack access to large databases or OLAP (Online Analytical Processing) software, which limits opportunities for hands-on practice and experiential learning. To bridge the gap between theoretical knowledge and practical application, this study designed a project-based learning model that simulates offline data analysis using Excel, grounded in the "learning-by-doing" educational theory. The research employed paired-samples Z-tests to evaluate performance across pretest, midtest, and posttest assessments. Additionally, the study examined the relationships between students' gender, total hours absent, and the number of assignments submitted with their final grades through a multiple regression model. The findings indicated that the guided project-based learning model significantly improved students' learning outcomes. Furthermore, the number of assignments submitted via e-learning software was positively associated with final grades. The development of project-based learning methods for practical e-learning lessons is crucial for many industries, emphasizing the importance of hands-on practice and completing practical projects. The instructional model proposed in this study offers a feasible solution to existing challenges by utilizing available software and resources to enhance practice opportunities for students.

Keywords: *Data analysis, Guided project-based learning, Higher education, Online analytical processing, Software-integrated learning.*

1. Introduction

Business intelligence or big data analysis has received considerable academic and practical attention. To facilitate data analysis processes, lots of companies in Taiwan use various business intelligence tools, among which online analytical processing (abbreviated as OLAP) is widely employed because it enables real-time multidimensional data analysis and marketing management through simple click-and-drag operations [1-5]. However, students lacking hands-on experience with business intelligence tools may face a major disconnect between theoretical instruction and real-world marketing practices. This challenge is particularly critical in Taiwan, where most schools lack large databases or OLAP software, thus limiting opportunities for hands-on practice or learning.

In response to the aforementioned challenges, project-based learning and software-integrated methods have gained increasing attention in technology education because of their ability to address diverse student needs [6-10]. Project-based learning is an extension of "learning-by-doing" theory, in which students collaborate in groups to solve challenging real-world problems, potentially producing superior outcomes to those in traditional teacher-centered, lecture-based models. However, most studies on project-based learning have focused on general universities and have rarely explored software-integrated courses or used paired-sample research designs [3, 5, 7, 11-14].

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To fill the aforementioned research gaps, the present study developed a software-integrated and project-based learning model for technology education. Because students in technology-related fields require stronger connections between learning and practice, the model incorporated Excel software as a practical tool to simulate offline OLAP-like data analysis in a technical university Insurance Data Analysis course. This model enabled students to analyze simulated multidimensional customer data and learn hands-on software practice; part of student performance was evaluated using practical e-learning indicators, such as the number of assignments submitted.

This study was conducted to address the following research questions:

1. Does the guided project-based learning model improve the ability of second-year technical university students to search for and interpret insurance indicators?

2. Are gender, total hours absent, or the number of assignments submitted on the teaching platform significantly associated with students' final grades?

This study's contributions are outlined as follows: First, the study applied a pretest, midtest, and posttest to examine learning ability using paired samples. Second, it presents a research design and insights that may serve as a reference for hands-on learning courses on business or information technology. Third, it demonstrates the associations of students' gender, total hours absent, and number of assignments submitted with their final grades, which can inform instructional design and practice.

2. Literature Review

Traditional instructional models are typically teacher-centered, with course content primarily delivered through one-way lectures. This approach limits teacher–student interaction, student-driven learning opportunities, and practical skill development. Dewey's "learning-by-doing" theory, a key pedagogical concept in contemporary education, serves as the foundation of project-based learning [15, 16]. In project-based learning scenarios, students explore and solve challenging real-world problems in groups [11, 12].

Several studies have demonstrated higher student satisfaction and improved learning performance under project-based learning models compared with traditional instruction. Project-based learning provides students with practical and relevant learning experiences in key fields, such as computer science, engineering or finance [13, 14, 17]. Additionally, numerous studies have indicated that project-based learning can increase course satisfaction among students and foster their development of critical skills, such as self-presentation, teamwork, creativity, and communication [5, 16, 17].

Numerous variables affect learning performance. Ahlam and Azza suggested that students' learning engagement and level of technology acceptance positively affect their academic performance [6]. Related literatures indicated a positive, statistically significant effect of e-learning on academic performance across three dimensions, namely the quality of the course lecturers, quality of educational content, and quality of the electronic system [8-10]. The reviewed studies accounted for students' gender, e-learning knowledge level, and academic specialization.

Most of the existing studies on project-based learning have focused on students in general universities or non-software courses and have not included paired samples [3, 5, 7, 11-14]. To address these gaps, the present study developed a software-integrated project-based learning model for a technology-related course and evaluated student performance in terms of key e-learning indicators, such as the number of assignments submitted.

3. Course Design and Research Method

3.1. Course Design

Participants included second-year students in an Insurance Data Analysis course at a 4-year university of technology. The course primarily involved a step-by-step teaching method combining hands-on practice with the creation of final project reports. Computer-assisted teaching was performed through an online learning platform for 10 assignments, material-sharing functions, and tests. The course was designed in accordance with the structure of project development and included practical

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OLAP workflows. The course was also aligned with the seven essential elements of project-based learning proposed by Boss and Larmer [18]. The phased design chart for the course is illustrated in Figure 1.

3.1.1. Searching for and Understanding Insurance Indicators

The students learned how to search for relevant insurance data indicators online and interpret the meanings of these indicators, providing crucial preparation for the creation of relevant data fields within the customer database.

3.1.2. Creating a Customer Database

Each student team selected a company or organization and used Excel software to create a micro database for that customer. The students collected and edited the datasets, inserted formulas, and created customer-related fields.

3.1.3. Performing Pivot Table and Chart Analysis

The students performed simulated multidimensional analysis through pivot tables or charts generated in Excel. They filtered the pivot tables or charts to select meaningful components to include in their project slides, accompanied by brief text.

3.1.4. Planning Promotional Campaigns and Presenting Project Reports

Final project reports included an introduction to the company, explanation of the field names in the customer database, analysis of pivot tables or charts, and outline of planned promotional campaigns.

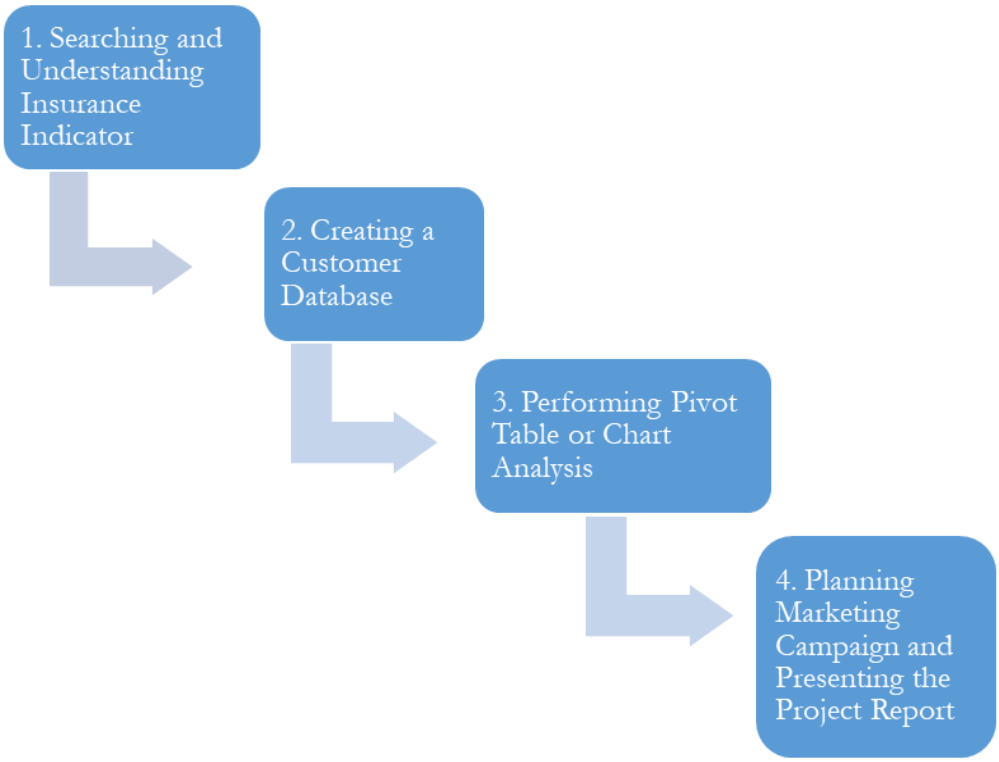

Figure 1.
The Phases Design for Insurance Data Analysis Course.

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The course was conducted over 4.5 months for one semester during the 2023–2024 academic year. The goal of the study was to improve teacher–student interaction and reduce the gap between classroom learning and industry practice through a novel instructional design.

Course instruction involved a two-step teaching method. First, the teacher introduced the topic and demonstrated one or more cases during the lecture to enhance the students' understanding. Second, the students completed hands-on assignments in the e-learning platform through Excel or related office software. At this stage, the teacher served as a coach to guide the students' efforts.

3.2. Hypotheses Regarding Learning Performance and Variable Associations

To evaluate changes in the learning performance of paired students, this study adopted paired-samples Z-tests method for the performance among pretest, midtest, and posttest. Accordingly, the following research hypothesis was developed:

H_1: Students' midtest and posttest scores would be significantly higher than their pretest scores.

The associations of students' gender, total hours absent, and number of assignments submitted with their final grade were also investigated through Ordinary least squares multiple regression model. Accordingly, the following hypothesis was established. The study

H_2: Students' gender, total hours absent, and number of assignments submitted will be significantly associated with their final grade.

A detailed summary of the research process is presented in Figure 2.

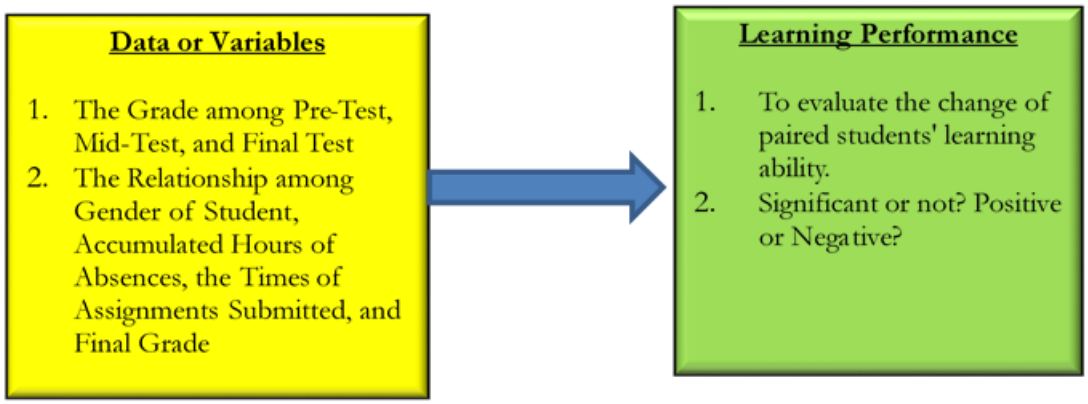

Figure 2.
The Research Summary.

Data were collected through the e-learning platform and internal teaching system. One pretest, midtest, and posttest were conducted to examine the students' learning performance.

3.3. Project Evaluation and Challenges Encountered

A total of 17 project groups were created, which comprised 11 projects on the life insurance industry, 4 projects on the property and casualty insurance industry, and 2 projects on the banking industry. The students selected their own industry of focus. The project reports were evaluated according to a rubric with two main sections: content (70% of project grade) and presentation (30% of project grade). The project report content included four key components: company introduction, customer database introduction, customer data analysis, and promotional campaign. Project presentation was evaluated on the basis of the quality of the slides and the students' oral presentation skills. The rubric grading approach helped the students to better understand the structure and content requirements of the project report.

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The students encountered numerous challenges during project-based learning. Under the guidance of classmates and the instructor at each step, the students' data analysis abilities and project reports improved throughout the course. Upon completion, each team presented and discussed their project with the teacher and other students. The main challenges encountered by the students are summarized as follows:

3.3.1. Challenges in Company or Unit Selection

To overcome challenges in company selection, the teacher allowed the students to choose organizations outside of the life insurance industry and provided them with suggestions on possible project directions, enabling them to determine the focus of their project.

3.3.2. Inadequate Project Report Structure

The rubric-based grading method was adopted to assist the students in organizing their project reports. However, several project reports were structured in a manner that contradicted their chosen topic.

3.3.3. Insufficient Multidimensional Customer Analysis

The identification of customer needs and marketing opportunities through customer analysis is a crucial but complex process. Although the rubric specified the number of pivot tables or charts required for the project report, several teams provided insufficient pivot tables or charts.

3.3.4. Difficulties in Connecting the Promotional Campaign with Pivot Tables or Charts

The rubric specified the requirement for promotional campaigns to be precisely connected to the results of pivot table or chart analysis. However, most teams experienced difficulties in connecting their customer analysis with the promotional campaign.

Despite these challenges, the guided project-based learning approach improved the students' learning performance, enabling hands-on project work and practice opportunities. When left to complete assignments or projects individually after class, the students often struggled to solve difficulties, prolonging the time spent on project work.

4. Result Analysis

4.1. Descriptive Statistics for Pretest, Midtest, and Posttest Results

A total of 37 students were enrolled in the course. However, five students either never attended or only attended once because of personal reasons. Because these five students did not participate in any hands-on learning, they were considered invalid samples and excluded from further analysis. Thus, a total of 32 students were included in the final sample, as detailed in Table 1.

The first half of the midtest and posttest included questions identical to those in the pretest. The same teacher evaluated all tests according to the same criteria to assess changes in learning performance scores between the pretest, midtest, and posttest.

Table 1.
Statistics of Valid and Invalid Student Samples.

Items	Valid	Invalid	Number of Students
Pretest	32	5	37
Share	86%	14%	100%
Midtest or Posttest	32	5	37
Share	86%	14%	100%

Statistical tests were performed to collect descriptive statistics for the pretest, midtest, and posttest (Table 2). The average midtest score was 68.3 points, representing a nearly 12-point improvement over the pretest average of 56.6 points. On the posttest, the average score increased further to 74.5 points.

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The standard deviation also increased from 11.2 in the pretest to 12.8 in the midtest and further to 16.7 in the posttest, indicating that the dispersion of scores increased over time. Based on the skewness coefficient, the pretest scores were right-skewed; this skewness decreased in the midtest, and the distribution became left-skewed in the posttest. This finding corresponds to a gradual rightward shift of the overall score distribution.

Table 2.
Descriptive Statistics.

Items	Average	Standard Deviation	Medium	Skew Coefficient	Max. Value	Min. Value
Pretest	56.6	11.2	55.0	0.92	90	35
Midtest	68.3	12.8	65.0	0.50	100	35
Posttest	74.5	16.7	72.5	-0.13	100	35

All participants were second-year daytime students with a similar age and income level. Therefore, data analysis did not control for age and income variables. To reduce potential biases, the same teacher evaluated all test results according to the same rubric.

4.2. Learning Performance Results

After the variance was calculated, paired-samples Z-tests were conducted to assess mean differences in student performance between the pretest, midtest, and posttest [19]. The resulting p values were all significant ($p < 0.05$); thus, H_1 was supported.

4.3. Regression Analysis of Gender, Absence, Number of Assignments Submitted, and Final Grades

4.3.1. Descriptive Statistics

In the regression model, students' gender, total hours absent from the course, and number of assignments submitted were included as independent variables, and their final grade was selected as the dependent variable. Collinearity diagnostics indicated that the variance inflation factor values for the three independent variables were below 2, signifying that collinearity was negligible. The descriptive statistics are summarized in Table 3.

Table 3.
Descriptive Statistics.

Items	Average	Standard Deviation	Medium	Average (Male)	Average (Female)
1. Number (number of assignments submitted)	3.4	1.5	4.0	2.9	3.8
2. Absence (total accumulated hours of absences)	4.7	3.4	3.5	6.1	3.5
3. Final Grade (Final Grade of the course)	76.4	10.3	80.0	73.4	79.1

During the course, the instructor assigned five practice assignments on insurance data analysis through the online teaching platform. The average number of successful assignments submitted was 3.4. The class comprised a slightly higher proportion of female students, accounting for 53% of the sample. In the analysis, female students were coded as 0 and male students as 1, and regression analysis was performed with a dummy variable model. As presented in Table 3, the average number of assignments submitted by male students was 2.9, and that submitted by female students was 3.8, suggesting gender-based differences between groups. The total accumulated hours of absence were determined using attendance records in the online system. On average, the students were absent for 4.7 hour, with a standard deviation of 3.4 hour. Male students had a higher average absence (6.1 hour) compared with female students (3.5 hour). The overall average final grade was 76.4 points, and female students had a higher average final grade (79.1 points) than male students (73.4 points).

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4.3.2. Correlation Analysis Results

Correlation analysis results revealed a moderate correlation (0.4–0.69) between several variables. Specifically, the results indicated a negative correlation between absence hours and the number of assignments submitted, a negative correlation between absence hours and final grades, a positive correlation between absence hours and gender, and a positive correlation between final grade and the number of assignments submitted. No correlation coefficient exceeded 0.7, signifying that no variables were strongly correlated. The correlation coefficients for each variable are presented in Table 4.

Table 4.
Pearson Correlation Summary.

Variables	Number	Absence	Gender	Final Grade
Number	1			
Absence	-0.666	1		
Gender	-0.334	0.403	1	
Final Grade	0.678	-0.627	-0.280	1

4.3.3. Regression Results

A significantly positive relationship was observed between the number of assignments submitted and final grade. Specifically, students who submitted more assignments achieved a higher final grade. This finding supports the effectiveness of hands-on learning practices. No significant relationship was observed between students' gender or course absence hours and their final grade under 95% confidence interval. Therefore, H_2 was partially supported. The regression analysis results are presented in Table 5.

Table 5.
Ordinary Least Squares Regression Analysis Results.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	69.80875	6.424375	10.86623	**0.0000**
Times	3.299769	1.249262	2.641375	**0.0134**
Absence	-0.970063	0.557778	-1.739156	0.0930
Gender (Male)	0.081633	2.918639	0.027970	0.9779
R-squared	0.515368	Mean dependent var		76.40625
Adjusted R-squared	0.463444	S.D. dependent var		10.24808

5. Conclusion and Recommendation

To reduce the gap between learning and practice, this study designed a course model to simulate offline data analysis in Excel according to "learning-by-doing" theory. The guided project-based learning model significantly improved students' learning performance in staged assignments and projects. Additionally, this model helped the students to better understand the course material and project report requirements through a rubric-based grading method, which clearly listed requirements and grading standards.

Paired-samples Z-tests were conducted to evaluate score differences between the pretest, midtest, and posttest. The Z-test results revealed a significant improvement in students' learning scores, supporting H_1.

Ordinary least squares multiple regression analysis was performed to examine the relationships of students' gender, hours of course absence, and number of assignments submitted with their final grade. A significant positive relationship was observed between the number of assignments submitted and the final grade; specifically, a greater number of assignments submitted corresponded to higher grades. No significant relationship was observed between students' gender or absence hours and their final grade; hence, H_2 was only partially supported.

Previous research has indicated that students require sufficient hands-on practice opportunities to become familiar with searching for relevant indicators, creating pivot tables and charts, and planning

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promotional campaigns. Accordingly, this study integrated the guided project-based learning model with "learning-by-doing" theory and related practice opportunities, representing a more effective instructional model than typical project- and lecture-based approaches.

Hands-on demonstrations provided by the teacher for every assignment were a key contributor to the observed improvement in student learning performance. Because data analysis skills are particularly crucial within the insurance and finance industries, students who can improve their Excel software and data analysis abilities will generally be more employable. In this study, the number of assignments submitted on the e-learning platform was identified as a significantly positive predictor of final grades. The study findings suggest that the number of assignments submitted may serve as a practical and innovative variable in assessing student learning outcomes, particularly in software-related or online learning environments.

5.1. Implications for Research, Practice, and Policy

5.1.1. Educational Practice

Most schools in Taiwan lack large databases or OLAP software to provide students with hands-on practice opportunities. To reduce the gap between course learning and industry applications, this study integrated project-based learning with Excel to simulate offline data analysis in a Data Analysis course at a technical university. This model allowed students to practice analyzing simulated multidimensional customer data through Excel software. In technology and software courses, students frequently encounter difficulties. The instructional model in this study represents a feasible solution to these difficulties that leverages existing software and resources to increase practice opportunities for students.

5.1.2. Industry Relevance

Data analysis skills are particularly vital in the many industries, in which employees are often required to create regular business and financial reports and assess the state of industry competitors. Students with superior Excel software and data analysis abilities will generally be more employable. To development of project-based learning method for practical e-learning software lessons is vital for many industries. The research proposed the importance of hand-on practice and completion of practical project.

5.1.3. Policy and Society Recommendations

On the basis of the findings, this study recommends that the government provide universities with more comprehensive software and hardware resources to increase students' in-class interactions and improve their performance. Government databases include substantial big data resources. Although some of these databases are open source, they are not generally available or feasible for simulated practice opportunities. The government may consider releasing certain big data for use in academic research and education on the basis of de-identification on personal data. Additionally, lots of lessons may refer the design and finding for improving learning performance in the research.

5.2. Research Limitations

This study has some limitations that should be acknowledged: (1) Only one class of students was included in this study, preventing comparative analysis between project-based and traditional lecture-based learning models. (2) Course content primarily focused on database creation and pivot table or chart analysis with Excel software. Real-time OLAP software operation, database system construction, and software and hardware system development and management were not included in the scope of the course.

5.3. Recommendations for Future Research

Based on the findings, this study has the following recommendations for future studies: (1) To increase the novelty and effectiveness of course instruction, researchers can adopt diverse study designs

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incorporating various business intelligence software tools. (2) Project-based learning approaches can be applied to the creation and use of popular OLAP software in order to examine its effects on students' learning performance and satisfaction.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Copyright:

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Appendix

1. Course Design and Project Stages

The course design presented in this study involved phased teaching, course material sharing, and assignment practice on an online learning platform and integrated a guided project-based learning approach. From weeks 1 to 5, course content primarily focused on the search for and interpretation of insurance data indicators; weeks 6 to 9 of the course focused on the creation and analysis of customer databases, pivot tables, and charts. Weeks 10 to 13 of the course involved further pivot analysis practice. The students also planned promotional campaigns and wrote their presentation content. During weeks 14 to 18 of the course, the students present their project and participated in Q&A sessions. A pretest, midtest and posttest were conducted to examine the learning performance of the students. The course design and project stages are summarized in Appendix-Table 1.

Appendix-Table 1.
Course design.

Week	Topic	Teaching Method	Project Stage
1–5	• Introduction of key • Insurance indicators and online search strategies.	• Demonstration of search for and interpretation of selected indicators • Completion of online practice questions and assignments • Pretest	• First stage: understanding and searching for insurance indicators • Learning output or material: related indicator or data from website
6–9	• Customer database creation and pivot table and chart analysis • Midtest	• After the teacher's explanation and demonstration, all students created a customer database for their project through Excel software. • After the teacher's explanation and demonstration, all students practiced creating and analyzing pivot tables and charts through Excel software. • The midtest was conducted online and covered data search strategies, database creation, and pivot table and chart analysis.	• Second stage: creating a customer database • Third stage: creating and analyzing pivot tables and charts • Learning output or material: customer database and pivot tables or charts
10–13	• Further practice with pivot table and chart analysis • Promotional campaign planning • Presentation preparation	• Students practiced pivot table and chart analysis and created meaningful tables or charts for their project report presentation. • Students planned promotional campaigns to include in their presentation.	• Fourth stage: planning promotional campaigns and creating the project report presentation • Learning output or material: presentation file

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14–18	• Student presentations • Posttest • Related topic presentation by Teacher	• Students presented their project reports • Students made presentations on insurance technology topics	• Learning output or material: revised project files on e-learning platform

2. Rubric-Based Project Report Grading

The students' project reports were graded according to a two-part rubric outlining content (70% of project grade) and presentation (30% of project grade) requirements. Content was graded across four main categories: company introduction, customer database introduction, customer data analysis, and promotional campaign planning. The rubric is presented in Appendix-Table 2.

Appendix-Table 2.
Project report rubric.

Items / Score ranges	**Below Average 40–69 (Group must present again)**	**Average 70–79 (Group must present a specific part of the project again)**	**Above Average 80–89**	**Excellent 90–100**
	Content: 70 points			
Presentation includes the following items: 1. Company introduction 2. Customer database introduction 3. Customer analysis 4. Promotional campaign	Includes 0–1 item	Includes 2 items	Includes 3 items	Includes all 4 items
Customer analysis 1. At least 4 charts or tables 2. At least 2 charts or tables with two or more dimensions. 3. Every table or chart includes a written key points 4. Customer analysis is clearly linked to the promotional campaign	Includes 0–1 item	Includes 2 items	Includes 3 items	Includes all 4 items
	Presentation: 30 points			
Aesthetic design 1. Font size is ≥18 2. At least 15 words of explanatory text are provided on every slide 3. Content presentation is clear and aesthetically pleasing	Includes 0 item	Includes 1 item	Includes 2 items	Includes all items
Oral expression 1. Fluency in expression and eye contact 2. Asks other students at least two questions 3. Provides appropriate answers during Q&A	Includes 0 item	Includes 1 item	Includes 2 items	Includes all items

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