Development of Analytical Thinking Using Flipped Classroom Approach for Big Data Analytics Courses

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Abstract
This research clarified the development of analytical thinking skills through 10 hands-on lab sessions conducted among undergraduates at Universiti Teknologi PETRONAS (UTP). This systematic review study examined 30 publications from 2017 to 2022 that were discovered through a comprehensive systematic mapping process for a more in-depth analysis. Previous studies indicate that most instructors and students believe the flipped classroom approach improved analytical thinking among undergraduates. Therefore, in order to determine the effectiveness of the flipped classroom approach for the development of analytical thinking, 134 UTP undergraduates enrolled in Big Data Analytics (BDA) course are considered as the participants in this study. One complete module with detailed teaching and learning activities (TLA) was developed for an immersive learning experience, and students were provided with pre-class instruction. The performance of the flipped classroom approach was evaluated using immersive learning experiences and a student satisfaction survey. The results show that the flipped classroom approach is successful in developing students' analytical thinking skills among the participants of this study. The research has been reviewed and approved by the university through the Scholarship of the Teaching of Learning (SoTL).

Keywords: Flipped Classroom, Analytical Thinking Development, Teaching Methodology

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Introduction

Analytical thinking is an important component of visual thinking as it enables us to solve problems quickly and efficiently. It provides a person with the ability to analyze, examine, and interpret a topic to create complex ideas and solutions (Amer, 2005; Aziz, Akhir, & Ali, 2020; Nuroso, Siswanto, & Huda, 2018; Spaska, Savishchenko, Komar, & Maidanyk, 2021; Sulejmani & Xhaferi, 2020). Practical or experiential learning can enhance students' analytical thinking and critical thinking capability (Miharja, Hindun, & Fauzi, 2019). This can be achieved by engaging students to be positively involved during the learning process in a classroom. Providing students with contemplative activities that require knowledge processing allows them to use their brains to think (Spaska et al., 2021). Our brain will actively think to formulate thoughts, solve questions, reason, and make decisions (Amaliah, 2020). Our critical and analytical thinking capabilities distinguish humans from other species.

This study focused on exploring the existing literature through a systematic review process while providing evidence on the performance of the flipped classroom approach to enhance analytical thinking among undergraduates. This study considers two sources, which are the students' immersive learning experience and a student satisfaction survey as proof to measure the performance of the flipped classroom approach.

Systematic Planning

Our systematic study follows Khan's five-phase model (Khan, Kunz, Kleijnen, & Antes, 2003) as guidelines to conduct the study process. The model helps in selecting the most relevant studies, as systematic reviews and meta-analyses have intensified in recent years. Several studies were referred to as example for creating a high-quality systematic studies (Hussain, Salleh, Talpur, & Talpur, 2018; Talpur et al., 2022). This study seeks to evaluate secondary data by obtaining, synthesizing, and evaluating existing information on a topic logically, clearly, and analytically. Thus, this systematic study uses a precise technique to find, select, assess, analyze, synthesize, present, and discuss the findings, following the process presented in Figure 1.

Figure 1: The five-phase model for a systematic study

The following subsections explained the steps conducted in complying with the systematic study guideline shown earlier.

A. Framing the research questions

This study begins with research questions (RQ) formulation, which helps to guide the direction of this study. This study embarks on the following research questions:

RQ1: What is big data analytics (BDA)?
Motivation: To understand the definition of BDA.

RQ2: What is the relation between BDA and analytics?
Motivation: To explain the relations between BDA and analytics.

RQ3: What is a flipped classroom?
Motivation: To define the concept of the flipped classroom.

RQ4: Why flipped classroom is considered innovative teaching?
Motivation: To explain the reason that makes flipped classrooms innovative.

RQ5: Which components of the flipped classroom help in the development of analytical thinking among undergraduates?
Motivation: To study the components in the flipped classroom that influence the development of undergraduates' analytical thinking.

B. Identifying relevant publications

This systematic study was conducted based on literature searches on two main sources: ScienceDirect, and ACM DL. The search process began by utilizing authors' keywords found in relevant studies to find related articles published in the recent six years (2017–2022) on the selected databases. Next, the search results from each database were examined and the search parameters were refined to obtain results that contain articles that are closely related to this study. As a result, the keywords "big data analytics" and "flipped classroom" were selected for retrieving the relevant studies. The search was last performed on 31 May 2022 and covers only studies authored in the English language and published within the last six years (2017–2022). The full search syntaxes used to retrieve the results are given in Table 1.

Keyword	**Database (Last Retrieved)**	**Full Query Syntax**
Big data analytics + Flipped classroom	ScienceDirect (31 May 2022)	General query: big data analytics Title, abstract, keywords; AND "flipped classroom" Year published: 2017 – 2022
	ACM DL (31 May 2022)	Title:(Big data analytics) AND Fulltext: (Big data analytics) AND Fulltext: (flipped classroom) Filter by: Publication Date: (01/01/2017 TO 31/05/2022), ACM Content: DL, NOT VirtualContent: true

Table 1: Full keyword search strategy

The keywords "big data analytics" and "flipped classroom" helped us retrieve 3,909 studies: 386 from ScienceDirect and 3,523 from ACM DL. Next, the studies are filtered following the inclusion and exclusion criteria as given in Table 2.

Inclusion Criteria	**Exclusion Criteria**
• Published between 2017-2021 • Article available in full text • Written in the English language • Published in the selected databases • Related to the RQs	• Published before 2017 or after 2021 • Article unavailable in full text • Not written in the English language • Not published in the selected databases • Not related to the RQs • Duplicate studies

Table 2: Inclusion and exclusion criteria

As a result, 1,097 studies are excluded and the remaining 1,812 studies that pass the inclusion criteria are compiled in a spreadsheet file. The downloaded list contains information about the article name, authors, keywords, DOI, and abstract. From the compiled list, we carefully deduplicate the studies based on the study name column, thus, leaving 1,537 unique studies.

Following that, a four-person review team assesses the relevance of the studies retrieved by carefully reading the titles, keywords, and abstracts of these papers. Thus, 1,326 studies are excluded as they are unrelated to our study, while only 211 studies pass the screening. The systematic mapping process used to find relevant studies is depicted in Figure 2.

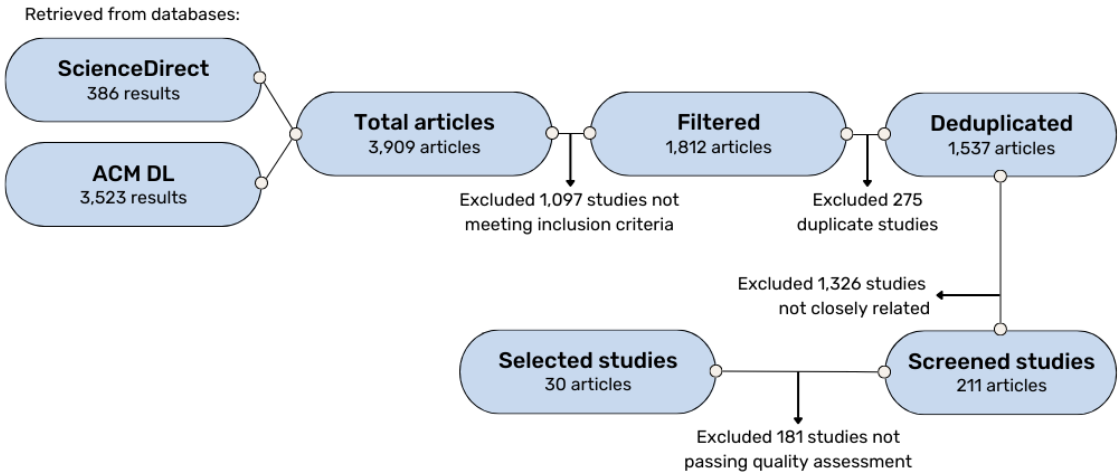


Figure 2: Systematic mapping process

C. Assessing study quality

Once the screening process is complete, the 211 studies passed screening were evaluated for their quality and eligibility before inclusion into this systematic study. Only studies with a minimum score of 2.5 are considered to ensure that only high-quality studies are used as references. The quality of the studies was determined using the criteria listed in Table 3.

Criteria	Score	Description
Does the study discuss the relationship between flipped learning and students' analytical thinking?	1 0.5 0	Yes, the study clearly discussed the subject. The study briefly discussed the subject. No, the study does not touch the subject.
Does the study implement a clear methodology?	1 0.5 0	Yes, the methodology used is clear. The methodology is presented, but insufficient. No, the study does not have a clear methodology.
Does the study include sufficient citations and refer to reliable sources?	1 0.5 0	Yes, it includes sufficient and reliable sources. Citation is available, but insufficient. Citation is insufficient and/or not reliable.

Table 3: Scoring criteria for the study quality assessment

Consequently, 30 studies were selected after reviewing the research articles using the scoring criteria. Following this, our study conducted a thorough analysis to examine the 30 selected studies published between 2017–2022, including full-text articles from online sources.

D. Summarizing the evidence

All 30 studies were downloaded and saved in EndNote software, which will be used to help us answer our RQs. Following that, we looked at the selected studies published between 2017–2022, as well as full-text articles from online sources.

E. Interpreting the findings

Interpretation of the findings is provided in the next section (Research Question Discussion).

Research Question Discussion

The RQs introduced in the Systematic Planning section are explained in this section.

A. Big Data Analytics (BDA)

The phrase big data generally refers to the volume of data that is too large for most software tools to gather, curate, manage, and process in a timely manner . The characteristics of big data are known as the big data three V's which stands for the volume (quantity of data), velocity (speed of which data is being generated), and variety (various range of data types and sources) (Aziz, Abdullah, Osman, Musa, & Akhir, 2023; Aziz, Abdullah, & Zaidi, 2020; Ranjan & Foropon, 2021). The adoption of current emerging technologies such as cloud computing and the Internet of Things (IoT) has led to a better value for adopting big data solutions for customers and businesses (Ranjan & Foropon, 2021). In addition, long-term investments in areas such as health, administration, agriculture, defense, and education have catalyzed the deployment of large-scale big data systems in several countries. Big data systems can handle and manage data that is too large for standard software and data analysis tools. Therefore, BDA is described as a new technology generation of technologies and architectures designed to collect, discover, or analyze huge amounts of data coming from various sources and generated at a very high rate (Rossi & Hirama, 2022).

B. The relation between BDA and analytical thinking

Currently, big data course in Malaysian higher education are in their infancy, and the student learning process is frequently criticized for failing to prepare students for the necessary industrial skills and moral standards demanded by employers (Aziz, Akhir, et al., 2020). Therefore, analytical thinking skills that include gathering and analyzing data (Khan et al., 2003), transforming data into a meaningful format, and providing insight into action are required in the big data era (Aziz, Akhir, et al., 2020; Rossi & Hirama, 2022). Furthermore, these skills can ensure that business decision-makers have valuable information and knowledge for making sound decisions. Analytical thinking skills can also change the way we learn in various ways. For example, the use of learning analytics allows educators to take a different approach to e-learning, encourages student and teacher engagement, and enables individuals to achieve their learner's goals (Aziz, Akhir, et al., 2020).

Analytical thinking is a mental process that involves breaking down conceptual knowledge or extensive evidence into essential factors or fundamental concepts to make better decisions (Miharja et al., 2019). According to Khan et al. (2003), analytical thinking is the ability to evaluate and conduct research, which is one of the most critical bits of intelligence for innovation. It is also known as the ability to evaluate an individual's thoughts (Montaku,

2011), assess strengths and shortcomings (Permana, Hindun, Rofi'ah, & Azizah, 2019), and give recommendations to improve analytical thinking abilities (Azid & Md-Ali, 2020). These qualities include the ability to use rational ideas to solve complex problems. In essence, analytical thinking attempts to analyze information by breaking it down into sequential and step-by-step solutions (Amer, 2005; Aziz, Akhir, et al., 2020; Nuroso et al., 2018; Spaska et al., 2021; Sulejmani & Xhaferi, 2020). Thus, the characteristics of analytical thinking include (1) the ability to distinguish a question from one another and understand its components; (2) the ability to understand procedures or techniques to solve a problem; (3) the evaluation of two or more details; or (4) the ability to compare and contrast features of an object.

C. Flipped classroom

The flipped classroom (also known as the inverted classroom) is a recent educational trend that focuses on assisting students in reaching a higher level in the taxonomy domain (Ulaş, 2021). Flipped learning is different from the traditional teaching and learning strategy since it "flipped" the old technique. In a flipped classroom, students are given materials to read, study, and review on their own time while out of class. Lower-level learning tasks (e.g., understanding concepts) are completed independently outside of the classroom. It aims to train students to be self-directed learners who seek out new information without the assistance of instructors.

Since the materials are covered during the student's own time outside the classroom, flipped learning allows students to devote more time in the classroom to explore higher-level learning activities (e.g., group discussions). Flipped learning emphasize higher-level learning over lectures and lower-level thinking activities. Hands-on lab activities and fundamental learning support allow for more in-class time to be spent on higher levels of learning, from application to assessment. Therefore, the flipped classroom approach has gained huge interest, allowing students to participate actively in learning either through physical classroom (offline learning) or remote study (online learning) (Heiss & Oxley, 2021).

The research on flipped classrooms was based on Bloom's updated taxonomy of cognitive domain theory. This taxonomy categorizes learning into six stages, which are organized from the most basic to the most complex mastery level. Students in flipped classrooms will progress from the lowest mastery level of remembering to the highest mastery level of creating. The students' analytical thinking abilities are measured based on the revised version of the six levels of learning of Bloom's taxonomy, visualized in Figure 3.

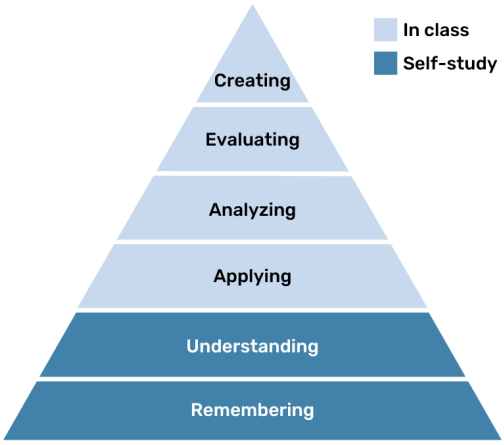


Figure 3: Bloom's updated taxonomy in the flipped classroom (Anderson & Sosniak, 1994)

The six levels of learning are remembering, understanding, applying, analyzing, evaluating, and creating. Table 4 explains each level in greater detail.

Scale	Level of Learning	Abilities
1	Remembering: Can the students recall or remember the information?	Students can identify, duplicate, name, remember, and replicate information.
2	Understanding: Can the student explain ideas or concepts?	Students can define, characterize, explain, recognize, find, report, interpret, paraphrase and pick.
3	Applying: Can the students use the information in a new way?	Students can pick, display, play, use, explain, interpret, function, plan, draw, solve, use, and write.
4	Analyzing: Can the students distinguish the different parts?	Students can assess, analyze, contrast, criticize, differentiate, distinguish, analyze, evaluate, ask, and examine.
5	Evaluating: Can the students justify a stand or decision?	Students can analyze, argue, justify, evaluate, pick, endorse, support, and evaluate.
6	Creating: Can the students create a new product or point of view?	Students can assemble, construct, plan, create, formulate, and compose.

Table 4: Level of learning in Bloom's updated taxonomy

D. The differences between the traditional classroom and flipped classroom

The main distinction between traditional and flipped classrooms is the learning experiences. In a traditional classroom, students will only have the opportunity to learn and be taught once the lecture or class begins. The students have no idea which topics will be covered before the class begins. The physical class session only provides a learning experience based on an instructor's explanation, whiteboard content, and in-class material. Question and answer (Q&A) sessions are also restricted to the classroom and self-study/independent learning, which is typically based on the homework assigned.

Alternatively, the flipped classroom differs from the traditional classroom in that it provides more immersive and interactive learning experiences during lectures. Flipped classrooms are typically held digitally before class so that students can access the recording online (Fisher, LaFerriere, & Rixon, 2020). The traditional classroom employs a lecture-based model in which students listen to lectures and apply their knowledge by completing homework on their own. Table 5 summarized the differences between traditional and flipped classroom tools.

Level of Learning	Traditional Classroom Tools	Flipped Classroom Tools
Remembering	Physical class	Lecture, hands-on lab activities
Understanding	Q&A session	Collaboration, reflection, and peer-to-peer discussion
Analyzing	Homework	Individual and group activities during 10 hands-on lab sessions
Applying, Evaluating, Creating	Homework	Independent self-learning, projects, presentations, and instructor-evaluation

Table 5: Traditional versus flipped classroom tools

E. Flipped classroom components that assist in analytical thinking development

The flipped classroom combines independent study and immersive learning experiences, which can help undergraduates develop analytical thinking skills. This approach typically requires providing students with pre-class instruction for independent study, where the students are introduced to the material in various media formats, including video and text (Ulaş, 2021). Students can watch videos and study whenever they are available (Heiss & Oxley, 2021; Ulaş, 2021). Furthermore, students who are taught in this way are encouraged to think both inside and outside of the classroom. At the same time, students are given more time to learn creatively, and technology is used to encourage students to learn about topics before classes (Mohamed & Lamia, 2018; Zou, 2020). Students were able to review course material at home first and train themselves to participate in related class exercises, pose questions, and collaborate with peers in problem-solving. Students' problem-solving ability, teamwork abilities, conflict management abilities, time management, and team building can be improved in flipped classroom learning (Mohamed & Lamia, 2018; Zou, 2020). The most important aspect of the flipped classroom is facilitating more advanced learning during in-class hours so that students can engage in more meaningful ways through self-research, debates, learning advanced concepts by example, and collaborative projects.

The immersive learning phase engages students in a variety of interactive events such as Q&A, advanced topic descriptions, and discussions (Elmaadaway, 2018). Immersive learning experiences at school require students to take more responsibility for their learning and require more complex thinking and reasoning abilities (Long, Cummins, & Waugh, 2017). Engaging students in classroom activities transforms them from passive to active students in the classroom (Kim, Park, Jang, & Nam, 2017). Educators can deliver pre-recorded lectures to their students (Heiss & Oxley, 2021; Ulaş, 2021; Zuber, 2016), allowing them to spend more time preparing learning materials for hands-on activities in the classroom and assessing students' emotions (Prohoroff, 2016). An advanced classroom environment allows students and teachers to discuss scenarios that are typically not feasible in a traditional classroom.

Several studies (Chusni, Saputro, & Rahardjo, 2020; Prihandini; Sulejmani & Xhaferi, 2020; Wulandari & Puspadewi, 2020) have shown that analysis can help develop critical elements in students' learning processes. Furthermore, the flipped classroom paradigm was discovered to be implemented in various educational fields to increase engagement and personalized communication between students and teachers (Uzunboylu & Karagozlu, 2015).

Methodology

In this study, two sources were used to evaluate the effectiveness of the flipped classroom approach for the development of analytical thinking among undergraduates enrolled in BDA courses. The first is through immersive learning experiences and the second is through a student satisfaction survey. The research has been reviewed and approved by Universiti Teknologi PETRONAS through the Scholarship of the Teaching of Learning (SoTL). One complete module with detailed teaching and learning activities (TLA) was developed for an immersive learning experience, and students were provided with pre-class instruction.

A. Respondents

This study considers undergraduates enrolled in BDA courses at Universiti Teknologi PETRONAS (UTP) as the respondents. The study was conducted over four semesters to

ensure that the approaches and lesson plans are beneficial to the development of analytical thinking skills in undergraduate students. All students were informed that their performance would be monitored and used as data for this research study. Figure 4 visualizes the gender distribution of 134 participants aged 21 to 23 years: 80 (59.7%) are male students, while 54 (40.3%) are female students.

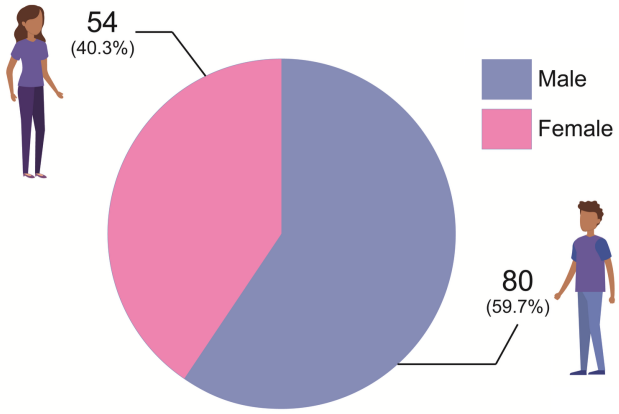


Figure 4: Distribution of participants' gender

B. Source 1: Immersive Learning Experience

The immersive learning experience consists of ten hands-on lab sessions with a detailed rubric assessment that each student must complete. Students will be given tasks and lesson objectives by a lab instructor. Throughout the lab sessions, the instructor will reinforce the partnership between practice and assessment of these skills and behaviors to improve participants' analytical thinking skills and decision-making. Once the hands-on lab sessions are complete, students are required to complete one group project and present the outcome to the lab instructor. This goal is to assess students' analytical thinking after they have completed immersive learning.

All tasks assigned to students were related to solving the identified business case scenario, which encouraged students' critical reasoning abilities and analytical potential. The grades are as follows: A (80–100%), B (60–79%), C (40–59%), D (20–39%), and E (0–19%). Students who score 80% or higher demonstrate strong analytical thinking and problem-solving abilities. Students with scores ranging from 60–79% represent a moderate level of analytical thinking skills. Students with scores ranging from 0–59% are considered weak since they struggle to finish the project and have poor analytical thinking skills.

Group	Participants	Male	Female
1	70	48	22
2	14	7	7
3	30	13	17
4	20	12	8

Table 6: Distribution of participants' gender based on groups

Table 6 shows that the 134 participants were divided into four small groups for the immersive learning experience (hands-on lab sessions) and were assessed using a detailed rubric. Table 7 presents the hands-on lab activities and active learning (AL) designed to develop analytical thinking skills among students through the BDA course.

Lab Activities	**Skills Advanced**
Lab 1: Descriptive Analytics using Excel Dashboard Activity: Making sense of data and prepare insight to action AL: Individual self-study	• Data preparation skills (data cleansing, data understanding, and data quality assessment) • Data visualization skills by creating interactive dashboard designs
Lab 2: Problem Solving for descriptive analytics Activity: Conduct business analytics on financial case study AL: Think pair and short-case scenario	• Business understanding • Data understanding • Provide insight to action recommendation • Create dynamic dashboard and analytical report
Lab 3: Descriptive Analytics using Big Data Analytics Dashboard Activity: Making sense of data and prepare insight to action AL: Short-case study and brainstorming	• Data preparation skills for massive data • Data cleansing, data understanding, and data quality assessment • Data modeling and visualization • Provide insight into action recommendations • Create dynamic dashboard and analytical report
Lab 4: Problem-solving Big Data Analytics (superstore case study) Activity: Short-case study AL: Think pair and short-case scenario Remarks: Descriptive analytics	• Data understanding • Analyze and integrate information from outsources to solve a real problem • Provide insight into action recommendations • Create dynamic dashboard and analytical report
Lab 5: Data Modelling and Data Visualization using Python for predictive analytics AL: Think pair and share	• Data modeling and data visualization • Determine the relationship between the data • Identify systematic visualization of the data • Provide insight into action recommendations • Create dynamic dashboard and analytical report
Lab 6: Machine Learning for predictive analytics AL: Group discussion	• Use programming and logical skills • Provide insight into action recommendations
Lab 7: Time Series Forecasting for Predictive Analytics AL: Group discussion	• Define a suitable chart for time series analysis • Provide insight into action recommendations • Create dynamic dashboard and analytical report
Lab 8: Sports Analytics using Moneyball Case Study	• Analyze and identify a suitable solution to the real problem and justify the decision • Create dynamic dashboard and analytical report
Lab 9: Health Analytics using Cancer Data Case Study	
Lab 10: Business Analytics using Sales and Marketing Case Study	

Table 7: Summary of the 10 hands-on lab sessions

C. Source 2: Student Satisfaction Survey

A satisfaction survey was distributed to each participating student at the end of each lab session to assess student satisfaction with the flipped teaching approach used in the hands-on lab session. The results of the satisfaction survey are provided in the next section. The students rated their satisfaction with the flipped learning teaching in three categories:

1. Very satisfied: Students are very satisfied with the teaching method and believe it is very effective in improving their analytical thinking skills.
2. Satisfied: Students are satisfied with the teaching method and believe it is moderately effective in developing analytical thinking skills.
3. Not satisfied: Students are unsatisfied with the teaching method and believe it is ineffective for improving their analytical thinking skills.

Results and Discussion

The findings of this study are divided into two subsections. The first subsection described the outcomes of an immersive learning experience by using descriptive statistics to clarify simple data features for data analysis based on a dataset of student performance. Meanwhile, the second subsection described the results of the student satisfaction survey.

A. Results of the Immersive Learning Experience

This study measures the ability of students' analytical thinking based on the participants' test performance, ability to solve the lab assignments, and the quality of their group project presentations. Table 8 shows the maximum marks a student can receive for each evaluation.

Evaluation	**Full Mark**
Test	10 points
Lab activity	20%
Project	100%

Table 8: Maximum scoring for each evaluation criteria

Descriptive statistics and basic graphical analytics were used to extrapolate the marks obtained by the participants as they provide clear overviews and metrics of the study, which form the foundation of nearly all quantitative data analysis. To describe the result in greater detail, several important measurements are used, including the maximum value, mean, minimum value, range, standard deviation, and variance.

Evaluation	Group 1 (N=70)	Group 2 (N=14)	Group 3 (N=30)	Group 4 (N=20)
Test Full mark: 10	Mean(μ) = 7.13 Min = 3 Max = 10 SD (σ) = 1.454	Mean(μ) = 8.57 Min = 7 Max = 10 SD (σ) = 1.016	Mean(μ) = 8 Min = 5 Max = 10 SD (σ) = 1.531	Mean(μ) = 7.5 Min = 5 Max = 9 SD (σ) = 1.235
Lab activity Full mark: 20%	Mean(μ) = 15.17 Min = 8.7 Max = 19.1 SD (σ) = 2.533	Mean(μ) = 15.14 Min = 13 Max = 17 SD (σ) = 1.657	Mean(μ) = 16.83 Min = 0 Max = 20 SD (σ) = 3.688	Mean(μ) = 17.8 Min = 17 Max = 19 SD (σ) = 0.761
Project Full mark: 100%	Mean(μ) = 75.84 Min = 43.5 Max = 95.5 SD (σ) = 12.664	Mean(μ) = 80.86 Min = 65 Max = 95 SD (σ) = 10.394	Mean(μ) = 84.17 Min = 0 Max = 100 SD (σ) = 18.340	Mean(μ) = 89 Min = 85 Max = 95 SD (σ) = 3.840

Table 9: Descriptive statistics for the evaluation of analytical thinking skills

The descriptive statistics for evaluating undergraduates' analytical thinking skills were validated using three different strategies: test, hands-on lab activity, and project (Table 9). The results obtained demonstrated the effectiveness of the teaching method, as students were able to score the test based on what they had learned during the immersive learning session.

A-1. Test marks

Table 9 presented the mean test score for the four groups assigned ranging from 7.13 to 8.57. Based on the test result, students in Group 2 achieved the highest mean score, while students in Group 1 achieved the lowest mean score. The average test result is above 7.0, indicating that most students were able to use analytical thinking skills to answer their tests. The results also show that the standard deviation for all groups ranges from 1.016 to 1.531, which is considered low and consistent. A low standard deviation value indicates a low dispersion range among all marks with the mean, indicating high precision. This demonstrates that the flipped learning approach can produce consistent and predictable results over the course of four semesters, making it suitable for improving undergraduates' analytical thinking skills.

A-2. Lab activity marks

The hands-on lab activity is part of the immersive learning experience and is intended to assess the student's analytical thinking skills. All four student groups have nearly the same mean score based on their performance. The highest average laboratory mark obtained is 17.8, while the lowest average laboratory mark obtained is 15.14. According to these findings, most students have an average level of analytical thinking skills. The group project results revealed statistically significant differences in mean values between Group 2 and the other groups, with a 15.02 difference from Group 1, a 6.69 difference from Group 3, and a 1.56 difference from Group 4. Group 1 had the lowest mean value of test results despite having the largest sample size compared to the other groups.

A-3. Project marks

Table 9 and Figure 5 show that of 134 students, 79 of them scored grade A, 48 students got B grade, 6 students got C grade, none getting D grade and only 1 student got E grade. The student who scores E grade was found to have an absenteeism issue. This shows that the immersive learning experience of the 10 hands-on lab sessions has equipped the students with

excellent analytical thinking skills for learning the BDA course. Consequently, the implemented innovative teaching approach helped in developing the analytical thinking skills of undergraduates. Goals, outline plans, and best approaches for making sense of data and transforming it into a meaningful format can be used to foster analytical thinking abilities. Therefore, the flipped classroom approach is suitable for the BDA course since it exposes students to creative TLA and immersive learning experiences, both of which are great for fostering critical thinking skills.

Grade	Group 1 (n=70)	Group 2 (n=14)	Group 3 (n=30)	Group 4 (n=20)
A (80–100%)	Male = 17 Female = 12	Male = 2 Female = 3	Male = 11 Female = 14	Male = 12 Female = 8
B (60–79%)	Male = 26 Female = 9	Male = 5 Female = 4	Male = 1 Female = 3	Male = 0 Female = 0
C (40–59%)	Male = 5 Female = 1	Male = 0 Female = 0	Male = 0 Female = 0	Male = 0 Female = 0
D (20–39%)	Male = 0 Female = 0	Male = 0 Female = 0	Male = 0 Female = 0	Male = 0 Female = 0
E (0–19%)	Male = 0 Female = 0	Male = 0 Female = 0	Male = 1 Female = 0	Male = 0 Female = 0

Table 10: Students' project grades based on flipped classroom approach by groups

Table 10 shows marks for student projects using the flipped classroom approach based on group, along with detailed gender distribution scores. The results show that most students in each group scored grades A and B. Six students in Group 1 received grade C, while one student in Group 3 received grade E (due to absence).

Grade	Male	Female	Total
A (80–100%)	42	37	79
B (60–79%)	32	16	48
C (40–59%)	5	1	6
D (20–39%)	0	0	0
E (0–19%)	1	0	1
Total	80	54	134

Table 11: Summary of students' project grades

Table 11 summarizes the students' analytical thinking performance based on group project marks. Most male students receive A and B grades, with one male student receiving an E due to absenteeism. Meanwhile, most female students received A and B grades. Overall, all students can utilize group project tasks because the majority have high and above-average analytical thinking scales when assessed based on their group project marks. Figure 5 depicts the outcome of students' analytical thinking skills based on group project presentations.

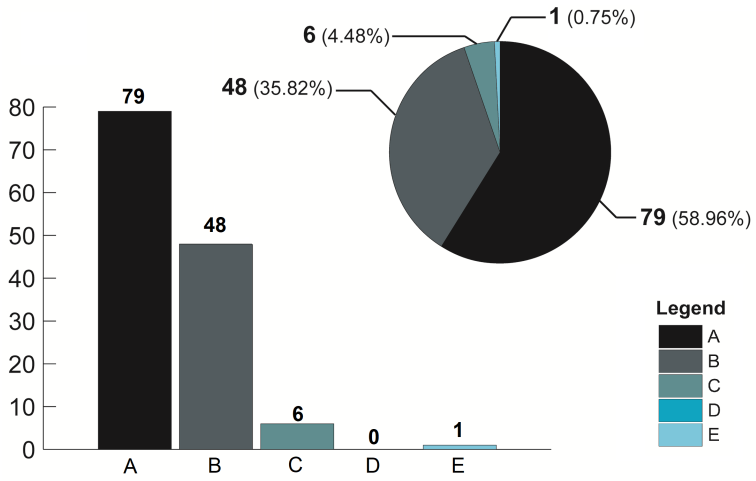
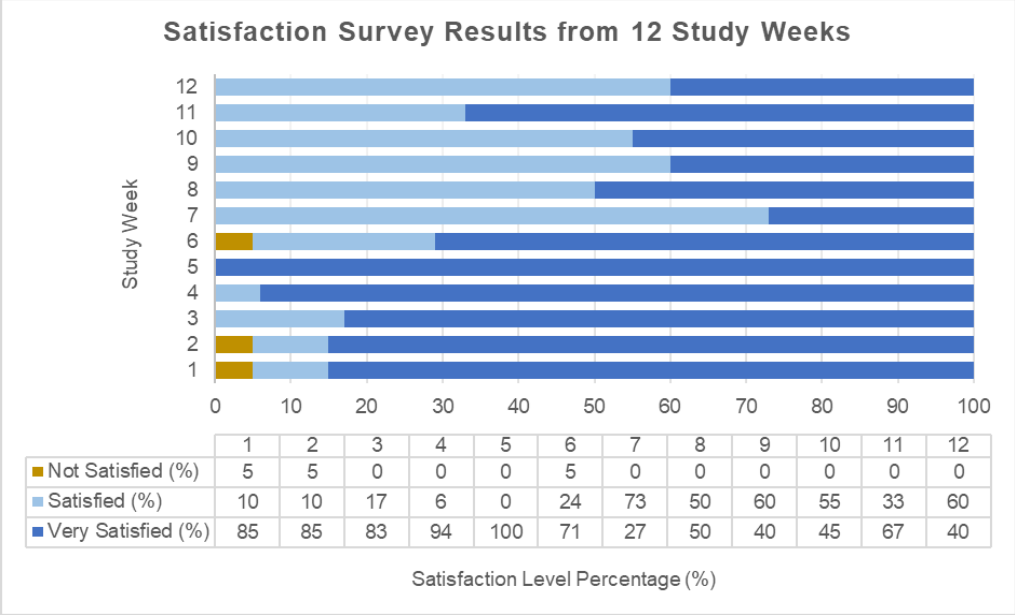


Figure 5: Project presentation grade distribution

B. Results of the Student Satisfaction Survey

Following that, we analyzed students surveys using three-points Likert scales to measure their satisfaction with the flipped classroom approach. According to the survey results, most students were pleased with the flipped classroom course plan (Figure 6).



	1	2	3	4	5	6	7	8	9	10	11	12
Not Satisfied (%)	5	5	0	0	0	5	0	0	0	0	0	0
Satisfied (%)	10	10	17	6	0	24	73	50	60	55	33	60
Very Satisfied (%)	85	85	83	94	100	71	27	50	40	45	67	40

Figure 6: Satisfaction survey result

Conclusion

In this pilot study, the participating students were guided to solve complex business problems using analytical thinking skills through 10 hands-on lab sessions. Analytical thinking abilities are required and in high demand, particularly when solving BDA tasks. Participating students have demonstrated their ability to compare different sources of information, transform data into a meaningful format, use their analytical thinking skills to break down complex problems into manageable components, and propose an appropriate solution to the problem.

The final project presentation has shown that students were able to interpret data and perform descriptive analytics and forecasting using the provided HR dataset. Furthermore, students were able to identify hiring strategy issues and hidden patterns in the dataset, generate insight into action, and propose a reliable solution to the new hiring strategy, resulting in quality decision-making for business analytics. According to the results of the experiment, flipped classroom approach is successful in developing students' analytical thinking skills. The evaluation enabled researchers to:

- construct meaning through identified relevant TLA
- students and instructors have a more fulfilling and successful TLA experiences
- determine the best solution and provide quality decision-making

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