Comparative Analysis and Evaluation between Traditional and Online Learning in Engineering Education, Focused on Introduction to Engineering

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Abstract

Due to the COVID-19 Pandemic, face-to-face interactions are prohibited by the government, pushing various institutions to shift from the traditional to the online style of teaching. However, the question is whether online learning is as effective as the traditional learning mode. This research explores the learning experience and current issues within engineering education. It compares the learning experience between traditional learning and the enriched virtual mode of learning in Introduction to Engineering. The researchers conducted the study at the University of Santo Tomas, where they identified two groups of students. The control group consists of students from the traditional learning method, and the experimental group consists of students from the enriched virtual mode. The researchers used the Mann-Whitney-U test to see if there is a significant difference between groups under the factors chosen by the researchers that affect the learning experience. The main findings of the research state that there is no significant difference between the control and experimental groups in learning effectiveness, student performance, and student confidence. Researchers found a significant difference between the two groups in the two dependent variables, student satisfaction and faculty interaction. The study concluded that online learning is as significant as traditional learning methods and is even superior to the traditional method in some factors used in the study. Lastly, the researchers recognize that online learning can be adapted as the learning tool used in delivering Introduction to Engineering in the Faculty of Engineering at the University of Santo Tomas.

Keywords
Online, Learning, Engineering, Education, Traditional.

1. Introduction
Higher Education is critical for students to prepare for global citizenship, develop a sense of well-being, and foster personal and social responsibility (Aragoni 2019). One of the fields of higher education includes Engineering. Engineering Education focuses on providing societal growth by systematically applying both science and mathematics. The application of engineering education helps create new products, economic growth, and human development associated with technological advancements. Innovations necessitating scientific and technological knowledge are part of the processes that enable new markets to emerge and speed growth (Cabaces 2018).

Furthermore, Cabaces elaborated that with the fast-paced changes in technology, there is a need to update engineering education to keep up with these changes. Thus, educational guidelines are proposed and issued to develop an outcomes-based education (OBE) system. This is not the traditional education system wherein the instructor lectures, and students' learnings are assessed mainly through examinations. This system will enhance students' ability to work efficiently and effectively with other people, solve complex problems, and learn independently (Moore et al. 2017).

The Conceive-Design-Implement-Operate (CDIO) initiative aims to re-emphasize teaching human-centered engineering practices and learning methods regarding the engineering curriculum to better prepare the graduating students for real-world engineering tasks. The summarized goals of a CDIO based engineering education are to: master a deep working knowledge of the technical fundamentals; lead in the creation and operation of end products, processes, and systems; and understand the importance and strategic impact of research and technological development in society (Laurito 2019).

The Faculty of Engineering of the University of Santo Tomas aims to utilize the CDIO approach in all the engineering programs they offer, such as Bachelor of Science in Civil Engineering, Chemical Engineering, Electrical Engineering, Electronics Engineering, Industrial Engineering, and Mechanical Engineering. Students are required to take the pre-major year collaborative program under the Faculty of Engineering in their freshman year, which is called the EPYC program. This program includes an Introduction to Engineering course, which acquaints students with the various engineering professions, and covers topics such as: systems thinking; observation and perception activities; critical and creative thinking activities; and design thinking activities.

This Introduction to Engineering course was originally taught in the traditional classroom setup. Due to the COVID-19 pandemic, President Rodrigo Duterte announced the suspension of classes for a couple of months, which led some universities to shift from the traditional to the enriched virtual mode of learning to adapt to the new normal. Traditional face-to-face learning is what most schools and universities utilize, and online teaching and learning are new to them.

Adjustment is another challenge encountered by students, parents, and teachers during online learning, as Midcalf and Boawright (2020) stated. Apart from the lack of resources such as access to the internet, there is also the unavailability of a conducive learning environment. Students' surveys also revealed that their main concern with the enriched virtual mode of learning is the lack of face-to-face communication and interaction between professors and students. Instead of asking their professors directly, students opted to do self-directed learning (Xhaferi and Xhaferi 2020). Students are not the only ones burdened with this type of learning. Teachers are also given the additional responsibility of providing effective online learning. They need to develop an engaging and deeper connection with their students (Abramson 2020). Lastly, Xhaferi (2020) mentioned that one of the major setbacks of the enriched virtual mode of learning is that not all courses can be learned virtually. In other words, some subjects require experimental activities that can only be conducted in school laboratories.

With the growing number of students enrolling in the Faculty of Engineering, adapting the enriched virtual mode of learning to the new curriculum will benefit faculty members and students. Therefore, the learning experiences of students in the new method of learning give rise to this research. A deeper understanding of the difference in learning experiences between traditional and enriched virtual modes of learning is crucial to providing knowledge and guidelines for students, faculty, policymakers, and further research.

1.1 Objectives

The research will be conducted on the Faculty of Engineering students who took the Introduction to Engineering course in the traditional setup, and students who took the course in an online setup. Thus, the primary objective of the study is:

- To compare the learning experience between the traditional learning and the enriched virtual mode of learning in the Introduction to Engineering course.

The secondary objectives of the study are the following:

- To compare the Learning Effectiveness of students from the experimental group and control group.
- To compare the Satisfaction Level of the students from the experimental group and control group.
- To compare the Student Performance from the experimental group and control group.
- To compare the Confidence Level of the students from the experimental group and control group.
- To compare the Faculty Interaction with students between the experimental group and control group.
- To compare the Student Interaction with students from the experimental group and control group.

2. Literature Review

The purpose of this research revolves around Engineering Education with regards to the traditional and enriched virtual modes, therefore identifying the significant elements is critical. These elements or factors include: Online Learning is Superior, Traditional Learning is Superior, and the resemblance between traditional and online learning (Table 1).

Table 1. Relevant Criteria

Criteria	Relevance/Significance	Reference
Online Learning is Superior	Numerous universities are leaning towards online course delivery as it promises to be effective while also allowing for flexibility in scheduling.	Bergeler and Read (2020)
	For asynchronous learning, pre-recorded lectures on learning content, videos, quizzes, and module assignments are uploaded online. Interactive discussions and higher-order learning activities like problem-solving then occur during the class as the synchronous component.	Rehman et al. (2021)
Traditional Learning is Superior	Technology separates human-to-human interaction, an essential factor in a student's learning experience.	Lay Kee (2020)
	Students preferred interactive lectures over video lectures because they were more agreeable. Students found e-learning to be less persuasive than traditional teaching methods.	Jamil et al. (2021)
The resemblance between Traditional and Online Learning	The similarities between both practices are the keys to effective learning: a clear understanding and delivery of instructions and two-way communication from both teachers and students.	Glazier and Harris (2020)

Multiple industries have been affected by the tragedy caused by the COVID-19 pandemic, where industries have transitioned into the "new normal" of working at home. Studies have shown that this new normal setup has both positive and negative effects on a person's performance, including other interconnected factors. Furthermore, the "new normal" is called "enriched virtual learning," wherein all activities are done online in the educational industry. Existing studies on this topic contradict one another, but key factors in addressing the effects of this educational approach overlap one another, which the proponents identified.

2.1 Framework Used in the study

The Community of Inquiry is a framework for engagement and communication that focuses on the quality and dynamics of online teaching, the learning process, and the online learning experiences, which occur through the interaction of three elements, namely, social presence, teaching presence, and cognitive presence. These three elements are the vital components for effectively producing a quality educational experience and learning outcomes. A study by Nagel and Kotze (2011) was based on the study of the Community of Inquiry framework by Garrison and other co-authors in the year 2000. In the mentioned framework, it is used to achieve the best possible outcome in learning processes and to improve higher-order thinking skills in students through critical reflection and critical discourse between students and teachers.

2.1.1 Social Presence

The elements of social presence are emotional expression, found in affective responses, open communication, found in interactive responses, and group cohesion, found in cohesive responses (Maddrell 2017).

2.1.2 Cognitive Presence

This element is an essential component in critical thinking because it represents the extent to which the students construct meaning through critical reflection and discourse (Nagel and Kotze, 2011).

2.1.3Teaching Presence

Teaching presence is made possible through a reliable and competent mentor. Without an effective teacher, education would fail because they play an essential role in establishing a critical community of inquiry (Figure 1).

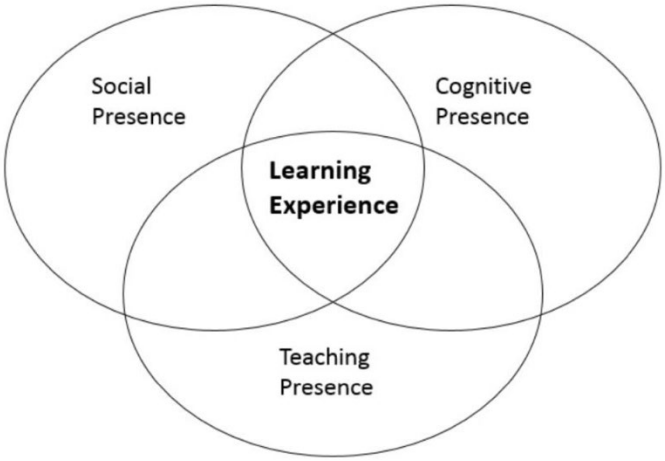

Figure 1. Community of Inquiry Framework (Garrison et al. 2000)

3. Methods

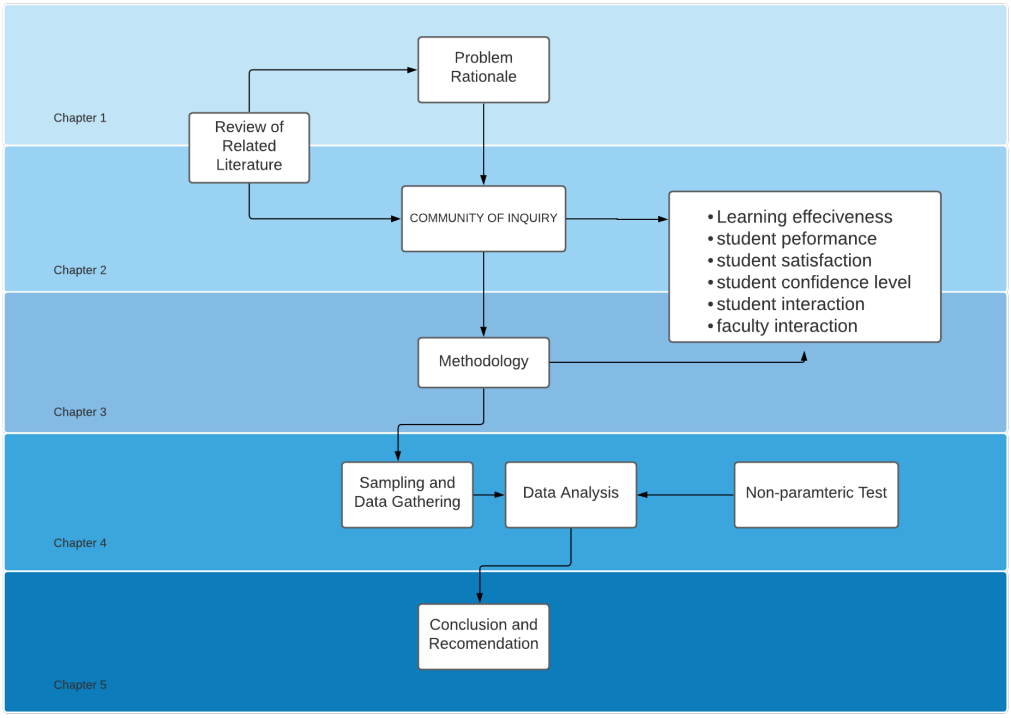

Figure 2. Research Paradigm

The proponents of the research utilized a process flow chart to create the study's conceptual framework for the process to be followed in detail for the research (Figure 2). The study started by identifying the learning experience in the "enhanced virtual mode" of learning and its difference from the traditional method of learning. Thus, the proponents compared the difference between students' learning experience, satisfaction, performance, confidence, and faculty, student interaction from the conventional mode of learning, identified as the control group, and students from the "enriched virtual mode'' identified as the experimental group. Alongside relevant literature, through pilot testing and tool validation, factors were identified that had a significant impact on the learning experience, which were used in assessing the two modes of learning. The proponents of the research then proceeded to Sampling and Data Gathering to identify the respondents, sampling size, and mode of analysis of the study. The collected data has undergone Data Cleaning to ensure the quality of the data set by removing outliers and insignificant responses from the sample. Data Analysis was conducted by the proponents from the valid data set. This data was analyzed through non-parametric tests to identify the difference between the results from the two groups. All things considered, the proponents have provided a conclusion for their study and a recommendation for the Faculty of Engineering of the University of Santo Tomas and for future researchers.

3.1 Data Analysis

The proponents of the research used a non-parametric statistical method, specifically the Mann-Whitney U-test. Therefore, the data that was collected should be compliant with four assumptions to proceed with the said test. The first assumption that needs to be satisfied is that the dependent variable should be measured on an ordinal scale or a continuous scale. The second assumption is that the independent variable should be two independent categorical groups. The third assumption is that observations should be independent. In other words, there should be no relationship between the two groups or within each group. Lastly, the fourth assumption is that observations are not normally distributed.

4. Data Collection

The study was conducted in the Faculty of Engineering of the University of Santo Tomas. The study focused on students who took the course Introduction to Engineering in the traditional method (A.Y. 2019-2020), which was identified as the control group, and those who took the course in the "enriched virtual mode" (A.Y. 2020-2021) which was identified as the experimental group for the study. To examine the factors affecting learning experience in the different learning modes, students who experienced the different methods of learning under the CDIO approach were chosen. The proponents utilized a probability sampling technique, specifically simple random sampling. The proponents of the research obtained a master list of students for the Class of 2023 and 2024, and all subjects were selected randomly. The proponents classified the respondents by engineering major to ensure that each major was represented in the study. For the Data Gathering procedure, the proponents of the research utilized survey questionnaires and related literature. The proponents created a survey questionnaire utilizing the 5-point Likert Scale, developed from modified questions from the related research and specific questions formed for the study. This survey would be the primary source of data for this research. Supporting journals and articles were included to support and strengthen the conclusions derived from the data gathered.

5. Results and Discussion

5.1 Cronbach's Alpha

The proponents of the research utilized Cronbach's Alpha test to see if their multiple-question Likert scale surveys were reliable. Based on Table 2, the dependent variables Learning Effectiveness, Student Satisfaction, and Faculty Interaction have an excellent internal consistency while the dependent variables Student Performance, Student Confidence, and Student Interaction have good internal consistency. To conclude, the dependent variable groups have acceptable internal consistency, making the questionnaire utilized reliable.

Table 2. Cronbach's Alpha

Descriptive statistics and coefficients of reliability of Questionnaire			
Dependent Variable	Questions	Cronbach's Alpha	Internal Consistency
Learning Effectiveness	1 - 13	0.928	Excellent

Student Satisfaction	14 - 18	0.924	Excellent
Student Performance	19 - 25	0.871	Good
Student Confidence	26 - 37	0.865	Good
Faculty Interaction	38 - 41	0.903	Excellent
Student Interaction	42 - 44	0.814	Good

5.2 Assumptions

The researchers used the Mann Whitney U-test to analyze the data they had collected. In using the Mann-Whitney U-Test, the data that was collected should be compliant with four assumptions to proceed with the said test.

The first assumption is that the dependent variable should be measured on an ordinal scale or a continuous scale. For this research, the proponent has identified 6 dependent variables, which are: Learning Effectiveness, Student satisfaction, Student performance, Student Confidence, Faculty Interaction, and Student Interaction, and these dependent variables are measured through a Likert Scale questionnaire which utilized the scale of 5: Strongly Agree, 4: Agree,3: Neutral, 2: Disagree, 1: Strongly Disagree. The data collection produced an ordinal scale data set for the dependent variables; thus, the first assumption is compliant.

The second assumption is that the independent variable should consist of two independent, categorical groups. For this research, the proponent has identified 2 independent variables, namely the control group, which are the students from the Class of 2023, and the experimental group from the Class of 2024, thus the second assumption is compliant.

The third assumption is that observations should be independent. In other words, there should be no relationship between the two groups or within each group. The data samples for this research are observed to be independent of each other because the participants of the research were not influenced by each other as the data gathering is done through an online platform, thus the third assumption is compliant.

The last assumption is that observations are not normally distributed. However, they should follow the same shape.

Table 3. Tests of Normality

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	BATCH	Statistic	df	Sig.	Statistic	df	Sig.
LEARNINGEFFECTIVENESS	1.00	.324	192	.000	.799	192	.000
	2.00	.302	192	.000	.817	192	.000
STUDENTSATISFACTION	1.00	.244	192	.000	.849	192	.000
	2.00	.336	192	.000	.732	192	.000
STUDENTPERFORMANCE	1.00	.323	192	.000	.812	192	.000
	2.00	.285	192	.000	.849	192	.000
STUDENTCONFIDENCE	1.00	.226	192	.000	.906	192	.000
	2.00	.253	192	.000	.896	192	.000
FACULTYINTERACTION	1.00	.226	192	.000	.882	192	.000
	2.00	.285	192	.000	.766	192	.000
STUDENTINTERACTION	1.00	.249	192	.000	.784	192	.000
	2.00	.307	192	.000	.745	192	.000

a. Lilliefors Significance Correction

Table 3 shows that all the data collected is not normally distributed since its p-value is less than Alpha (0.05). Furthermore, to be able to identify the difference between groups, the proponents of the research utilized a histogram and compared the shape of the distribution of the dependent variable. When the distribution has a similar

pattern, the medians can be used to summarize the differences between the dependent variables. However, if the distribution has a different pattern, the difference in the mean ranks would be used to summarize.

To summarize, the observed data are all compliant under the assumptions of the Mann Whitney U test. Thus, the researchers utilized this statistical tool to analyze the observations and hypotheses of the study.

5.3 Mann-Whitney U Test

Table 4. Summary of the Main Findings

Summary of Findings				
Reseach Questions	Factor	Group	Mann Whitney U Test	Conclusion
Questions 1-13	Learning Effectiveness	Controlled Group Experimental Group	0.333	No significant Difference
Questions 14-18	Student Satisfaction	Controlled Group Experimental Group	0.000	Significant Difference
Questions 19-25	Student Performance	Controlled Group Experimental Group	0.359	No significant Difference
Quesiosn 26-37	Student Confidence	Controlled Group Experimental Group	0.350	No significant Difference
Questions 38-41	Faculty Interaction	Controlled Group Experimental Group	0.000	Significant Difference
Questions 42-44	Student Interaction	Controlled Group Experimental Group	0.087	No significant Difference

Table 4 outlines the research questions and the summary of findings obtained through the analysis done by the proponents of the research. The main quantitative findings are:

- For the dependent variables Learning Effectiveness, Student Performance, Student Confidence and Student Interaction, there is no significant difference between the control and experimental groups as their p-value is greater than 0.05.
- For the dependent variable Student Satisfaction, a significant difference were found between the control and experimental groups as their p-value is less than 0.05.
- For the dependent variable Faculty Interaction, a significant difference was found between the control and experimental groups as their p-value is less than 0.05.

Table 5. Significant Difference

Significant Difference				
Reseach Questions	Factor	Group	Mean Rank	Conclusion
Questions 14-18	Student Satisfaction	Controlled Group	167.150	Student Satisfaction is higher for the Experimental group
		Experimental Group	217.815	
Questions 38-41	Faculty Interaction	Controlled Group	156.240	Experimental group is more satisfied with the Faculty
		Experimental Group	228.760	

Based on the main findings, there is a significant difference between the control and experimental groups for the dependent variables of Student Satisfaction and Faculty Interaction. Table 5 outlines the difference in mean rank between the groups, and the findings are:

- A significant difference was found between the control group and experimental group in terms of Student Satisfaction, with a value of 167.150 and 217.815 respectively. It can be concluded that students from the enriched virtual mode are more satisfied with what they learn compared to those who took the course in the traditional mode. A study by Elfaki et al (2019) supports the results arrived at by the survey conducted by the proponents because in their study, it claims that students who are more engaged in virtual learning are performing better than those who are in traditional learning. Additionally, the study of Sharma et.al (2020) that was based on the COVID-19 Pandemic setup, shows that more than half of the population of their respondents,

which are the students at Chitwan Medical College, are satisfied with virtual learning. This concluded that virtual learning is now a better alternative to traditional learning and even with the COVID-19 situation, educators can still provide the service that the students need. The factors that also helped the proponents with this conclusion are the online tools that help students in collaborative learning and offer students a chance to have their own pace in academic requirements or asynchronous setups. (Zhang et al. 2020).

- A significant difference was found between the control group and experimental group in terms of Faculty Interaction, with a value of 156.240 and 228.760 respectively. It can be concluded that students from the enriched virtual mode are more satisfied with the faculty interaction compared to those who took the course in the traditional mode. Gultom and Suhartini (2020) emphasized the importance of interaction in the teaching and learning process. Numerous studies have shown that lack of comprehension among students is higher through online learning compared to traditional learning due to limited interaction. During this time, the quality and quantity of student-teacher interaction is one of the most crucial factors that affect student's learning and is associated with increased student satisfaction (Ralston-Berg et al., 2015). A study by Ni (2013) supports the results arrived at by the survey conducted by the proponents because the research states that since online courses substitute classroom interaction (between student and teacher, and student and student) with discussion boards, synchronous chat, and emails, the effectiveness of an interactive online venue is undisputed. When it comes to student-teacher interaction between synchronous and asynchronous sessions, Alhih et al. (2017) found that synchronous sessions are more effective than asynchronous. Synchronous sessions allow students to interact more with one another and their teacher since they can ask questions or clarifications on the spot just like the traditional setup.

6. Conclusion

6.1 Achievement of Research Objectives

Table 6. Achievement of Primary Objective

Achievement of Primary Research Objective	
Research Objectives	Achievement of Research Objectives
To compare the learning experience between the traditional learning and the enriched virtual mode of learning in the Introduction to Engineering course.	This objective was fulfilled through extensive literature review in the areas of both traditional and online learning. Survey questionnaires are formulated around the factors identified by the researchers that influences learning experience. This study shows that online learning is as effective as the traditional method of learning and is even superior to the latter in some aspect.

Table 6 presents the primary objectives and how it is achieved through the research.

Table 7. Achievement of Secondary Objectives

Research Objectives	Achievement of Research Objectives
To compare the Learning effectiveness with students between the experimental group and control group.	This objective was fulfilled through the analysis of the survey questions under the factor "Learning Effectiveness". SPSS was utilized for the analysis, where the proponents of the research identified that there was no significant difference between the learning effectiveness of the groups.
To compare the Satisfaction level with students between the experimental group and control group.	This objective was fulfilled through the analysis of the survey questions under the factor "Student Satisfaction". SPSS was utilized for the analysis where the proponents of the research identified that students from the enriched virtual mode of learning are more satisfied compared to students from the traditional

	mode of learning.
To compare the student performance with students between the experimental group and control group.	This objective was fulfilled through the analysis of the survey questions under the factor "Student Performance". SPSS was utilized for the analysis where the proponents of the research identified that there was no significant difference between the student performance of the groups.
To compare the Confidence Level with students between the experimental group and control group.	This objective was fulfilled through the analysis of the survey questions under the factor "Confidence Level". SPSS was utilized for the analysis, where the proponents of the research identified that there was no significant difference between the confidence levels of the groups.
To compare the Faculty Interaction with students between the experimental group and control group.	This objective was fulfilled through the analysis of the survey questions under the factor "Faculty Interaction". SPSS was utilized for the analysis where the proponents of the research identified that students from the enriched virtual mode of learning are more satisfied with the faculty interaction compared to students from the traditional mode of learning.
To compare the Student Interaction with students between the experimental group and control group.	This objective was fulfilled through the analysis of the survey questions under the factor "Student Interaction". SPSS was utilized for the analysis where the proponents of the research identified that there was no significant difference between the student interaction of the groups.

Table 7 presents the secondary objectives and how it is achieved through the research.

6.2 Main Findings

The main findings of the study are the recognition of online learning as an additional learning tool in engineering education. This study concludes that online learning is as significant as the traditional learning method and is even superior to the traditional mode in some of the factors used in the study.

The key contributions of this study are

- Awareness for the Students, Faculty of Engineering, and the Higher Education on the effectiveness of online learning as a tool other than traditional learning.
- A recognition that online learning can be adapted as the learning tool used in delivering Introduction to Engineering in the Faculty of Engineering at the University of Santo Tomas.

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Biographies

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Bea Santos is a fourth-year Industrial Engineering student from the University of Santos Tomas. She is currently taking a specialization track in Production Engineering. She previously joined the UST Industrial Engineering Circle as the Executive Associate for Finance. Throughout college, she has acquired certificates of completion in her courses for SAP Business One – SAP Basic Logistics and Financials. Moreover, upon completion of her internship in Philippine Koktai Steel Corp., she has been given internship awards of excellence such as Outstanding Leadership and Outstanding Work Ethics.

Charmina Lou C Bautista is an assistant professor from the University of Santos Tomas since 1997. She graduated BS Industrial Engineering from UST in 1995 and MA Educational Studies with Honors from the University of Western Australia in 2001. She also served the University as Executive Assistant in the Office of Planning and Development from 2002-2004 and as Chairperson of the Industrial Engineering Department from 2010-2012. She founded WEI2SUCCESS, INC., a training and consultancy company in 2012.