A Proposed Decision Matrix on Student Engagement for Engineering Online Learning Using Factor Analysis and Analytical Hierarchy Process

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Abstract

There were many attempts to establish online learning in the education system that solely conducted the traditional face-to-face way of teaching and learning over the course of time. The expeditious development of the digital age made online learning emerge along with difficulties in dealing with engagement and misbehavior that is unique to the online environment. The study aimed to propose a decision matrix with respect to laboratory, lecture, assessment, and examination that will support and enhance the student engagement of students in an online learning set-up. Additionally, the study also identified the common misbehaviors that students portrayed in an online set-up. The target respondents of the study are Engineering students and instructors across Metro Manila. Data collection was done via survey questionnaire for the students which were analyzed through Exploratory Factor Analysis (EFA). Moreover, an expert interview was conducted for the instructors to complete the Analytical Hierarchy Process (AHP) which was utilized to determine the most preferred component per criterion; laboratory prefers Collaboration with Peers, lecture prefers Student Support, assessment prefers Accessibility to Course Materials, and examination prefers Student Support. Common misbehaviors of Engineering students were also found to be present and common to most of the respondents.

Keywords

Student engagement, Online learning, Engineering, Exploratory Factor Analysis (EFA), Analytical Hierarchy Process (AHP)

1. Introduction

Online learning, also known as E-learning, distance learning, or web-based learning, has been defined to be any type of education that involves the usage of information technology to deliver instruction to learners. (Ruiz et al. 2006 as cited in Philips 2015). While there are attempts to establish online learning, it was never fully utilized because a

face-to-face setting was more favored (Dookwah and Julien 2020). Albeit not completely implementing this, online learning has brought forth its convenience to the field of education especially now in the 21st Century. Online learning offers numerous opportunities; however, these opportunities are also affiliated with doubts and disadvantages.

The outbreak of COVID-19 has everyone shaken and realized that multiple countries are not ready and has disrupted the educational sector all over the world. In developing countries, online learning remains a challenge (Zheng et al. 2020). CHED has implemented an alternative set-up however it was suspended due to different factors (Toquero 2020). Furthermore, this proposal has been met with concerns as a large number of the population have limited access to electronic devices, having an unstable internet connection, lack of financial support, low resources (Pastor 2020, Mirandilla-Santos 2016, as cited in Lapitan et al. 2020; Khalil et al. 2021).

Engineering Education is a particular area of tertiary education (Ozadowicz 2020). Ozadowicz (2020) also mentioned that this area will be considered to have effective learning and teaching based on the outcomes of the practical exercises, laboratory classes, experiments; thus, it is crucial to have laboratory classes in Engineering Education. In online learning, not all students can possibly perform experiments in their homes or to provide home-based labs (Morris 2015 as cited in Pg-Ya'akub 2018). With the current technological progress, there is a possibility to force changes in the approach with the usage of online services and tools (Jara et al. 2011, Potkonjak et al. 2016, Arras et al. 2017, as cited in Ozadowicz, 2020). Overall, there is a need for universities to re-evaluate their system. Due to these factors, the application of this change in practice to Engineering education is observed to be relatively slow in trend (Ozadowicz 2020).

Both faculty and students are experiencing frustrations and hardships to cope up with the challenges of the new system (Pastor 2020, Mirandilla-Santos, 2016, as cited in Lapitan et al., 2020). These issues and challenges contribute to problems with engagement and behaviors shown by the students. It is the utmost priority of faculty members to ensure that students are engaging even if everything shifts online. Student engagement is very important in online learning because students seem to have fewer opportunities to be engaged with the university (Bolliger and Martin 2018). Engagement can be evidence of students' effort in developing their knowledge which leads to a high level of student success (Britt 2015, as cited in Bolliger and Martin, 2018). In addition to that, being aware of the students' misbehaviors during online learning is also essential. While there are studies about classroom misbehaviors, it is almost exclusive to the traditional face-to-face settings (Vallade Kauffman, 2018).

With the said challenges and issues, the researchers will focus on Engineering students to be able to mitigate the gap seen in an Engineering online set up which is the lack of student engagement. Moreover, the study will contribute to the Engineering sector regarding student engagement in an online set-up.

1.1 Objectives

The research study will be conducted on Engineering students and the primary objective of the study is:

- To propose a Decision Matrix for student engagement in online learning with respect to laboratory, lecture, assessments, and examinations.

While the secondary objective of this study includes the following:

- To determine which engagement strategies have a significant effect on student engagement.
- To determine the factors that influence student engagement
- Exploration of the common misbehaviors of the Engineering students in the online learning set-up.

2. Literature Review

In this work, the study focuses on engineering education thus finding the relevant factors for online learning is essential. Four (4) items namely, lectures, laboratory, assessment, and examination were seen to be relevant factors in engineering education; therefore, in accordance to how significant they are, the researchers utilized these as the criteria for the study. Moreover, from these challenges, similar or common factors that affect engineering student engagement are identified to be in terms of Environment, Resources, and an Instructor's Approach and Role (Table 1).

Table 1. Relevant Criteria

Criteria	Relevance/significance	Reference
Laboratory	A laboratory course is an essential part of the Engineering curriculum and plays a big part in improving the knowledge and skills of students. "The engineer must 'feel' the structure, understand how the material behaves under various loads, and be able to make measurements correctly."	O. Smirnova and N. Smirnova (2020)
Lecture	The implementation of seminars and lectures is one of the specific factors towards a successful Engineering education. These are essential in Engineering education for students to be guided for their learning; thus, to gain substantive knowledge.	Ozadowicz (2020)
Assessment	Homework assignments have different content specifics depending on a particular engineering course and are considered a critical avenue for out-of-class learning to deepen students' understanding of in-class knowledge.	Li et al. (2018)
Examination	Analyzing and designing simple devices and structures, as well as more sophisticated systems, is a significant aspect in any engineering course. Examination is a way for students to be tested on their knowledge and abilities by solving problems that can be approached in a variety of ways while still yielding the same outcome.	Andersen (2020)

Multiple studies have shown the importance of engagement in the field of education. Therefore, engagement in the online set-up is as important and fundamental in the traditional setting (Lin et al. 2016; Martin and Bollinger 2018). It is said that engagement strategies are vital for it can provide positive learning outcomes for the students in activities, such as participation in discussions and collaborative work. In addition to that, instructor presence in an online learning set-up is vital and is believed to promote a higher level of engagement (Lee et al. 2021).

Student misbehavior is something an instructor cannot avoid (Johnson et al., 2016), and these can occur either in traditional face-to-face learning or in the online mode of learning. Erdem and Kocyigit (2019) simply referred to student misbehavior as something that is undesired student behavior. Generally, studies about student misbehaviors in the online set-up are under-researched. Li and Titsworth's (2015) study about student misbehaviors have found that while there are similarities of misbehaviors between traditional and online set-up, they also found that there are ones that are unique in the online set-up. Furthermore, similar student misbehaviors were also found in the study of Posner (2016) but it was done in the perception of the instructors.

2.1 Framework Used in the Study

Moore's interaction model, which proposes three interaction categories: student-student, student-instructor, and student-content, is one of the major models that define interaction in distance education (Khalil et al. 2021). Moreover, Moore's framework (see figure 1) is widely cited in distance education literature (Moore et al. 2016) as it "provides an easily observable, measurable variable to evaluate the impact of interaction in online courses" (Roblyer and Wiencke 2003 as cited in Lin et al. 2016). It is established that interactions with peers, teachers, and content can help learners become more active and engaged in their courses (Lear et al., 2010 as cited in Martin and Bolliger, 2018). Using the interaction framework will help us understand the interaction that occurs among the instructor, student, and content (Lin et al. 2016). In the study of Khalil et al. (2021), they utilize Moore's framework in emergency online learning with low resources as it only requires minimal interactions that can still produce effective learning. It was further added that this framework represents one of the most robust bodies of research on an online learning setup (Hodges et al. 2020 as cited in Khalil et al. 2021) (Figure 1).

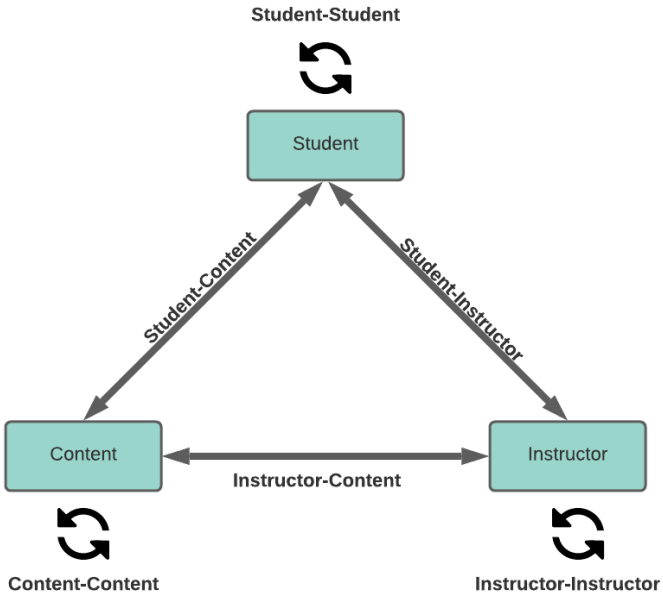

Figure 1. Types of Interaction from Martin and Bollinger (2018), based on Moore's Interaction Framework (1989)

Student-Student
Considered as an inter-learner interaction between one student to another, where it may be in the form of a small group, and it can be whether an instructor is present or not (Moore, 1989). It is implied that in the online learning set-up, this interaction is deemed to be extremely vital (Moores, 1989; Martin and Bollinger, 2018; Khalil et al., 2021). This interaction is found to be an effective strategy for increasing student engagement.

Student-Instructor
Student-Instructor interaction is defined as the communication between student and teacher (Lin et al., 2016). This is crucial in online learning and also preferred by students in order for them to increase engagement (Martin and Bollinger, 2018 as cited in Khalil, 2021). This interaction can be done by having educational, asynchronous and synchronous modes through utilizing communicative tools; such as skype, telephones, and many more (Blankson et al., 2016).

Student-Content
Learner-content interaction refers to a variety of pedagogical tools and assignments such as audio and video presentations, individual or group projects, links to other resources, online chats and discussion forums. As such, learner-content interactions potentially reinforce students' roles as creators of knowledge (Anderson, 2003; Moore, 1989; Moore and Kearsley, 2011; as cited in Lin et al., 2016, pp. 9-10).

3. Methods

3.1 Respondents

391 engineering students from different universities across Metro Manila have participated in this study. The respondents were randomly selected regardless of their major, age, gender, race, or ethnicity.

Moreover, the researchers conducted four (4) expert interviews of instructors who are currently teaching in the Engineering courses around Metro Manila. Instructors are chosen based on each criterion; Laboratory, Lecture, Assessment, and Examination (Table 2).

Table 2. Respondents profile

Variables		Frequency
School	Private School	300
	Public School	91
Major	Chemical Engineering	50
	Civil Engineering	89
	Electrical Engineering	43
	Electronic and Communication Engineering	25
	Industrial Engineering	89
	Mechanical Engineering	53
	Others	42
Year Level	1st Year	27
	2nd Year	47
	3rd Year	84
	4th Year	215
	5th Year	18

3.2 Data Analysis

The researchers analyzed the collected data by utilizing Factor Analysis, specifically Exploratory Factor Analysis (EFA) through the statistical software SPSS to properly interpret the data collected. The Communalities table determined which variables are significant, the Eigenvalue and Scree Plot showed how many factors were included in the Rotated Factor Matrix. The cut-off value used for this study was 0.30. The Rotated Factor Matrix showed the clustered strategies per student engagement into components. Additionally, the researchers determined the weight of the given factors and components by using the decision tool, Analytical Hierarchy Process (AHP). The output from the AHP concluded the main objective of the study by proposing a decision matrix for student engagement in an online setup.

4. Data Collection

The data for the student respondents were collected through a survey questionnaire administered in Google Forms. Respondents were randomly selected in different universities under the Engineering department. The survey questionnaires for each participant were sent out via email and social media. Furthermore, the expert interviewees were contacted via email, and the interview was done through a Zoom conference call.

5. Results and Discussion

5.1 Exploratory Factor Analysis Result

Table 3. Summary of Components

Student-Student Engagement		Student-Instructor Engagement		Student-Content Engagement	
Collaboration with Peers	**Individual Participation**	**Student Support**	**Interactiveness and Motivation**	**Accessibility to Course Materials**	**Outsourced Learning**
Students use group chat to discuss class matters or common interests	Students introduce themselves in class using an icebreaker discussion	The instructor is available and responsive for student inquiries during and after class hours.	Instructors provide an opportunity for students to give their honest feedback via surveys, journals, etc.	Usage of video recordings to help students take down notes.	Class events or guests talks are done through a live or synchronous web conferencing
Students work collaboratively using online communication tools to complete case studies, projects, reports, etc.	Students have choices in the selection of readings (articles, books) that drive discussion group formation	The instructor provides clear feedback for submitted work.	The instructor provides grading rubrics everytime they post assignments	Learning materials provided to students are available in multiple formats (e.g video, text, infographics, powerpoints, interactive games, etc.)	Advance reading or overview of handouts/textbook before the course discussion begins
Students prepare and present lectures together based on their interests	Students post audio and/or video files in threaded discussions instead of only written responses.	The instructor regularly sends/posts reminders, announcements and due date checklists.	The instructor utilizes various features of communication tools for synchronous sessions (polls, emoticons, whiteboard, text, or audio and video chat) in order to interact with their students.	Guided questions or summaries are provided for deepening understanding of students	Online activities improve the students' understanding about the subject.
Students prepare for exams together using online communication tools	Students interact with peers through student presentation (asynchronously or synchronously)	Instructors creates specific place or forums to answer questions or inquiries of students	The instructor gives time and encourages students to participate in online discussions. (e.g. asking questions, comments, and clarifications)	Method for the delivery of presentations, discussions, etc. are of student's choice	Use of additional online resources to deepen their understanding about the topic.
Working in groups during class activities using tools such as Breakout rooms, Google docs, etc.	Students peer-review classmates' work.	The instructor creates a clear course orientation for the students	Instructor gives our incentives to encourage students to participate in class discussions	Share screening during online classes.	Selection of materials to be used is based on the interest of students. (e.g. articles, journals, and books)
Choice of grouping is based on peers	Students are required to rate individual performance of team members on projects.	Instructor provides short video lectures	Instructors ensure their students are mentally and physically present by asking them questions or making sure that they are keeping up with the lesson.	Online materials/resources are uploaded and accessible in the learning management systems. (e.g. Blackboard Learn, Google Classroom, etc.)	Self-tests on important elements of the course are provided and can be freely answered to test their understanding.
Motivating one another to accomplish tasks		The instructor builds a respectful relationship with the students.	The instructor suggests platforms for the students to learn from each other.	Taking of screenshots or recording parts of class discussions	Tasks (e.g case studies, research paper, etc.) given to students have realistic scenarios where they can apply their learnings
Allotting more time for group works					

The table 3 summarizes the clustered engagement strategies namely, Collaboration with Peers, Individual Participation, Student Support, Interactiveness and Motivation, Accessibility to Course Materials, and Outsourced Learning. These components together with the identified factors influencing student engagement, namely Environment, Resources, and Instructor's Role and Approach, were used to construct the analysis for the Analytical Hierarchy Process (AHP). Therefore, the researchers were able to create a decision matrix and determine the preferred component under each criterion.

5.2 Analytical Hierarchy Process Results

The researchers utilized Analytical Hierarchy Process (AHP) in establishing the proposed decision matrix for the study. AHP is a kind of decision matrix where it is used by the researchers to analyze the weights of each factor and component to determine the best strategy for each criterion.

5.2.1 Laboratory

Table 4. Sensitivity Analysis for Laboratory

	Environment	Resources	Instructor's Approach and Role	Overall
Criteria Weights	**0.467**	**0.467**	**0.067**	
Collaboration with Peers	0.529	0.529	0.529	**0.529**
Individual Participation	0.163	0.163	0.163	0.163
Student Support	0.064	0.064	0.064	0.064
Interactiveness and Motivation	0.138	0.138	0.138	0.138
Accessibility to Course Materials	0.053	0.053	0.053	0.053
Outsourced Learning	0.053	0.053	0.053	0.053

Table 4 shows the table of the sensitivity analysis for the Laboratory criteria. The table displays an analysis of which among the six (6) components is most preferable with regards to the criteria weight of the three (3) factors. As shown, Collaboration with Peers is most preferable in terms of laboratory with an overall weight of 0.529 and can be noticed that it has a large difference compared to the next preferred component. With this, Individual Participation has the next highest obtained overall weight with 0.163 and lastly, Interactiveness and Motivation has an overall weight of 0.138.

5.2.2 Lecture

Table 5. Sensitivity Analysis for Lecture

	Environment	Resources	Instructor's Approach and Role	Overall
Criteria Weights	0.435	0.487	0.078	
Collaboration with Peers	0.204	0.192	0.202	0.198
Individual Participation	0.199	0.216	0.184	0.206
Interactiveness and Motivation	0.150	0.032	0.206	0.097
Accessibility to Course Materials	0.126	0.117	0.035	0.114
Outsourced Learning	0.144	0.083	0.040	0.106
Student Support	0.177	0.427	0.400	0.316

Above shows the table 5 of the sensitivity analysis for the lecture criteria. The table displays an analysis of which among the six (6) components is most preferable with regards to the criteria weight of the three (3) factors. As shown, Student Support is most preferable in terms of lecture with an overall weight of 0.316. Additionally, Individual Participation has the next highest obtained overall weight with 0.206 and Collaboration with Peers as third with an overall weight of 0.198.

5.2.3 Assessment

Table 6. Sensitivity Analysis for Assessment

	Environment	Resources	Instructor's Approach and Role	Overall
Criteria Weights	0.474	0.474	0.053	
Collaboration with Peers	0.069	0.180	0.041	0.120
Individual Participation	0.218	0.024	0.058	0.117
Student Support	0.226	0.184	0.149	0.202
Interactiveness and Motivation	0.088	0.282	0.263	0.189
Outsourced Learning	0.207	0.244	0.314	0.230
Accessibility to Course Materials	0.191	0.268	0.304	0.234

The sensitivity analysis for assessment is shown above table 6. The table displays an analysis of which among the six (6) components is most preferable with regards to the criteria weight of the three (3) factors. As shown, Accessibility to Course Materials is most preferable in terms of an assessment with 0.234 weight. Following this is Outsourced Learning and Student Support with an overall weight of 0.230 and 0.202 respectively.

5.2.4 Examination

Table 7. Sensitivity Analysis for Examination

	Environment	Resources	Instructor's Approach and Role	Overall
Criteria Weights	0.405	0.480	0.115	
Collaboration with Peers	0.149	0.171	0.042	0.147
Individual Participation	0.125	0.149	0.099	0.134
Interactiveness and Motivation	0.106	0.170	0.188	0.146
Accessibility to Course Materials	0.318	0.224	0.272	0.268
Outsourced Learning	0.046	0.033	0.090	0.045
Student Support	0.256	0.365	0.252	0.308

Above shows the table of sensitivity analysis in examination. The table 7 displays an analysis of which among the six (6) components is most preferable with regards to the criteria weight of the three (3) factors. As shown, Student Support is most preferable in terms of examinations with a weight of 0.308. Followed by Accessibility to Course Materials with 0.268 and Collaboration with Peers with 0.147.

5.3 Proposed Improvements

The study presented has produced beneficial outputs, however, it is not without limitations. The limitations the researchers recommend exploring further are predominantly on the methodology. The present study only focused on Engineering students enrolled in Metro Manila. Thus, considering other types of respondents, such as having controlled groups from both public and private schools, there might be other factors that might affect the results between these two (2) groups or explore other courses for the reason that their curriculum structure might be different from the Engineering sector. Secondly, the expert interviewees were just limited to four (4) instructors for each criterion, consider adding more instructors to interview and further validate the values as each instructor may have different perspectives.

On the topic of the criteria, future researchers may also want to consider adding another criterion or separating the criterion into specifics such as Lectures can be divided between theoretical and computational lectures. Furthermore, the present study only tackled the identification of common misbehaviors of Engineering students in an online setup. With this, future researches could further address what triggers the appearance of misbehaviors in an online set-up and identify ways on how they could possibly mitigate these.

6. Conclusion

This study was able to fill a gap in the knowledge on proper online delivery of courses by providing a solution through a proposed decision matrix for student engagement with respect to laboratory, lecture, assessments, and examinations.

Table 8. Summary of Analytical Hierarchy Process Results

Cases	Rank	Component	Weight	Engagement	Description
Laboratory	1	Collaboration with Peers	0.529	Student-Student	Collaboration with peers is the type of learning situation where the students are studying or academically working together.
	2	Individual Participation	0.163	Student-Student	Individual participation is defined as each student is actively participating and engaging with the instructor and fellow students as interactive as possible.
	3	Instructiveness and Collaboration	0.138	Student-Instructor	Instructiveness and motivation are defined as instructors using methods that would make them interact and motivate their students.
Lecture	1	Student Support	0.316	Student-Instructor	Student support is defined as instructors providing assistance to students encompassing all aspects of their learning and development.
	2	Individual Participation	0.206	Student-Student	Individual participation is defined as each student is actively participating and engaging with the instructor and fellow students as interactive as possible.
	3	Collaboration with Peers	0.198	Student-Student	Collaboration with peers is the type of learning situation where the students are studying or academically working together.
Assessment	1	Accessibility to Course Materials	0.234	Student-Content	Accessibility to course materials is defined as students being able to utilize learning materials provided by instructors, and allowing them to do different methods that are most convenient for their learning styles.

	2	Outsourced Learning	0.23	Student-Content	Outsourced learning is defined as students doing activities that would deepen their knowledge about the subject, such as attending events, doing advanced readings, and utilizing other learning materials.
	3	Student Support	0.202	Student-Instructor	Student support is defined as instructors providing assistance to students encompassing all aspects of their learning and development.
Examination	1	Student Support	0.308	Student-Instructor	Student support is defined as instructors providing assistance to students encompassing all aspects of their learning and development.
	2	Accessibility to Course Materials	0.268	Student-Content	Accessibility to course materials is defined as students being able to utilize learning materials provided by instructors, and allowing them to do different methods that are most convenient for their learning styles.
	3	Collaboration with Peers	0.147	Student-Student	Collaboration with peers is the type of learning situation where the students are studying or academically working together.

The table 8 summarizes the results gathered from the AHP. As seen in the table, for each criterion, components are ranked from top one (1) to three (3) together with their respective weights. Moreover in the summarized table, the researchers showed the student engagement where each component is destined. Descriptions are also shown to further explain each component (Table 9).

Table 9. Results of Misbehavior

Misbehavior	Frequency	Misbehavior	Frequency
Inattentiveness during online class (e.g. multitasking, sleeping, etc.)	369	*Unallowed collaboration*	171
Procrastination	327	*Plagiarism*	139
Cheating	255	*Aggressiveness towards teacher*	66
Slacking over group work	234	*Aggressiveness towards classmate*	56
Slacking over individual work	193	*Others*	22
Abusing Technology	191		

Additionally, from the responses of the Engineering student regarding the common misbehaviors, the researchers were able to conclude that there is an occurrence of misbehaviors among Engineering students in the online setup such as Inattentiveness during online class, procrastination, cheating, slacking over group works, etc.; although some respondents have stated other examples it still fell under the same category of the given list of misbehavior.

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Biographies

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Jeremy Santos is a fourth year Industrial Engineering student from the University of Santo Tomas. He managed documents and events for the organization as Director for Operations Research Society of the Philippines-UST Chapter (ORSP-UST). He is currently the Director for Social Responsibility, and a Director for Community affairs during his previous academic year (AY 2020-21). He was awarded with academic honors (Dean's List) in his junior year, first semester (AY 2020-21). He also received a certificate of completion for SAP Business One - SAP Basic Logistics and Financials and (AY 2020-21). Furthermore, he obtained a Technical Drafting National Certificate II under Technical Education and Skills Development Authority (TESDA) last 2018 before taking his Undergraduate Degree in Industrial Engineering.

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