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Project-Based Learning: Contrasting Experience Between Traditional Face-to-Face Instruction and Virtual Instruction

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Project-Based Learning: Contrasting Experience between Traditional Face-to-Face Instruction and Virtual Instruction

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Abstract
The Introduction to engineering (EGGN-100) is a project-based course offered every fall semester to first-year students with undecided engineering majors at California State University, Fullerton (CSUF). The primary objective of this course is to provide project-based learning (PBL) and introduce these students to major projects in Civil, Mechanical, Electrical, and Computer Engineering projects so that they can make an informed decision about their major. The PBL is an active learning method that aims to engage students in acquiring knowledge and skills through real-world experiences and well-planned project activities in engineering disciplines. The course comprises four team-based unique projects related to Civil, Mechanical, Electrical, and Computer Engineering. The project involves using a variety of engineering tools like AutoCAD, Multisim, and Arduino platforms. For the first time, due to the COVID-19 pandemic, the hands-on project-based EGGN-100 course was offered virtually. In this research, we document the learning experiences of students who attended EGGN-100 in a traditional face-to-face mode of instruction and students who participated in the same course in a virtual instruction mode. Surveys conducted during seemingly different modes of instruction show varying levels of satisfaction among students. Of the students who attended the course in traditional and instructional instruction mode, 69% and 90% responded that discipline-specific projects enabled them to make an informed decision, and PBL helped them choose their preferred major. Even the percentage of students who believed the PBL helped them make an informed decision about their major, they like to do more hands-on projects and prefer to attend the classes on campus. Students rated higher satisfaction in virtual instructional mode primarily due to the availability of video lectures, self-paced learning, and readily accessible project simulations. Learning by doing would have bought out the challenges and minor nuances of designing and executing an engineering project. Learning by watching is surficial and not necessarily exposes students to minor details that are critical. As such, the significance of this study is that maybe, after all, not all courses can be taught in a virtual environment, and some courses may be strictly taught in a traditional, hands-on instruction mode. We also study the socio-psychological impact of traditional and virtual learning experiences and report the remedies to cope with stress and loneliness in the online learning environment.

Keywords
Project-based Learning, Virtual Learning, Engineering Freshmen, Engineering Education, Socio-psychological Impact of COVID pandemic.

1. Introduction

Learning experiences in early engineering classes are fundamental to student's long-term perseverance in engineering disciplines. These experiences are particularly critical for students who have not yet chosen their engineering major. Students must be exposed to all major engineering disciplines before making an informed choice about the discipline they want to pursue in engineering studies. Project-based learning (PBL) is a critical tool that provides students with hands-on, engaging, and application-based learning experiences. Learning by doing forms the fundamental tenet of the PBL. It is expected that sustained intellectual excitement created by project-based activities will help students choose their major and persevere throughout their engineering education. Hence Science Technology Engineering and Mathematics (STEM) courses must effectively integrate PBL activities to enhance their overall learning experiences to enable students to make an informed choice. Ideally speaking, the very nature of STEM-based PBL courses requires students to have a major engineering discipline project (Civil, Electrical, Mechanical, and Computer Engineering) that offers a hands-on and immersive learning experience. Unfortunately, the global pandemic forced first-year students to have these experiences in a virtual mode instead of the traditional face-to-face instruction. Forced with these hard choices, expectedly learning experiences will be different. In this paper, we document instructional innovations and the challenges encountered by first-year students, and their overall satisfaction in the course. We briefly narrated the socio-psychological impact of the COVID-19 pandemic on their learning experiences.

1.1 STEM enhanced learning experiences through PBL

Despite the inherent limitations of the '*chalk and talk*' instructional approach, it remained a predominant form of instruction at most STEM institutions worldwide [1]. Scarcity of resources (financial and technical) and lack of institutional commitment are largely responsible for the continued proliferation of this ineffective instructional approach. For more than 20 years, sustained efforts on the part of the dedicated STEM administrators and a renewed emphasis on student engagement and inquiry-based learning have paved the way for PBL. It was Russ Edgerton who eloquently emphasized the need for student engagement in 2001 his Education White Paper [2], in which he stated, "*Learning about things does not enable students to acquire the abilities and understanding they will need for the twenty-first century.*" It was precisely the beginning of '*pedagogies of engagement*' as espoused by Edgerton. Lately, greater emphasis is placed on providing hands-on experiences through such programs as first-year research experiences for undergraduate students. These efforts are targeted primarily towards freshman engineering students to generate intellectual excitement about their chosen disciplines. However, for undecided engineering majors, hands-on learning experiences are geared towards developing interests in engineering disciplines enabling them to make a well-informed choice about their majors. As such, the importance of PBL cannot be underestimated. The shift from a traditional problem-solving approach to hands-on PBL has recently become commonplace, at least in the first year of engineering education. Many studies have highlighted the importance of enhancing STEM education through PBL. Given the surge in technological development, it is expected that the 21st-century workforce should demonstrate skills that are adequate to meet the competing demands of interdisciplinary engineering education [3].

Expectations are such that the students are strategically equipped with the skills and knowledge required to succeed as global engineers [3]. Recently a study has eloquently summarized the experiences and insights gained through the two-decade-long implementation of

PBL [4]. The authors highlighted the importance of PBL and reported that PBL promotes enhanced collaborative learning in technical, interpersonal, and contextual competencies. Engineers should be technically versatile, solve critical problems, communicate, and function in diverse teams. The Accreditation Board for Engineering and Technology has modified its accreditation criteria to emphasize PBL and self-directed learning, supporting life-long learning [5]. Hence, the undergraduate educational curricula must keep evolving to provide students with a proper learning environment to prepare them for a professional career. While several pathways exist to accomplish curriculum reform, integrating PBL experiences early on in engineering appears to be a common theme. PBL has become prevalent in engineering because of the student-centered nature of learning compared to traditional learning modes. The PBL approach act as a driving force for understanding the fundamental principles to learn the design process that leads to a solution. Enhanced student participation [6], problem-solving [6], students' conceptual understanding [7], retention of material [8], and critical and proactive thinking [9] are some of the most notable gains reported from the implementation of PBL. Long-term studies documented that PBL leads to an overall increase in student retention and perseverance in engineering [4], [6], [10].

1.2 Freshman Engineering Course: Efficacy of PBL in Traditional Vs. Virtual Mode

PBL - instructional approach gives students a contextual environment that makes learning relevant and focused. In a traditional classroom setting, the implementation of PBL activities has been studied widely. Integration of design content into the freshman year is not a new concept; in 1990, many *Freshman Design* courses were taught at universities nationwide. National Science Foundation's Gateway Engineering Education Coalition [11] emphasized introducing design early in the engineering curriculum to help student retention. In the early years, the engineering design course was mainly intended to introduce the students to the engineering profession and design components instead of engaging them in hands-on fabrication and testing [12].

Many universities use Rube Goldberg-based design projects for first-year engineering students as a general engineering design course [14], [15]. Rube Goldberg projects were also used for specific majors like Electrical Engineering [16], Engineering Dynamics [17], and Civil Engineering [18] in freshmen year to introduce students to the engineering design process. Odeh et al. (2016) presented an innovative design concept for first-year engineering students, [13] incorporating various techniques to help students better engage with the subject matter. The redesigned course curriculum includes three engineering design problems that require students to apply basic engineering skills. The students could attempt the design problem based on their preference for the intended major.

Traditionally PBL based courses are designed for in-person instruction simply because it promotes social engagement, effective communication, teamwork, and collaborative problem-solving. However, the implementation of PBL in engineering in an online/virtual environment is not well explored. Very few studies have examined the efficacy of PBL in online mode. For example, Sabuncu and Sullivan (2020) designed a project-based online engineering experimentation course in a mechanical engineering department by integrating Arduino or Raspberry Pi, boards, sensors, actuators, and transducers. However, the projects were performed by individual students and not in a group [19]. Brodie (2009) delivered a fully online PBL course for distant education students where the projects were entirely carried out in virtual asynchronous mode [20]. The course was successful, and students effectively work in virtual teams. The study did not use a hardware-based project. Martin and Devenish's study [21] on project-based pedagogical approaches also implemented PBL courses in virtual mode for engineering skills. It concluded that the pedagogy and assessment need to be altered to fulfill the needs of online learners.

While delivery of PBL to on-campus students is widely used in US Universities, there was scant data related to online delivery of PBL courses, especially for electrical, civil and, mechanical engineering majors. Considerable efforts are required when conducting the PBL in an entirely virtual environment. Such measures include establishing a learning community in a virtual space to engage with their team, their facilitator, and other students in the course remotely.

1.3 PBL Activities for EGGN 100

The Introduction to engineering courses for freshman engineering students covers various topics, from an engineering profession overview to discipline-specific contents, and elucidates the skills engineers possess. This course is offered to first-year students of all engineering disciplines. The main objectives of this course are to

1. familiarize the students with the engineering profession and engineering disciplines,
2. motivate them to stay in an engineering major,
3. engage them in problem-solving,
4. foster team environment,
5. helped them understand the design process for exploratory projects.

In most engineering programs, the Introduction to engineering courses is offered based on discipline-specific contents.

Introduction to engineering (EGGN-100) at California State University, Fullerton (CSUF), is offered to first-year and undecided engineering majors every fall semester. Besides the objectives mentioned earlier, one of the primary goals of this PBL course is to "*introduce undecided freshman engineering students to major projects in Civil, Mechanical, Electrical, and Computer Engineering projects so that students can make an informed choice about their major*." The course starts with an active introduction to the engineering profession, different engineering disciplines, engineering ethics, team building, and engineering successes and disasters. Then, the focus drifts to specific discipline projects. This course highlights four team-based unique projects related to electrical, computer, civil, and mechanical engineering, each given three to four weeks for completion. The project involves the use of a variety of engineering tools like AutoCAD, Multisim, Arduino platforms. In 2019 the course was offered in the traditional mode, while in 2020, it was offered in virtual mode. The instructor divides the students into teams typically comprising of four to five students per team. The team configuration remains the same throughout the semester, while individual team members' responsibilities may vary. Out of four projects, three projects require hands-on fabrication and testing. The final project deliverables include submitting a formal project report documenting the design/fabrication process, flow charts, schematics, and results and discussion. The students were also required to demonstrate their project, make a formal PowerPoint presentation, and compete against mechanical and civil engineering projects. The students were required to sign the code of conduct and document each team members' contribution to each project with details of their executed tasks. The students very much enjoyed working in a team environment.

2. Research methodology

Teaching and learning engineering education processes are strongly determined by practical exercises, experiments, and laboratory classes. Engineering students learn by doing, acquiring technical and social skills. COVID-19 pandemic radically changed all the aspects of our daily lives, forcing instructors to innovate content delivery in seemingly challenging courses, including the first-year engineering course, which is primarily a hands-on, face-to-face course. Despite technological advancement in learning management systems, online content delivery and dissemination of information has limitations, especially for first-year students who are novices to university life. The research methodology used in this course was evaluating the efficacy of the first-time deployment of the entire course in virtual instruction mode and compared student learning experiences between the traditional and virtual instruction modes. Surveys were designed to assess the learning efficacy and understand students' perceptions about virtual instruction of a traditional hands-on course. Two separate groups (nearly 26 students) of student participants were administered surveys in Fall 2019 (traditional mode) and Fall 2020 (virtual mode) at CSUF. The main objective of the survey is to inspect the contrast between face-to-face and online education in the PBL course.

Furthermore, given the extraordinary learning circumstances, we also evaluated the socio-psychological impact on underrepresented minority student's perseverance. It is important to note that minority students were disproportionately affected by the pandemic. It exacerbated their economic situation, living condition and introduced additional stressors in their living environment. The net result their living condition would have potentially impacted their emotional, psychological, and social well-being resulting in ineffective learning, reduced competencies, and overall reduced academic performance

2.1 PBL during COVID 19 challenges and opportunities

The contagion and virulence of COVID-19 have presented unprecedented challenges to education systems. Like every part of society, engineering education has endured profound change during this pandemic. Schools and universities were closed, and all face-to-face courses were canceled. University campuses transformed into a virtual world, and faculty were forced to shift instruction to the virtual mode, challenging the classes with a hands-on component. With minimal knowledge and time, the rapid shift to online learning presented unique challenges

- Students' engagement in the online environment - alteration in the content and delivery to actively engaging students
- Replacement of hands-on projects - redesign of hands-on projects with simulation-based activities
- Community building - additional activities for peer-peer interaction
- Fostering teamwork - extra efforts to motivate students to work together

Even though the pandemic has challenged engineering education's status quo and burdened the faculty with additional work, it provided an excellent opportunity to rethink our teaching. Faculty were forced to innovate ways for effective content delivery and student engagement to ensure the virtual instruction remained a viable alternative throughout the pandemic. Some level of normalcy and routinization soon followed initial chaos. This sudden shift from face-to-face instruction to virtual instruction is rightly summarized by Aldert Kamp, "*COVID-19 proves to be the change that futuristic educators have been preaching about – volatile, uncertain, complex, ambiguous, a VUCA world* [32]."

2.2 Redesigning PBL Activities in COVID

Three out of four projects in the EGGN 100 course were hands-on fabrication-based. Because of the transition to a virtual environment, the projects need to be altered to suit the online audience well. Instead of doing hands-on computer engineering projects, authors chose to use Multisim [22] software for electrical and computer engineering. Multisim is used widely in industrial and academia, so training students with the program's skills is beneficial for their technical careers. Using the same software for two projects reduces the student's burden to learn multiple tools. For the Civil engineering project, the authors utilized West Point Bridge Designer software— bridge simulator. Finally, the hands-on component was incorporated in a mechanical engineering project where students designed wind turbines using household stuff. This project was planned at the end of the semester, and when we received the feedback, we learned the hands-on project was better than simulator-based. However, having all hands-on projects has its implications in an online environment.

2.3 Data Collection and Survey Design

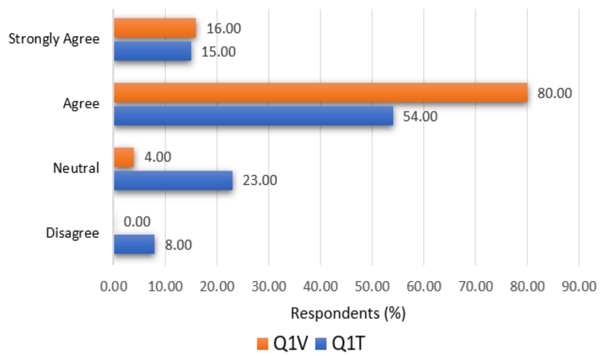
Towards the end of the semester, the authors collected the surveys to evaluate the course's effectiveness in Fall 2019—face-to-face mode and Fall 2020—virtual mode of instruction. Students were surveyed using a standard five-level Likert scale from "strongly disagree" to "strongly agree" on various statements about the learning experiences. In Fall 2020, we added two additional questions:

1. Do you think hands-on learning would be better off? - five-level Likert scale
2. What else should be done to improve the projects in a virtual environment? - *open-ended*

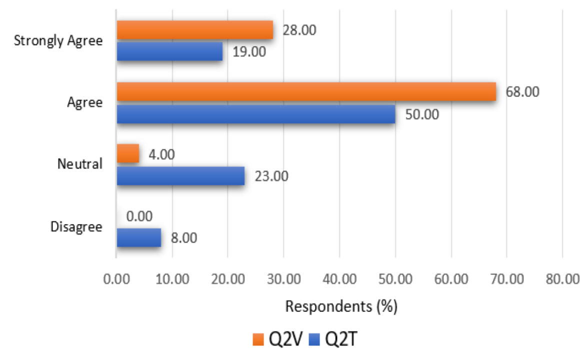
3. Results and Discussion

3.1 Learning experiences of first-year students during Fall 2019 (face-to-face mode) and Fall 2020 (virtual mode)

The surveys related to learning experiences were collected at the end of the Fall semester. 26 (79%) and 25 (66%) students participated in this survey in Fall 2019 and Fall 2020. One of the EGGN 100 class's primary objectives is to introduce students to major projects in four engineering disciplines— Civil, Mechanical, Electrical, and Computer-to make an informed decision about their major of interest. 69% (15% strongly agree and 54% agree) and 96% (16% strongly agree and 80% agree) agreed that discipline-specific project-based learning helped them choose their major in 2019 and 2020, respectively (Q1, Q2). Further, when asked, "Project-based learning helped me narrow down my choices of discipline "(Q3), 77% and 84% of participants admitted it did. In survey question 4 (Q4), "I discovered new friends and enjoyed working with them; in 2019, 92% of participants felt they did, but it was contrary to the observations made in 2020", where only 74% of students agreed. Indeed, physical interaction matters for students to make friends. For Q5 (Learning using hands-on projects is interesting to me), 100% of participants in the traditional mode acknowledged interest in the hands-on project, while the apparent decline was seen in 2020 (82%). Do you think hands-on learning would be better off? (Q6), and 88% would like that (38% strongly agreed and 50% agreed). An EGGN 100 course provides an active introduction to the different engineering disciplines through PBL. Participants responded to Q7 - Q10 related to their understanding of a specific major before and after the class. These results are presented in Table 1. As evidenced by our findings, students could comprehend the major better when they completed the course. Indeed, these survey results showed that the PBL course helped the freshmen to fulfill the objectives. When we asked students an open-ended question in 2020 (virtual mode), "What else should be done to improve the projects in a virtual environment?



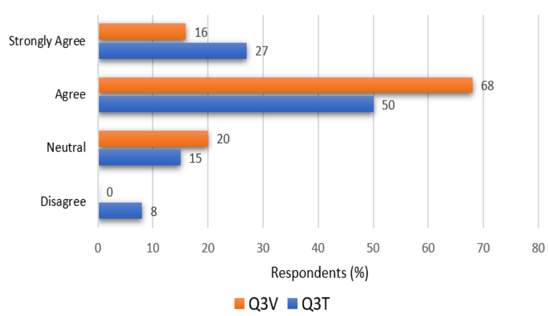
(a)



(b)

Q1. Working on discipline-specific project helped me to make an informed decision

Q2. Project-based learning enabled me to discover my choice for discipline?



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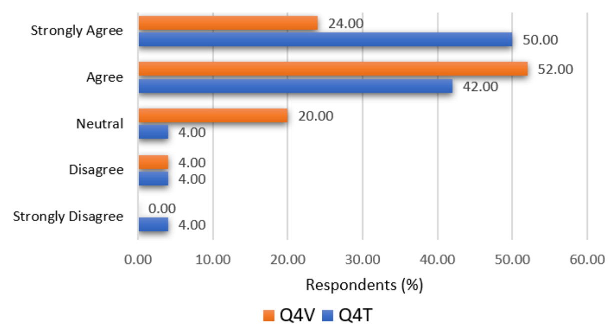
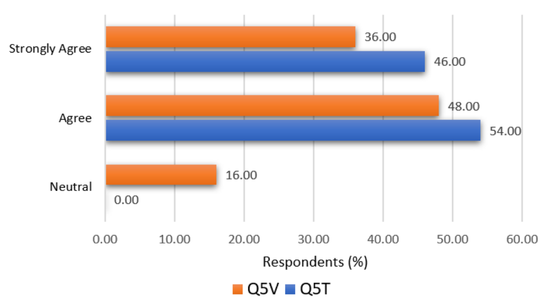


(d)

Q3. Project-based learning helped me narrow down my choices of discipline

Q4.I discover new friends and enjoyed working with them



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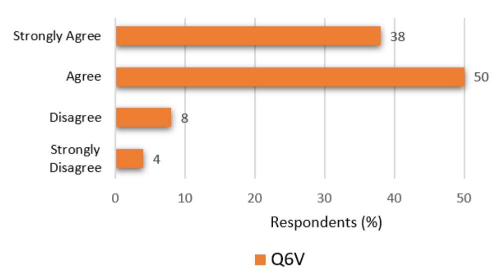

(f)

Q5. Learning using hands-on projects is interesting to me

Q6. Do you think hands-on learning would be better off?

*Q#T - Traditional instruction mode; Q#V - Virtual instruction mode

Figure 1. Survey Results

There was no overwhelming consensus since only 50% of participants appreciated the overall course design and project alignments. Of all the projects, most students enjoyed working on the wind turbine project in mechanical engineering.

Table 1. Understanding of Major

Questions	*2019*		*2020*	
	Before (%)	**Now (%)**	**Before (%)**	**Now (%)**
I have a better understanding of the Electrical Engineering discipline (Q7)	27	60	25	96
I have a better understanding of the Mechanical Engineering discipline (Q8)	31	80	26	96
I have a better understanding of the Civil Engineering discipline (Q9)	27	74	17	85
I have a better understanding of the Computer Engineering discipline (Q10)	27	66	37	76

More than 50% responded that they wished they could do more hands-on projects for other engineering disciplines if they provided the project kits. Some student comments are copied below:

- *"I think that the projects within a virtual environment were good. However, it would be really nice to work on more of those hands-on projects at home, like the windmill project."*
- *Like stated, I would think giving the students kits and other supplies would make them feel more like engineers and make the class even more enjoyable.*
- *Overall, I enjoyed this course very much, even though things were online. It was my favorite course this semester and I think it does a very good job of introducing incoming engineer majors to what the engineering field is all about.*
- *I believe this method of teaching was efficient and accessible by itself. Having kits of some sort would complicate something that does need to be complicated.*
- *I think all the project simulations were as helpful as they could be during these circumstances.*
- *I think it would still be a challenge for the hands-on experience because of the virtual learning we must use. However, I do feel once we are allowed to go back to school, we will be able to have a much better and improved experience with these projects.*

From the survey responses collected from the participants, it is evident that many students expressed a better understanding of engineering discipline when the course was offered in virtual mode. These responses do not necessarily reflect the enhanced learning experiences in the virtual mode because only 66% responded favorably rated their experiences compared to 79% respondents who attended the course in face-to-face instruction mode. The observed differences in perceived understanding of discipline majors could be attributed to the ready availability of video lectures, long-term accessibility of simulation projects, and a self-paced learning environment that enabled students to explore major engineering disciplines comprehensively. The survey results are not indicative of the overall learning experience but rather the accumulation of general information about the discipline because only 50% of student participants approved of simulated projects and preferred to have hands-on projects.

3.1 Socio-psychological impact on learning experiences

COVID-19 pandemic forced students to endure a quarantine lifestyle which itself is traumatic. Deprived of the company of their close friends and family, students have to learn to keep their morale high and remain academically productive throughout the pandemic. This additional stressor has impacted their overall well-being, which may have potentially affected their academic performance. Additionally, it is reasonable to expect students to experience positive and negative emotions related to multiple aspects of remote learning. Numerous studies reported that the impact of the pandemic is not uniform. Socially disadvantaged communities are being impacted far more seriously compared to the economically well-off. Given that CSUF is a minority-serving institute with many students being the recipient of financial aid, the impact of the pandemic was more significant on a large student population. Sokolovskaya (2020) demonstrated that socio-psychological factors characterize the efficacy of virtual learning [23]. The author showed that factors such as self-isolation, uncoordinated peer interaction, and interaction with instructors, can negatively impact the students' satisfaction with distance/virtual learning. Mental health concerns in university students have been recognized globally during the pandemic, with high rates of stress, anxiety, loneliness, and depression [24, 25, 26]. As reported in a global study, students experienced increased anxiety is due to the change in the mode of delivery, the uncertainty of university education, concerns in technological needs, being far away from home, social isolation, family member's job uncertainty, and future employment [27]. A similar observation was also reported through an interview-based survey showing elevated levels of stress and anxiety due to increased fear and worry about personal and family members' health, difficulty concentrating, disruptions to sleeping patterns, decreased social interactions due to physical distancing, and increased concern of academic performance [28].

Students use negative or positive coping strategies to overcome stress and anxiety caused by socio-psychological factors [29, 30]. Negative strategies include staying away from the COVID news, sleeping for longer hours, distracting themselves with other tasks like playing video games, drinking, and smoking. While the positive strategies include meditation, exercising, exploring hobbies, playing with pets, talking to someone they feel comfortable with, and watching Netflix. The studies also reported that students used workouts as a stress buster. Contrary to popular belief, a large study comprising 1009 participants showed that physical exercise does not help alleviate deteriorating mental health caused by the COVID pandemic [30]. Others have recommended a six-step intervention to reduce psychological impact risk. These steps included delivering positive pandemic-related information, reducing negative behavior, learning about stress management techniques, improving family relationships, increasing positive actions, and adjusting academic expectations [31].

University administrators play a crucial role in students' mental health. They could best serve students if they better understood the impacts of COVID-19 and the risk factors of its socio-psychological effects. Hence, proactive and innovative policies, programs, and practices to promote student health and well-being must be explored to navigate stress and depression. By understanding the significance of the socio-psychological impact, we incorporated the following remedies to further assist our students in coping with loneliness and stressful living environments.

- Add human factor and create a safe place during the online class sessions

- Understand student's needs, be flexible about deadlines
- Use of zoom breakout rooms during the class sessions for peer-to-peer interactions
- Use of Flipgrid video discussion forum for active engagement
- Use of social zoom hours for informal meetups (happy hours!)
- Offer extended office hours

3.2 Limitation of the Study

In this research, we evaluated the learning experiences of EGGN 100 in face-to-face and virtual settings. As expected, not many studies have documented the efficacy of PBL in the virtual instructional mode because it contradicts the fundamental requirement of PBL. Our results also support the observation on virtually learning experiences, especially in courses entirely based on the PBL approach, which is inherently inadequate to provide students with much-needed genuine experiences to make an informed decision about their engineering majors. This research has provided insight into the relative effectiveness and challenges encountered while implementing PBL in virtual mode. The virtual mode could never replace all engaging hands-on learning experiences irrespective of how enjoyable the course is. The proof of the pudding is in eating. We assumed that the results would offer clear contrast. However, there were many factors responsible for the observed anomaly. Some of these factors include the level of engagement, availability of recorded video lectures, and student's ability to refer to the project whenever they want, contributing to their increased overall satisfaction rating compared to traditional instruction.

Additionally, such observation would have been forthright had the student population remained the same (experienced the same learning of course material in virtual and traditional settings). Such results would be illuminating with deeper insights with the same set of students who attended the traditional and virtual instruction mode, which is possible if EGGN-100 is offered as a two-semester course. Nevertheless, this does not limit the generalization of the results, and this limitation will not distract the usefulness of this study. We think this study is timely and essential to learn the impact of instruction mode on freshmen students.

4. Conclusion

EGGN 100—Introduction to Engineering course is a project-based learning (PBL) class offered to undecided engineering freshmen students every Fall semester. The course starts with an active introduction to the engineering profession, the evolution of engineering disciplines, engineering ethics, team building, and engineering successes and disasters. The course introduces students to the core engineering disciplines such as Civil, Mechanical, Electrical, and Computer Engineering through the projects. The learning experiences involve hands-on projects using various engineering tools like AutoCAD, Multisim, and Arduino. The primary goal of the course is to familiarize undecided engineering students with four major engineering disciplines— Civil, Mechanical, Electrical, and Computer through PBL to decide the major of their interest. In general, a similar course in major US universities is conducted in traditional face-to-face learning. COVID pandemic radically altered the traditional pedagogical landscape shifting the traditional classroom to the remote. This work studied the contrast between face-to-face and online instruction in the EGGN-100 PBL course. The survey results showed that 69% and 96% of students agreed that discipline-specific project-based learning helped them choose their major in traditional and virtual mode. Even though students liked the online education and the simulation-based projects in Fall 2020, many think hands-on projects would have added more value and fun. Of the students surveyed, 93% of the participants hoped they could attend the classes in traditional format if such an opportunity comes their way. It means that PBL has long-term implications for the learning experiences of first-year engineering students. This immersive learning experience assists them in choosing their major. Further, this work also studies the socio-psychological impact of virtual learning experiences and recommends potential remedies and coping strategies in an educational setting. Future work will examine if the online offering of EGGN 100 impacted the retention of students.

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References

1. Mills, J. E, Treagust, D. F. (2003). Engineering Education – Is Problem-based or Project-based Learning the Answer. Australian Journal of Engineering Education http://www.aaee.com.au/journal/2003/mills_treagust03.pdf
2. Edgerton, R. (2001). Education White Paper. http://www. pewundergradforum.org/wp1.html.
3. Savage, R. N., Chen, K. C., Vanasupa, L. (2009). Integrating project-based learning throughout the undergraduate engineering curriculum. *IEEE Engineering Management Review*, vol. 37, no. 1, pp. 25-25, First Quarter 2009, doi: 10.1109/EMR.2009.4804346.
4. De los Rios, I., Cazorla, A., Diaz-Puente, J. M., Ygue, J. L. (2010). Project-based learning in engineering higher education: two decades of teaching competencies in real environments. Procedia Social and Behavioral Sciences 2, 1368–1378
5. Felder, R. M., and Brent, R. (2003). Designing and Teaching Courses to Satisfy the ABET Engineering Criteria. *Journal of Engineering Education*, Vol. 92, No. 1, 2003, pp. 7-25.
6. Hmelo-Silver, C. E., "Problem-Based Learning: What and How Do Students Learn? *Journal of Educational Psychology Review*, issue 16, pages235–2662002
7. Beichner, R. (2008). The SCALE-UP Project: A Student-Centered Active Learning Environment for Undergraduate Programs. *National Academy of Sciences*, 2008. Incomplete Reference
8. Dori, Y. J., Hult, E., Breslow, L., Belcher, J. W. (2007). How Much Have They Retained? Making Unseen Concepts Seen in a Freshman Electromagnetism Course at MIT. *Journal of Science Education and Technology*, vol. 16, no. 4, pp. 299–323, 2007.
9. Hadim, H. A. and Esche, S. K. (2002). Enhancing the engineering curriculum through project-based learning. *32nd Annual Frontiers in Education*, Boston, MA, USA, 2002, pp. F3F-F3F, doi: 10.1109/FIE.2002.1158200.
10. Knight, D. W., Carlson, L. E., Sullivan, J. F. (2007). Improving engineering student retention through hands-on, team-based, first-year design projects. *31st Intl. Conf. on Res. in Eng. Edu.*, Honolulu, HI, June 2007.
11. Milano, G. B., Parker, R., Pincus, G. (1996). A Freshman Design Experience: Retention And Motivation. Paper presented at 1996 Annual Conference, Washington, District of Columbia. 10.18260/1-2--6066.
12. Barr, R., Krueger, T., Aanstoos, T. (2002). A Project-Centered Freshman Engineering Graphics

and Design Course. *ASME 2002 International Mechanical Engineering Congress and Exposition*, pp. 757-762.
13. Odeh, S., McKenna, S., Abu-Mulaweh, H. (2016). A unified first-year engineering design-based learning course. *International Journal of Mechanical Engineering Education*, Vol. 45, pp. 47-58, 2016.
14. Pierson, H. M., and Suchora, D. H. (2002). The Rube Goldberg Three-Minute Timer: A Design Based Learning Tool for Engineering Freshman. *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition*, 2002.
15. Davis, J. L. & Chelbowski, A. C. (2017) Work in Progress: Oh… The Irony: A Six-Section Rube Goldberg Machine for Freshman Engineering Design, *American Society for Engineering Education*, Columbus, OH.
16. Lei, C., Kwok-Hay, H. S., Lam, E. Y., Wong, K. K., Kwok, R. Y., Chan, C. K. Y. (2012). Teaching introductory electrical engineering: Project-based learning experience. *Proceedings of IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE) 2012*, Hong Kong, China, 2012, pp. H1B-1-H1B-5, doi: 10.1109/TALE.2012.6360320.
17. Orr, M. K., Jordan, S. S. (2019). A Rube Goldberg Approach to Teaching Dynamics of Machine Element. Journal of *Advances in Engineering Education*, Fall 2019.
18. Acharya, S., Sirinterlikci, A. (2010). Introducing engineering design through an intelligent rube Goldberg implementation. *The Journal of Technology Studies*, 36 (2) (2010), pp. 63-72
19. Sabuncu, A. C., & Sullivan, J. M. (2020). *A Project-based Online Experimentation Course.* Paper presented at *2020 ASEE Virtual Annual Conference Content Access*, Virtual Online. 10.18260/1-2--34036.
20. Brodie, L. M. (2009). eProblem-based learning: problem-based learning using virtual teams, European Journal of Engineering Education, 34:6, 497-509, DOI: 10.1080/03043790902943868
21. Martin, F., Devenish, J. (2003). Project-based learning in distance mode: challenges and triumphs of online engineering student teams. Paper presented at *17th Annual Conference of the Australasian Association for Engineering Education*, Auckland, New Zealand.
22. https://www.ni.com/en-us/support/downloads/software-products/download.multisim.html Accessed on: February 02, 2021.
23. Sokolovskaya I. E. (2020). Socio-psychological factors of students` satisfaction in the context of digitalization of education during the COVID-19 pandemic and self-isolation. Digital sociology. Vol. 3, no 2, pp. 46–54. DOI: 10.26425/2658-347X-2020-2-46-54
24. Blake, H., Knight, H., Jia, R., Corner, J., Morling, J. R., Denning, C., Ball, J. K., Bolton, K., Figueredo, G., Morris, D., Tighe, P., Villalon, A., Ayling, K., Vedhara, K. (2021). Students' Views Towards SARS-CoV-2 Mass Asymptomatic Testing, Social Distancing and Self-Isolation in a University Setting during the COVID-19 Pandemic: A Qualitative Study. *Preprints* 2021, 2021010399 (DOI: 10.20944/preprints202101. 0399.v1).
25. Huckins, J. F., daSilva, A. W., Wang, W., Hedlund, E., Rogers, C., Nepal, S. K. (2020). Mental health and behavior of college students during the early phases of the COVID-19 pandemic: Longitudinal smartphone and ecological momentary assessment study. *J Med Internet Res*. 2020;22: e20185. pmid:32519963.
26. Elmer, T., Mepham, K., Stadtfeld, C. (2020). Students under lockdown: Comparisons of students' social networks and mental health before and during the COVID-19 crisis in Switzerland. PLOS ONE. 2020;15: e0236337–22. pmid:32702065
27. Aristovnik, A., Keržič, D., Ravšelj, D., Tomaževič, N., Umek, L. (2020). Impacts of the

COVID-19 Pandemic on Life of Higher Education Students: A Global Perspective. Sustainability 2020, 12, 8438.
28. Son, C., Hegde, S., Smith, A., Wang, X., Sasangohar, F. (2020). Effects of COVID-19 on College Students' Mental Health in the United States: Interview Survey Study. *J Med Internet Res* 2020 Sep 03;22(9):e21279
29. Fawaz, M., Al Nakhal, M., Itani, M. (2021). COVID-19 quarantine stressors and management among Lebanese students: a qualitative study. *Curr Psychol*. https://doi.org/10.1007/s12144-020-01307-w
30. Wilson, O. W., Holland, K. E., Elliott, L. D., Duffey, M., Bopp, M. (2021). The Impact of the COVID-19 Pandemic on US College Students' Physical Activity and Mental Health, *Journal of Physical Activity and Health*, *18*(3), 272-278. Retrieved March 08, 2021, from https://journals.humankinetics.com/view/journals/jpah/18/3/article-p272.xml
31. Chen B., Sun J., Feng Y. (2020). How have COVID-19 isolation policies affected young people's mental health? Evidence from Chinese college students. Front Psychol. 2020;11: 665. pmid:32373022
32. https://aldertkamp.weblog.tudelft.nl/. Accessed on: February 10, 2021.