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High School Students' Perspective of Active Learning in a Remote Classroom (Fundamental).

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High school students' perspective of project-based learning in online learning

Olushola Emiola-Owolabi, Medha Dalal, Adam Carberry, & Oluwakemi Jumoke Ladeji-Osias

The delivery mode of education for many high school students changed recently, confining students to attend classes virtually from home. Remote learning can sometimes give students fewer experiential learning opportunities. A focus group discussion was carried out with 35 high school students to explore their perception of their learning environment as it relates to active learning in a remote instruction delivery classroom. Kolb' s experiential learning theory was used to guide this study. The qualitative data gathered were analyzed thematically. Analysis from the data showed that remote learning impacted students' ability to support each other in project-based learning processes. The effect of remote learning also impacted students' access to peer group resources, materials, and tools needed for effective project-based learning. Results showed that some students preferred working with other students cooperatively on project-based activities while other students preferred working individually on project-based activities. The findings show that team building in high school students continues to be a challenge irrespective of the learning environment, either face-to-face or remote classrooms. Hence, educators have to continue to find ways to strengthen team-work and team building among the students.

Introduction

Several studies show that engineering students across educational levels are motivated in a learning environment that incorporates active learning instructional practices. Lesson plans that employ experiential learning activities that relate with the students' daily lived experiences increases the interests of engineering students [1]. Teaching high school students engineering is challenging because many things contend for the attention of the students. The attention span of most high school students today is short due in part to their attachment to their smartphones [2]. Teaching high school students with traditional teaching practices may not effectively yield positive student learning [3]. High school teachers will oftentimes teach abstract engineering concepts in a traditional way; presenting the concept from a planned lesson and giving out problems as classwork and/or homework from text books for students to solve.

This traditional approach is ineffective in teaching engineering to high school students in today's learning environment [4]. Current high school students use high end technology daily and have varying backgrounds and experiences. The teaching practices for high school students should include using project-based learning (PjBL) methods. Project-based learning (PjBL) involves students working on a multidisciplinary project/question that requires a long period of time to solve [5]. Several researchers have recommended that PjBL methods are effective in teaching students engineering concepts [2], [5]. This approach gives students opportunities for experiential learning, where they take charge of their learning process. These principles provide the basis for a new high school level engineering course, Engineering For Us All (E4USA), designed and implemented in nine schools across the U.S. during the 2019-20 academic year. The course was developed around four threads - discover engineering, engineering and society, engineering design, and engineering professional skills - woven into seven units. The course was designed to provide students with progressively complex engineering design experiences relating to real- world problems in local and global contexts. The curriculum had four 'levels' of problem

statements: 1) basic problems defined by the teacher, 2) local stakeholder problems, 3) global challenges, including the Grand Challenges of Engineering [6] and the United Nations' Sustainable Development Goals [7], and 4) challenges arising from the daily lives of students. Overall, the course offered students opportunities to 'think like an engineer' and develop skills of problem-solving, design thinking, interdisciplinary thinking, teaming, creativity, communication, and innovation.

This study explores the implementation of this high school engineering curriculum used in a transitioned in-person to remote classroom, due to the COVID-19 pandemic by investigating the following research questions:

1. How do high school engineering students experience remote learning?
2. How do high school students' experience project-based activities in a remote classroom?

Literature Review

Pre-College Online Learning

Pre-College online learning research is a recent phenomenon in the United States. There is some research in the field to support the growth of pre-college online learning dating back to a school starting an online program in 1991 [8], [9]. There is ample scholarship in areas such as effective support, effective design, and effective delivery of online curriculum in pre-college online environments. These environments go beyond the original asynchronous formats to include plenty of synchronous online learning [10]. As of 2011, pre-college online learning environments were available in most of the 50 states in the U.S [11], educating approximately four million K-12 students, 6% of students [12]. This number has fluctuated since then with estimates ranging between two and eight million pre-college students between 2016 and 2019 [13], [14], all of this occurring before the COVID-19 pandemic.

Project-Based Learning

PjBL started in France when architecture became an academic course instead of a vocation. At the time, architects craved an education that had foundations in experiential learning [15]. The traditional teaching approach used was not effective in teaching the contextual content of architecture. During the 18th century, the engineering field adopted PjBL approaches to combine the teaching of theoretical content and practice by giving students open-ended projects. Defining (PjBL) has been challenging, hence it has been done in various ways. In this study, in emphasizing a problem, PjBL can be referred to as an instructional student-centered method that allows students to conduct research, incorporate theory/conceptual framework and practice, and apply skill and knowledge to provide a useful solution to a defined problem [16]. When emphasizing the project piece of defining PjBL, it focuses on the solution to a problem achieved within a set timeline, which becomes an end product [17] while also connecting the context of teamwork [18]. We define PjBL in this study to encompass the essential parts of PjBL in engineering education, specifically, PjBL in a teamwork setting [18]. Furthermore, in this study, we see PjBL as a pedagogy guiding the practice of instructional approach and learning in engineering education [19].

The aim of this approach is to allow teachers to guide student teams to promote the learning process [20]. Students often form teams to solve real life, open-ended questions, building skills (e.g., teamwork and collaboration) as they proffer solutions to questions posed [21]. Students work collaboratively to identify problems and provide solutions as teams [22]. The approach has been described as an instructional style that promotes students' problem-solving skills and knowledge acquisition through the experiential real-world problems [23]. Sometimes the question requires the students to apply an interdisciplinary method that allows them to construct or reconstruct prior knowledge and incorporate new information. The approach is based on an authentic process that allows students to actively take charge in solving the challenge using their knowledge, content, and environmental context. PjBL gives students an active role in their learning process rather than being passive learners by creating a dialogical participatory learning environment, [24] which improves critical thinking [25].

PjBL in high school allows students to work through projects that will inspire critical thinking as students advance through the design process [26]. Defining the characteristics identified by Lamer & Ross [27] and Craig & Marshall [28] include: "(1) Beginning with a driving question or challenge that provides context and drives instruction, (2) Aligning with significant content learning goals, (3) Incorporating 21st century skills, (4) Facilitating in-depth inquiry that allows the student to explore the content, (5) Providing multiple opportunities for student choice and voice, (6) Providing multiple opportunities for self-critique and assessment, and (8) Presenting a final product to a community audience" [29]. These characteristics differentiate PjBL in pre-college classrooms today as instructional practice [30] from teachers' assumptions decades ago that "projects are the curriculum."

PjBL instructional lesson plans engage the students in an authentic, relevant problem [31]. Consequently, K-12 students that engage in PjBL driven curriculum demonstrate increased motivation in learning the course content [32]. This experiential approach allows students to take control of their learning process by providing them open ended choices about the learning process through resolving the driving question or problem. The open ended choice encourages intrinsic motivation, giving students higher persistence, and allowing them to follow through with tasks in appropriate ways, while instigating them to go on to larger challenges. Open ended choice challenges students and promotes deep, conceptual interests into learning [33]. PjBL instructional practices continue to feature primarily as a model of the project-based movement in curriculum administered in some pre-college engineering classrooms [34]. In E4USA engineering classrooms', the fundamental curriculum is conveyed employing PjBL and the engineering design process, which supports the unit projects to conform with the definition of PjBL adopted in this study.

Theoretical Framework

The theory that framed this study is Experiential Learning Theory (ELT) developed by David Kolb [35]. The theory has four stages of how students learn focusing on the internal cognitive learning processes of students as they engage in hands-on project activities [36]. This theory has four stages to new knowledge. 'Concrete Experience' describes when a student is exposed to new information or reinterprets prior knowledge. 'Observation and reflection' captures when a student reflects on new or reinterpreted information. 'Forming abstract concepts' is the next

stage where reflection develops into a new idea or modification of an existing idea. The final stage of 'testing in new situations' describes when active experimentation takes place and a student applies the idea to the real-world [35]. Kolb believed that a student attains new knowledge of new concepts through new experiences, i.e., "Learning is the process whereby knowledge is created through the transformation of experience" [35].

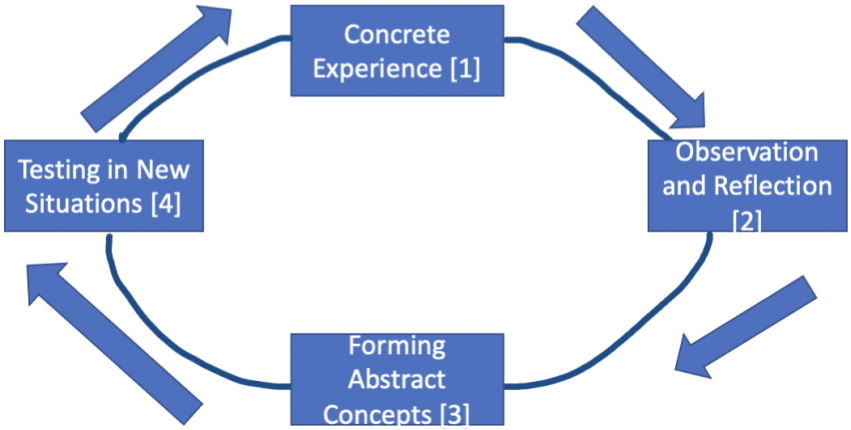

Figure 1.Experiential learning cycle

Methods

A qualitative approach was used to collect and analyze data for this study. A total of 35 students participated in batched focus group discussion sessions. The students were enrolled in the E4USA course. Instruction moved from face-to-face to remote learning during March 2020 in response to the COVID-19 pandemic. Most of the class sessions were synchronous, however, some student groups may have communicated offline. Eight focus group sessions were conducted towards the end of the school year, in May, 2020 at all, except one, of the nine participating high schools. The focus group sessions lasted between 60 - 90 minutes. The schools were a mix of large suburban charter schools, large city public schools, large suburban public schools, and small rural public schools. The students in the focus group consisted of four or five students per session. Questions focused on the students' perspective of project based learning in the remote classroom after Covid. The data used in this study are portions of the data collected for a larger research project. The qualitative data gathered were analyzed thematically. Questions analyzed for this study were:

1. How did your class change as a result of COVID-19?
2. Would you be able to explain the engineering design process to a new student?
3. How was this class for you generally, with engineering design activities?
4. Would you be able to explain the engineering design process to a new student?
5. How well do you all think that you understand what engineers do?
6. What were the difficulties of working in groups/teams?
7. What made it difficult to work online?
8. What are the things that you wish this online class should have covered, that you would like to know more, and that did not happen?

The students that participated in this study were from a subset of the 470 9th to 12th grade secondary school students who had enrolled in the E4USA course. Eight out of the nine pilot schools that partnered with E4USA schools participated in the focus group discussion. The schools were a combination of seven public schools and one charter school, during the 2019- 20 academic year. These schools were in five states across the United States including Washington, D.C. Although, demographics of the students that participated in the focus group discussion were not obtained, we know that the demographics of the schools that the students attend are a mix of White, Hispanic, and Black students.

An inductive data analysis approach was used [37] in conjunction with the ELT framework. The analysis involved two cycles, in the first cycle, units of data were coded openly by two of the research team members of this study based on the concepts underscored by participants in the focus groups [37]. In the second part of the cycle analysis, there was constant comparative analysis used to create a common set of repeated themes informed by the ELT. These themes pertained to meaning, self-efficacy, ways, intent, perceived support, and challenges associated with teaching a high school level engineering course.

Limitations

We recognize that online learning could be synchronous and asynchronous and it would affect the ability of the students to work in teams. It was difficult to judge how much of the online learning was asynchronous and how much synchronous as teachers used different approaches in different schools.

Findings and Discussion

A total of eight themes emerged from the data analysis process. These themes are presented under the categories of remote learning and project-based learning and mapped to the ELT framework.

Theme	Example Extract	ELT Construct
Remote Learning Themes		
Eliminated Teamwork Resources	*"Most of our projects are for group projects and learning how to work in a group and get through those challenges, as well as the actual project prompt and with these it was much more individual. I'm not even sure if anyone participated in a group."*	Testing in New Situations
Inaccessible Engineering Tools	*"and it's also, I don't have a lot of things too, like build stuff, because I do have some ideas but I'm also like, oh wait, I don't have some of the materials to make it so it made it more challenging for me to complete some of the work."*	Testing in New Situations
Reduced Project Scope	*" And the work is easy for right now. So yeah, but we get no hands on activity because we're not at school. So kind of sad about that."*	Concrete Information

	"majority was just bookwork instead of being more productive with the hands-on activities,"	
Project-Based Learning Themes		
Increased Confidence with the Engineering Design Process	*"and even if you do like messing up and your prototype doesn't work. You learn stuff through every step of the engineering design classes in a different way than you would in the scientific method." "Yeah. I also got a lot better at designing towards the constraints and fitting the requirements. And so I think I could do it. I couldn't build it, but I could draw it for sure."*	Forming Abstract Concepts
Increased Confidence in Team/Group Projects	*"Because there's a bunch of brains involved. So there's always somebody on the team that knows more about this and that so it gets you thinking even more. So most definitely we do miss working as a team."* *"I'm very comfortable working in groups. . . hey this class is like preparing for that. And I feel like I will work well in that environment."*	Forming Abstract Knowledge
Increased Problem Solving Skills	*"We had to make a windmill. Well not like a fully functioning one because you know, except for more time. . . . I designed it into a windmill and then I put the pencil through the cap. So be able to spin and I put the pencil inside the little spheric shaped thing that has enough space for it to move inside of it. So the way I tested it was with a blow dryer and it worked. So that's something that I came up with and designed myself." "When I successfully finish a project, it actually works. There is something so good about that."*	Testing in New Situations
Increased Career in Engineering Possibilities	*"And it developed my interest in engineering substantially in it still, I'm still very interested in it. So that's why I think that's what I'm going to pursue for my college career. I don't really think that's going to change because if you look at what engineers do, engineers will always be needed."*	Testing in New Situations
Students Prefer Individual Projects	*"I agree with YYY. It was really nice working at your own pace, because I also enjoy independent work."* *"there are definitely people who are kind of disrespectful. And I think a lot of that came down to it being a class that you didn't need to apply effort into to get something out"*	Observation and Reflection

Remote Learning Themes

Eliminated Teamwork Resources

This theme is mapped with the ELT construct 'testing in new situations.' The connection of the theme with 'testing in new situations' is apparent in the students descriptions of how the remote learning environment limited the students from collaborating with their course mates physically in a physical laboratory. This limitation deprived the students the opportunity to perform/test

their PjBL activities in new situations. Data from the study suggests that the remote learning environment did not sufficiently support teamwork or group work in an online environment. Some of the reasons the students gave were not having the physical lab space to work together, lack of social support from group members, and not having the ability to conduct face-to-face brainstorming sessions where they could all share ideas as a group in a physical space. Some excerpts to support this theme are:

"I don't think any class has done any teamwork because of how difficult it would be."

"I feel like it was more difficult, like creating the actual project, like group projects online because we couldn't really work together as good when we created the project. And this is the same group that worked together well. In person. "
"Yeah, I think that's hard to do with it. Because like, once, . . . I feel like there's like, lack of communication when it's online."

Inaccessible Engineering Tools

This theme is mapped to the ELT construct 'testing in new situations'. This theme is linked to the construct 'testing in new situations' because, lack of access to tools needed for the activities limited the students' testing of projects in real life situations that may enhance the knowledge making process. In this theme, students explained that remote learning restricted them from getting some tools to help them with their projects. This prevented students from not having the physical equipment required to carry out certain team projects. Sample excerpts of this theme are:

"We didn't really have resources like mixing with technology, but I'd like to see more of that in the real world, learning how I can apply engineering to a field that I would want to work in."

Reduced Project Scope

This theme is linked with the ELT construct 'concrete information.' This theme is linked to the construct 'concrete information' because the reduced scope of projects will limit the students exposure to concrete information that may enhance the students' knowledge making process. In this theme, the students described how the remote learning environment reduced the scope of projects they had to work on. Sample excerpts of this theme are:

"Yes, of course, because I feel like when we were doing teamwork, we're given projects that are a little bit more challenging than the ones we get now."
"we probably had a better chance of, well, more chances of doing hands on activities at school. But after the COVID incident, or pandemic, we started doing more of the research work."
"Yeah. No, he hasn't really assigned a collaborative work is basically things that we can just work on by ourselves."

Project-based Learning Themes

Increased Confidence with the Engineering Design Process

This theme is linked with the ELT construct ‘forming abstract concepts’. The connection of this theme to the ELT construct ‘forming abstract concepts’ is seen in the students description of how working on PjBL activities expanded their process of forming abstract knowledge. In this theme, students described how PjBL processes in an online learning environment increased their confidence in the engineering design process, helping them solve problems. The students explained how engaging in PjBL activities in the classroom boosted their confidence in using the engineering design process to solve problems they encountered in their homes. Some sample excerpts are:

“I can solve problems, because I'm actually using it a lot more now since I'm stuck at home. I use a new design process, I think almost every day to try and solve a problem.”

“I also think I could describe the engineering process to somebody just because we've used it so many times in this class.” “I also think that the engineering design process is more open minded, in a sense. It allows you to be more creative, because with science, there is usually a right answer, but with the engineering design process there are so many different possibilities.”

Increased Confidence in Team/Group Projects

This theme is linked to the ELT construct ‘forming abstract knowledge’. This theme is linked to the construct ‘forming abstract knowledge’ as the students described how working on the PjBL activities with their team members increased their confidence. Students explained how PjBL activities increased their confidence in team projects. Some of the students expressed a lack of interest in group or team projects prior to the course. Many said their interest increased after participating in the E4USA curriculum. Some excerpts of this team are:

“I know teamwork is a very significant aspect in engineering any field of it and I'm an extrovert. Um, I love working with people of all types.” “Group Work, teamwork. And I can see myself in the future, maybe like being a computer engineer. Working with a team of people that come up with an idea.” “Because I get to hear about other people's perspectives and then we work together to think of a new solution that no one else has ever thought of.”

“I think my favorite part of the class was I'm as this water filter project because I was paired With a group that I don't know if I fit well with but they had a lot of creative ideas and it allowed me to figure out what my position in a group is and like how I was the best, with collaborative work.”
“I got better at working with other people. And I think that's very valuable because now not just like engineering jobs but in other classes I'm like okay I'm fine with doing group work”.

Increased Problem Solving Skills

This theme is mapped with the ELT construct ‘testing in new situations’. The connection of this theme and the construct ‘testing in new situations’ is seen where the students explained that working on PjBL helped them to be problem solvers at home in new situations. In this theme, the students explained how PjBL activities prepared them as problem solvers helping them detect

problems and finding solutions to the problems. They further suggested that PjBL increased their interest in solving problems. Some sample excerpts are:

"I feel like I was very confident with the amount of projects that we've done, the amount of stuff that we put through in the brain testing that we've had, I feel like I'm very confident in using engineering to solve common things in the house, or more intermediate issues that has to do with engineering."

Increased Career in Engineering Possibilities

This theme is also mapped with the ELT construct 'testing in new situations'. This theme is tied to 'testing in new situations' construct because the students described the PjBL activities they participated in as assuring them to become future engineers. Students in this theme explained how the PjBL process gave them confidence in pursuing or considering engineering careers. Some of the students explained that having successfully engaged in the PjBL activities gave them confidence that they could be professional engineers in the future. Some sample theme excerpts are:

"Yeah, after this class. I'm definitely more interested in engineering, because before I was like, oh, I'm interested in it."
"When I started, I was like, yeah, I find it cool, but I don't really see a way it would fit in with something I would like, but now I can kind of understand that better and see maybe a future possibly"

"Okay, yeah, I think after this class, I am more interested and open and to pursue a career in engineering than I would have been"

Students Prefer Individual Projects

This theme is linked to the ELT construct 'observation and reflection'. This theme is linked to the construct 'observation and reflection' because some students explained that they prefer working singularly on PjBL activities to help them observe and reflect on their learning process at their own pace. The students in this theme explained how they prefer individual projects to team/group projects. Some of the students explained that during team projects, just a subset of the team members do the actual work. Others just are not so open to working in a team. Some sample excerpts are:

"I did it on myself individually" "But I didn't like the idea of working in groups and stuff because I usually am a very independent person."
"It became like a project for me. Like I could work on my own pace. You know, I could just go to the workshop and just think creatively and I like just I personally like being left to my own devices to just like think and build and create and what not."

Implications

The results of this study confirm that the principles of ELT framework were at play through this project-based, remote engineering learning experience. Prior to COVID-19, the students had the concrete engineering experiences in their classrooms. Before the COVID-19 pandemic, the students were able to collaborate with their peers and test and evaluate the designs they were working on in physical laboratories. During the pandemic, the remote classrooms gave the students the opportunity to work on their projects in new situations individually. The findings also confirm that high school students who are exposed to project-based activities are empowered in the engineering design process. This equips the students to learn engineering concepts in the courses using project-based learning activities [38]. The results of this study align with ELT's assumption that learning happens when a student is able to execute all stages of the ELT cycle. Analysis from the data showed that remote learning negatively impacted the students' ability to support each other in project-based learning processes.

Remote learning impacted students' access to peer group resources, materials, and tools needed for effective project-based learning. The findings support Savage, Chen, and Vanasupa's [39] assertions that while some students prefer working with other students cooperatively on projects, other students prefer working individually. Although the researchers in [39] and other researchers pointed out this finding in a face-to-face classroom, this study goes on to add that it is still a problem in a remote classroom. This means that educators have to keep working on how to make students' experiences better. Analysis from the data showed that remote learning impacted students' ability to support each other in project-based learning processes. This paper shows that having both cooperative and individual learning-based pedagogies may be more effective for high school engineering students. This year, several more high schools adopted the E4USA engineering curriculum in hybrid classrooms. Additional data is being gathered to further explore the themes that emerged from this study. Specifically, the research team will explore the nuances of institutional type (rural, urban, all girls, etc.), geographical location with the students' experiences and how project based learning is experienced in different contexts. Also, the findings imply that educators have to continue paying attention to team- building activities in their lesson plans and curriculums.

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