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A Project-Based Learning (PBL) Course Offered in Bulgaria in a Fulbright U.S. Scholar Project During the Pandemic

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A Project-Based Learning (PBL) Course Offered in Bulgaria in a Fulbright U.S. Scholar Project During the Pandemic

Abstract

The first author visited the Technical University of Sofia (TU-Sofia) in Bulgaria in Fall 2021 as a Fulbright U.S. Scholar to conduct a research/teaching combination project, with the support from the other authors of this paper at both institutions. A project-based learning (PBL) course was offered at TU-Sofia as a facultative course, with 13 students enrolled from two programs and from freshmen to seniors. This paper reports the extensive efforts on course planning, the adaptation of the course offering on the go, and a follow-up plan such as a faculty-led trip to provide an opportunity for the U.S. students to visit Bulgaria (although the May 2022 trip had to be canceled due to the nearby war, the connections that were made and the trip planning will enable another trip in the future). All these activities were impacted adversely by the pandemic, such as the postponement of this trip from Spring 2021 to Fall 2021, the transition of in-person instruction to online instruction in late October, and the less than perfect final project's completion rate, beyond the normal adaptation of a course in a different country given the facility and product differences. The different academic calendars in the U.S. and Bulgarian institutions also made it impossible in finding a suitable period for the students from both institutions to interact, but we were able to connect the students with other American visitors in Bulgaria to get comments on their designs. There were many other challenges, including the cultural influences on design, and communication (often asynchronous with English not being the mother tongue for some), on top of the normal project constraints, which were exactly what stretched the students. This project aimed at carrying out and evaluating high-impact practices such as PBL and vertical integration in a different institution, via a comparison between pre-course and post-course surveys. These practices could continue in various forms at TU-Sofia, and the collaboration could grow into COIL (Collaborative Online International Learning) opportunities. We encouraged the students to discover and learn from each other. From the students' point of view, the senior students will be prepared for their intensive 7-week capstone project in the next semester, and the younger students will gain valuable experiences while shadowing and actively engaging in the development of the projects. The practices presented in this paper could provide some timely ideas and inspiration for other colleagues who wish to continue international collaborations during the pandemic.

Introduction

Project-based learning (PBL) courses have long been proven to be effective to engage students to help them achieve a wide range of learning objectives, at every stage of student development from the freshman year to the senior year. For example, Emine Foust designed two projects for the students to work on in a first-year engineering design class, and the students went through the entire design process while learning the design tools in a teamwork environment. The student surveys showed that these projects were effective in achieving the course outcomes [1]. At Western Carolina University (WCU) that multiple authors are affiliated with, a five-PBL-course sequence (one course in each of the first three years and two courses in the senior year) is incorporated into the curriculum of all the programs within the department (encompassing electrical and mechanical disciplines in engineering technology and engineering programs), so that the students can gradually sharpen their technical expertise, professional skills, and

teamwork to perform well in the year-long capstone projects in their senior year, often sponsored by the local industry.

For an instructor or a class of students new to PBL, the uncertainty in PBL development may be daunting. Upon reflections from the students' point of view, Colin Dixon and Lee Michael Martin found out that the moments of uncertainty were the pivot points when the learners could re-position themselves and others to express their opinions to direct their problem-solving plans toward features, resources, and practices that served their interests [2]. From the instructor's point of view, Yoshiki Sato, Atsuo Hazeyama, Shoichi Nakamura, and Youzou Miyadera did a thorough analysis of the PBL Body of Knowledge (PBLBOK) framework [3], which outlines the PBL phases (Initializing, Planning, Executing, Monitoring, and Evaluating) and knowledge areas (Quality, Cost, Schedule, Risk, Communication, and Integration). Within this PBLBOK framework, Sato et. al. developed an adaptive support system for PBL practice, clarified the correspondence between the possible issues and the needed facilitation, found five themes (Production, Practice, Planning, Survey, and Experience), and categorized various activities often used in PBL [4]. The new practitioners of PBL could use the guidelines in this paper [4] and the book [5].

The problem-solving skills can be developed consciously in a PBL curriculum, such as by studying metacognition [6]. Douglas J. Hacker, Carolyn Plumb, Rose M. Marra, and Shann Bossaller studied the students in a self-directed learning (SDL) curriculum during a two-year period. They did the entering and exiting interviews with the participants and collected think-aloud data during the project, to find that once the students understood what SDL was, they enjoyed the new learning style, used the learning strategies successfully that they learned via SDL, and felt confident to meet new challenges.

The effectiveness of PBL can be further enhanced with vertical integration to encourage students from different year-standings to do peer-mentoring and create opportunities for them to learn from each other [7]. This approach may pose a logistical challenge, as different cohorts may not have a common time to meet, but if it is feasible, vertical integration is shown to help relieve stress, share the best practices, and augment personal confidence [8].

Given the advantages of PBL and vertical integration, the authors aim to implement PBL in a Fulbright Scholar program in Bulgaria during the pandemic, which came with another set of challenges beyond what was mentioned earlier. Originally, COIL (Collaborative Online International Learning) was planned for the students from both WCU and TU-Sofia to do a common project with remote collaboration, because COIL, as the global level PBL, was shown to help the students learn self-efficacy [9], but the mismatched academic calendars made the COIL plan impossible to materialize. However, some interactions between the Bulgarian students and the visitors from the U.S. in Bulgaria were made possible. Midway through the semester, due to the pandemic mitigation measures, all the college courses in Bulgaria went online. Although we were prepared to give each student an Arduino lab kit [10] from the beginning of the semester and give each group a Touchboard lab kit [11] for their final project, so that the students could do hands-on activities at home, the engagement with the students became more challenging after the courses went online than when we could meet in person.

When Nasser Alaraje did his Fulbright Scholar project in Qatar with the help of Mohammed Sayer Elaraj in 2018 [12], Alaraje enjoyed his teaching component as the students were very enthusiastic. In fall 2021, the authors felt the same that the Bulgarian students were resilient, motivated, and enthusiastic. Due to the pandemic and the nature of starting a practice in a new environment, our course offering was in constant adaptation, to address the upcoming challenges, anticipated or not.

To quantify the teaching effectiveness of PBL in the Fulbright Scholar project in Bulgaria, the authors conducted an anonymous pre-course survey among the 13 students in this course and got 6 responses. Then the authors conducted another anonymous post-course survey among the 7 students who have finished their projects and got 5 responses. Although the sample size was small, the response rate was at or more than 50% and reasonable.

The rest of this paper is organized as follows. The course setup will be introduced first, then the project topic will be described. The equipment used in the labs and project is then presented for readers as a reference. The survey results are compared between pre-course perception and post-course experience, with comments. The last section concludes the paper with suggestions for future work.

Course Setup

The first author, Dr. Yan, is a faculty member at WCU, who has taught multiple courses in the PBL course sequence from freshman seminar to senior capstone at WCU. She intended to offer the PBL course with vertical integration and interdisciplinary collaboration at TU-Sofia as part of the Fulbright Scholar project. This course needed to be taught in English (not in Bulgarian, given our language proficiency). Hence the recruitment was carried out by emails and word of mouth by the Dean and other colleagues of the English Language Faculty of Engineering (ELFE) at TU-Sofia towards students from all year standings and all programs as long as the students were comfortable with taking a course in English, without other prerequisites. The ELFE program offers the Industrial Engineering program taught solely in English at TU-Sofia, and naturally, the majority of the PBL class (9) was from this Industrial Engineering program, but the other students (4) were from the Electronic Engineering and Technologies program. The students who were interested in the course were encouraged to talk to Dr. Yan to get more information. The class cap was set by the number of Arduino kits that TU-Sofia prepared, and all the students who showed interest in the course were able to enroll in the course. There were two freshmen and one sophomore, while the majority of the students were juniors (6) and seniors (4). The demographic information of the class is presented in Table 1.

Table 1. Demographics of the Class

Year standing	Senior 4, Junior 6, Sophomore 1, Freshman 2
Program	Industrial Engineering 9, Electronic Engineering and Technologies 4
Gender	Male 11, Female 2

This PBL course was a special-topic elective, and the mere fact that the students enrolled in it demonstrated their motivation. On the other hand, TU-Sofia had initiated a change in Fall 2021 to compress their lecturing time in a semester from 15 weeks to 13 weeks, yielding pressure for both the instructors and the students to finish the same amount of content within a shorter time,

and hence the students in the PBL course often needed to prioritize their time to finish the assignments or exams in the required courses over this elective PBL course, and the authors were sympathetic for the students and often extended the deadlines for the tasks in the PBL course.

Given the busy schedules of the students and the fact that they were from different programs and different year-standings, the class time for the PBL course was decided using polls after their other schedules were set. The class had to be split into multiple sections to meet once a week, and the same content was covered in each section. Such a split made the vertical integration hard to achieve, but the students made up their own study groups, some of which consisted of students from different year-standings. The class duration was also shorter than what it would have been at WCU, and the students would need to spend time between classes to finish their activities and exercises.

When the class went online after about a month after it started, synchronous online lectures were provided when students could ask questions in real-time. The sessions were recorded for the students to review the content if/when needed.

Before the classes went online, a learning management system (Moodle) and emails were the main communication means. After the courses went online, the authors wanted to explore other options to create a more effective and direct communication channel than before. The students recommended the Discord app, as every student was using it. A server (a group of users) was created in Discord for the class and managed by Dr. Yan. Later on, each project group got a private text channel and a voice/video channel, which became the main Q&A venue with the instructor and for file sharing, for convenience, beyond Moodle and emails.

Project Description

The lecturing portion of this PBL course focused on programming the Arduino lab kit, doing 3D design in the CAD software, and learning project management strategies and teamwork skills. The final project would be the students' testbed to practice all these skills.

Each Arduino lecture required the students to do a hands-on exercise on programming, using the newly-learned sensor and actuator, and integrating with earlier content.

For 3D design, Dr. Yan did a demo in OnShape, which is an online CAD platform with a quick setup for new CAD users. Some students had learned to use SolidWorks or Inventor in other courses. Hence, the students were encouraged to use whichever software they were familiar with.

The lecturing portion would prepare the students for the project, and the project topic was selected to reflect the Fulbright mission. The Fulbright Program was proposed in a bill by Senator J. William Fulbright in 1945, attempting to promote peace and understanding through educational exchange. The Fulbright program's mission is to "bring a little more knowledge, a little more reason, and a little more compassion into world affairs and thereby increase the chance that nations will learn at last to live in peace and friendship" as said by Senator Fulbright. As such, the authors wanted to propose a project topic that would help promote the mutual understanding of Bulgaria and U.S. cultures while requiring technical expertise and encouraging teamwork. Especially at the beginning of the course planning, COIL was considered that would allow students from both universities to do the projects together remotely. Although COIL could

not happen due to the mismatched academic calendars, the element of that planning was kept in the project description, as presented below.

Super Duper Souvenir

The most-often asked question that Dr. Yan gets while she was in Bulgaria is "What do you think of Bulgaria?" Similarly, Dr. Yan is wondering "What do you think of the U.S.A.?" Dr. Yan wants to tell the stories of both Bulgaria and U.S.A. to everyone she knows who may come from either country or even from other countries. However, it is complicated as one can imagine. Can you help Dr. Yan to design a super duper souvenir that tells the stories of both cultures in the most entertaining and interactive way?

If COIL had happened, the U.S. students would lead the design of the U.S. cultural elements while the Bulgarian students would lead the design of the Bulgarian cultural elements, and then all the team members could learn more from each other and decide how such elements could be integrated together. Unfortunately, COIL could not happen due to the mismatched calendars, and the Bulgarian students chose the U.S. cultural elements that they perceived to be representative, and they got advice from the U.S. visitors in Bulgaria on their designs.

The students were provided with the Arduino lab kits and the Touchboard lab kits. The kit components are listed in the next section. The Touchboard has a built-in SD card reader and the board can be programmed to play the MP3 soundtracks on the SD card, making high-quality sound easily integrated into the project. The Touchboard also works well with conductive paint based on capacitive sensing. The Touchboard is programmed in the Arduino IDE (Integrated Development Environment), and hence only a minimum amount of tutorial was provided to the students, who were expected to learn to use the Touchboard on their own after they have used the Arduino boards.

The students were tasked to choose the theme of their projects, the sensor and actuator they would like to use, their teammates, and their team names. Although an initial grouping plan was proposed by the instructor, most students chose to work with the ones with whom they were already familiar. Given the limited class time, the authors did not object to their grouping plan, otherwise, if there was time for team building, grouping students who were not familiar with each other would help promote even more learning. At WCU, the students are often grouped by their programs, to have one or more students from each program to ensure capable interdisciplinary collaboration in teams.

The students often worked with their teammates in their remote locations, but some teams had received permission to occasionally work in a classroom. The deliverables of the projects include (1) a successful demonstration to the instructor (all happened to be in-person, although a remote option was also allowed), (2) a technical report submitted to Moodle, (3) creating a product page with photos and videos using a common template provided by the instructor for public viewing (https://yan.wcu.edu/eppvi/), and (4) leaving their projects in the classroom for the exhibition days when the students were not present, so that their projects should be in a reliable working state, and the only action on their projects was for the instructor to power it on or off. Some

photos that were taken when the Fulbright Commission staff and several faculty members visited the exhibition are posted at this blog post: https://yan.wcu.edu/bulgaria/ciao-ciao/

The overall timeline for this course's planning and execution during the pandemic is presented in Figure 1, to show the course modality, content, and material preparation within this timeline.

Figure 1. The overall timeline of the course planning and execution

Project Materials

The major project materials were sponsored by TU-Sofia and the Fulbright Project Grant, for which the authors are grateful. The students were provided the Arduino lab kits from the very beginning of the semester. The parts that were used in our class and the parts that didn't get used are listed in Table 2 in the first and second columns, respectively.

Table 2. Arduino Lab Kit Content

Used in Class	**Not Yet Used**
Arduino Uno;	Arduino Mega;
Resistors (220Ohm / 1K / 10K) - 30 pcs;	Arduino Nano;
LEDs (green, red, blue, yellow) - 16 pcs.	External power cable;
RGB diode;	Remote control + receiver;
Potentiometer 10K;	4x7 segment display;
Active/passive buzzers;	16x2 LCD display;
Micro buttons - 2 pcs;	i2C display module 16x2;
Temperature sensor LM35;	RFID card module RC-522;
Flame sensor;	Stepper motor with ULN2003 driver;
Photoresistor;	8x8 led matrix with MAX7219 driver;
Ultrasonic sensor;	Bluetooth module HC-06;
Servo motor SG90;	Real-time module DS1307;
2-channel relay module;	4x4 keyboard;
USB cables for Mega / Uno / Nano;	Tilt sensor;
Breadboard 830pin + rail;	DHT11 temperature sensor;
Jumper wires;	Sound sensor;
Plastic briefcase with compartments for storage	

Depending on the vendors the readers choose, the content of a lab kit could differ. The readers can, of course, elect to choose other lab kits and use any parts from the lab kit based on their course needs. The lectures and corresponding labs evolved around using this Arduino lab kit before the final project started.

In the classroom where on-site classes were held, soldering irons and stations with a power of around 30 W, multimeters, oscilloscopes, DC power supplies, cables, and computer stations could be used by the students. The students mostly brought their own laptops when doing the Arduino programming exercises and the final project.

For the final project, an additional Touch Board lab kit was provided to each student group, but not to each student, since each group needed to work on a common project. Some peripherals were also needed and purchased separately. The content in a Touch Board lab kit is shown in Table 3. Please note that the Touch Board can be used as the battery charger for the Li-Po battery pack, and hence the extra charger is not a must-have. We got the extra charger for convenience. Likewise, the battery connector was needed as the battery pack came with a different connector not matching the one on the Touch Board (JST PHR-2) and we needed to go through a great length to customize the connector with the help of a local vendor's technical support department that we were grateful for. If you can find a battery pack whose connector matches the JST PHR-2 port on the Touch Board, then you do not need an extra connector.

Table 3. Touch Board Lab Kit Content

	Used in Project	**Not Yet Used**
Bare Conductive workshop pack	Touch Board	Printed Sensors
	Conductive Paint 50ml jar	Instrument Sensors
	Conductive Paint 10ml tube	Guidebook
	Mini Speakers	Sticky Tabs
	MicroSD Card	Velcro Stickers
	MicroSD Card Reader	
	Micro USB Cables	
	Alligator Clips	
	Sheet Carbon Dots	
	USB Hub	
Separate orders	Rechargeable Li-Po Battery	
	Li-Po Battery Charger	
	Extra Wiring Kit	
	Paintbrushes	
	Thick Paper Sheet	
	Plastic Case	
	Battery Connectors	

For 3D printing, although there was a prototyping center on campus and there were commercial printing shops in town, it was not as convenient to use their service as with a printer in the department. The authors purchased a Creality Ender-3 V2 printer, with a printing volume of

22×22×25 cm, and four spools of PLA filaments of various colors, which worked well. The students would submit their design files to print, the instructor would print them and often record videos of the printing process for the students to watch as if the students would be printing the parts themselves, and then the students would pick up the parts following a properly arranged schedule without interfering with the anti-pandemic regulations.

Depending on the student group's interests and project ideas, they often need to use extra parts beyond what is provided and what can be 3D-printed. The students assume the ownership of their projects and they often find the extra materials on their own, although a course budget on such extra parts, if available, will be helpful. For example, in this course, one group wanted to work with water, and they needed to get the plywood to build the compartment for the electronics, the doorknob for the wooden box, the water pumps (they got two different types of water pumps, in case the first pump might not work out well, although it did work out and they did not need to figure out how to use the second pump), an extra battery holder to power up the water pump through a relay (the relay module was included in the Arduino lab kit), a water level sensor (in an extra sensor kit owned by the department), the clear water pipe that was used, a PVC pipe that did not get used eventually, the silicon glue tube to secure the 3D printed pieces, extra containers, and tools to work with such parts, etc. Every extra part, big or small, is essential to finish a project. Meanwhile, the students often get redundant parts as risk mitigation measures.

Survey Results

There were thirteen students in the PBL class regularly. The pre-course survey was conducted at the beginning of the course anonymously via the Qualtrics online platform and six responses were collected. For the final project, there were four groups (one group of five students, one group of three students, and two other groups of two students each). Note that the students chose their teams and hence the number of students in each group was not even. The fall semester at TU-Sofia would end in late Jan 2022, but Dr. Yan's Fulbright project ended one month earlier in late Dec 2021 since WCU's spring semester started in early Jan 2022. So the students were strongly encouraged to finish their projects before Dr. Yan left Bulgaria. However, only two groups were able to do so, while two other groups were too busy preparing for their other required courses' exams to work on the final project for this elective course. They were allowed more time, but they still could not find time to finish their projects. Therefore, the post-course survey was conducted among the seven students from the groups who have finished their projects anonymously via Qualtrics, and five responses were collected.

The groups that have finished the projects posed with their projects after their demonstrations to the instructor, as shown in Figure 2.

Although not all groups finished their projects, during the brainstorming sessions, the student groups all presented many ideas on what cultural elements to present, in both Bulgaria and U.S., and Dr. Yan was impressed by their Bulgarian pride and cultural awareness. Even though not all ideas on the cultural elements materialized, the ideas are presented in a blog post to show what could be possible https://yan.wcu.edu/bulgaria/bulgarian-pride/

The survey results' comparison is provided in Figures 3-6 and Table 4.

Figure 2. The two groups that finished their projects after demonstrations

Figure 3 presents the results when the students chose “agree”, “neutral”, or “disagree” on the three statements on teamwork.

- I have spent a lot of effort on the team-based project(s).
- I enjoy working with other people on a team.
- The project rendered a tangible deliverable.

Interestingly, after the PBL course, all the choices became “agree” although the pre-course choices had some “neutral”. The ones who have done the project would understand that although working on a project took time, it was enjoyable being in a team and fulfilling when the final deliverable was finished.

The data shown in Figures 4 and 5 were aimed to examine the students’ perceptions and experiences on working with teammates from lower or higher year-standings, respectively, in the intended vertical integration practice. In the five-student team, there was one lower-year-standing student while all others were in the same year standing. In the two-student team, they were in the same year-standing. As a result, the survey results could be skewed as there was not much chance for the students to work with people in a different year-standing than them.

The post-course survey results in Figures 4 and 5 showed more consistent opinions than the pre-course perception of the teammates. The results indicated that they did not get to mentor a younger student, but they would do so if there was a chance. They all felt beneficial to work with a senior student.

Table 4 and Figure 6 show the same data when the students were asked to choose if they were more aligned with the statement on the left or the statement on the right, or not leaning toward either statement. The statements have covered various aspects of teamwork and leadership.

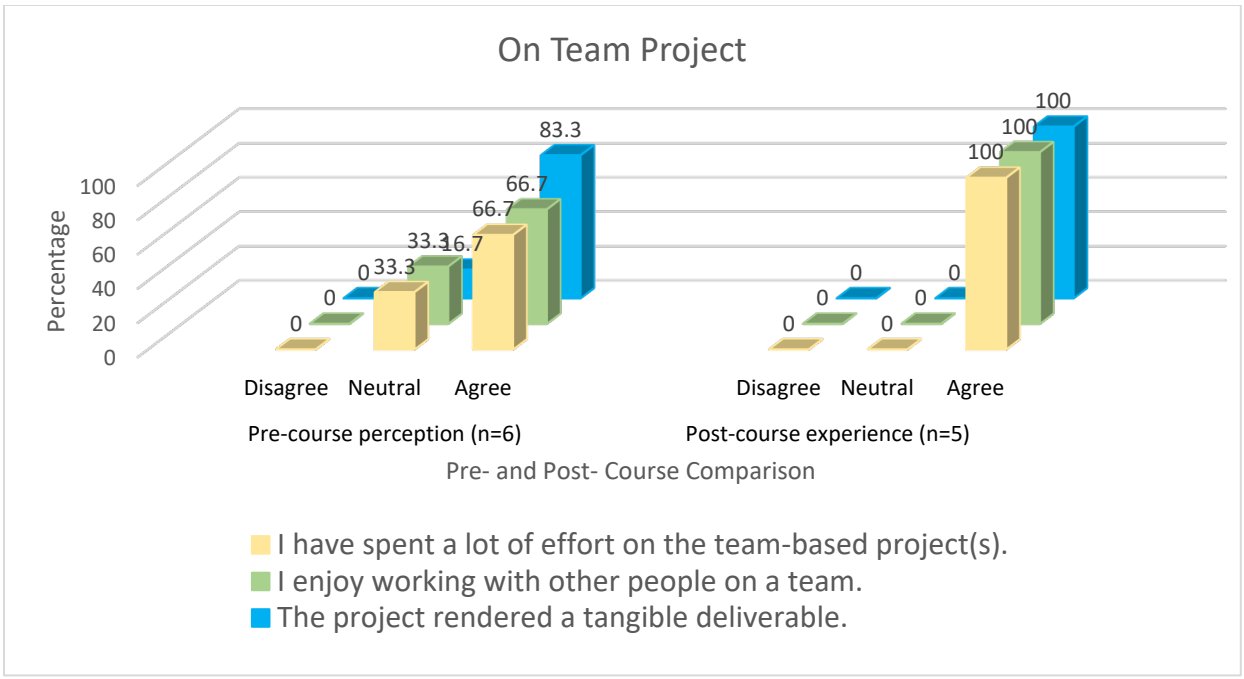

Figure 3. Student opinions on team projects

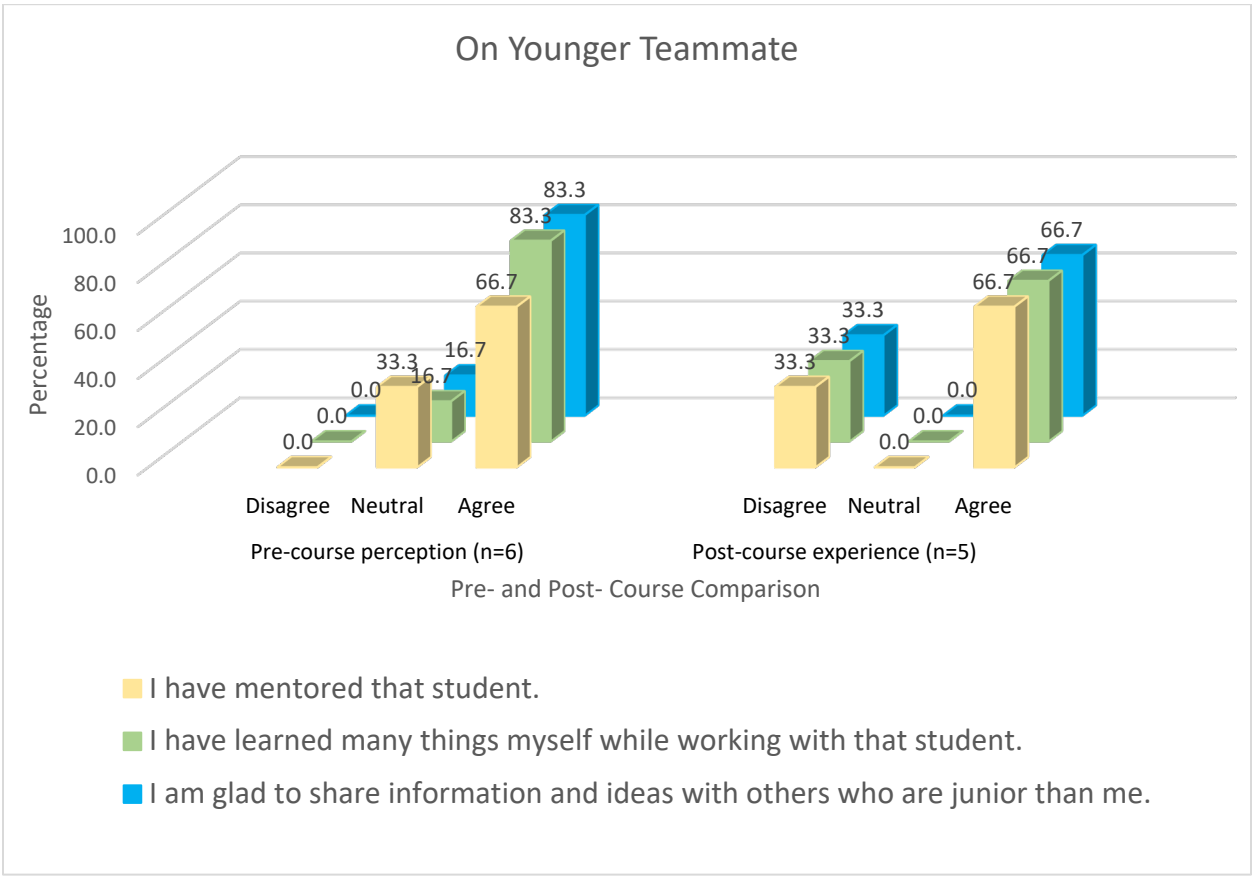

Figure 4. Student opinions on working with younger teammates

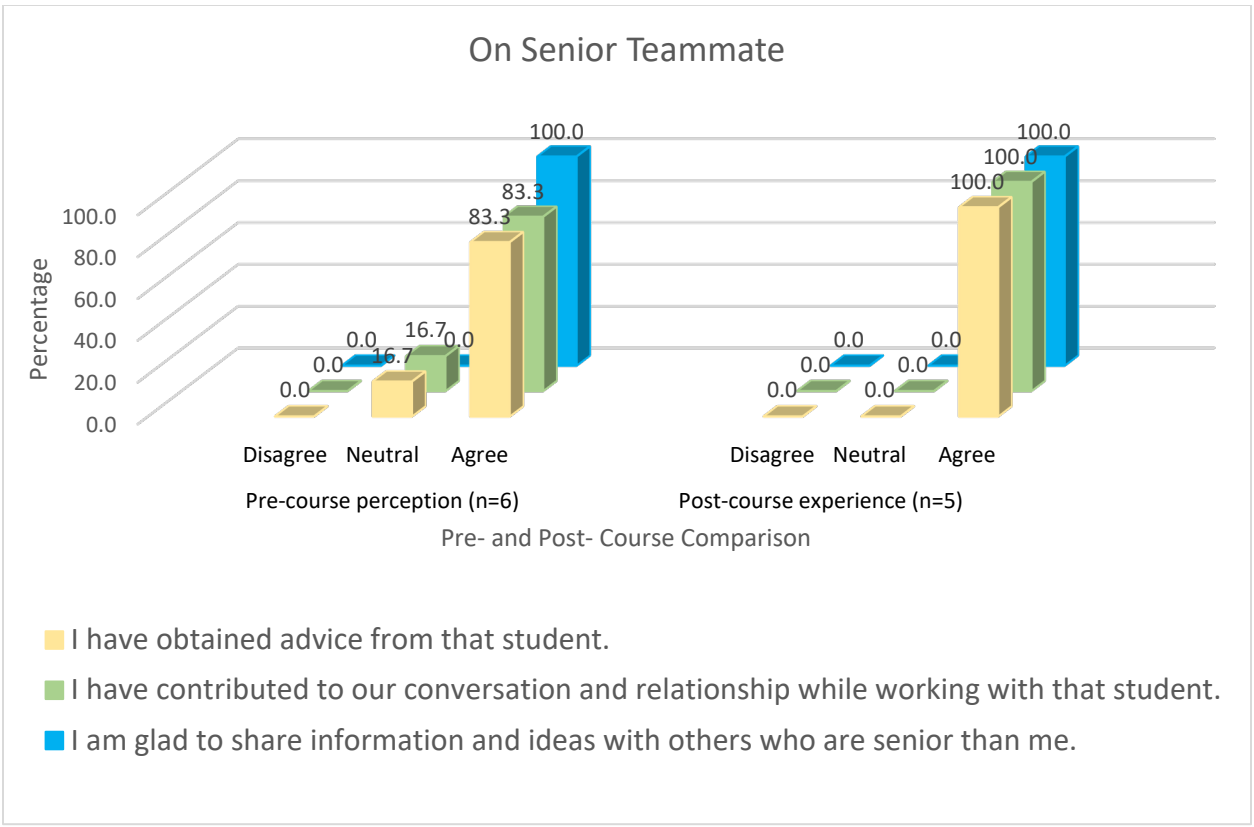

Figure 5. Student opinions on working with more senior teammates

The noteworthy changing trends between the pre-course perceptions and post-course experiences are marked in red font in Table 4. Figure 6 is another way for the reader to visualize the same data. The results can be summarized as follows:

- The students became more divided after the project phase on if they would ask for help or keep the academic problems to themselves. The instructor had encouraged the students to always seek help and often gotten questions, but the instructor occasionally felt that the students could've asked the questions sooner. Understandably it was a fine balance between when they should seek help or when they should spend more time on a problem by themselves.
- The students appeared to be more independent after the project phase than at the beginning of the course, perhaps due to the fact that online instruction had kept them to be apart anyway. Also, for the bigger team, some students would emerge as the ones who would be more responsive and responsible for making progress than others, and they might feel that they would not need the help from others who did not contribute as much.
- They all became more responsible for the team project's final product, and they enjoyed developing leadership skills and encouraging others and various views on the team.

Table 4. Student Perception and Experience on Teamwork and Leadership

Please indicate your level of agreement with the following statements by choosing a choice closer to the statement on the left or the one on the right. The choice in the center is not leaning towards either left or right.

	Pre-Course Perception (%)			Post-Course Experience (%)			
I usually reach out for help for academic problems.	16.7	66.7	16.7	40	20	40	I often keep the academic problems to myself.
I build strong relationships with other students for my academic success.	66.7	33.3	0	40	60	0	I don't need to work with other students to succeed.
I enjoy working with other students on projects.	50	50	0	80	20	0	I enjoy working on a project by myself.
I am comfortable with engineering problems with multiple possible solutions and no clear path to the solutions or project completion.	50	50	0	40	60	0	I am very nervous about engineering problems that have multiple possible solutions and no clear path to the solutions or project completion.
Team project's quality is every team member's responsibility.	83.3	0.0	16.7	60	40	0	Some student is more responsible than others for the team project's quality.
If my project team's project ran into difficult circumstances, I felt responsible for getting it back on track.	100	0	0	60	40	0	I am not responsible for our team project when it runs into issues.
Project Based Learning activities help me to understand leadership techniques.	66.7	33.3	0	100	0	0	Project Based Learning activities are not effective in fostering leadership.
I enjoy taking charge of a project while encouraging others to actively participate.	83.3	16.7	0	60	40	0	I enjoy supporting others to tackle a project.
When my project team discovers a flaw in our work, we work as a team to make it better.	83.3	16.7	0	100	0	0	When our project team discover a flaw in our work, we get stuck.
My project team members encourage diverse points of view, openly negotiate design changes and provide feedback to and from each other to improve team processes and project outcomes.	83.3	16.7	0	60	40	0	Our group ideas are focused early on and we don't need to think more.

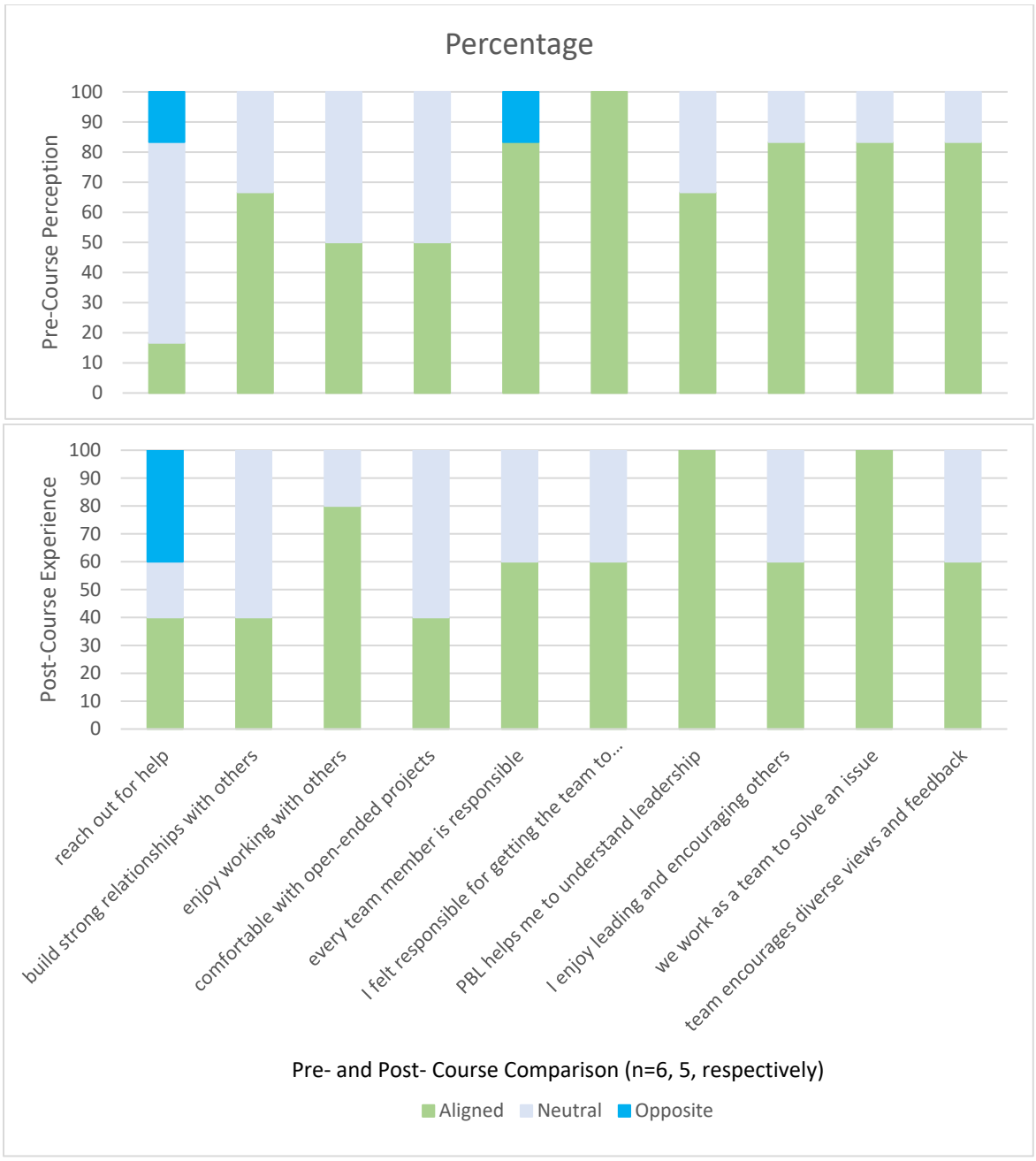

Figure 6. Student opinions on teamwork and leadership statements

All the student comments from the surveys as well as from the Fulbright office's anonymous course evaluation are provided below.

"*I really loved this course especially Dr. Yan's motivation and excitement in teaching. Dr. Yan truly did put gasoline to my already burning passion and ambitions about building a career in the field of engineering. In the beginning, we were really unopened students (speaking from my perspective) only taught to do work like machines and work things out by ourselves with little to no help from our professors, it definitely was weird the first two lessons while we got used to actually having the right to share our opinion even if it was wrong, to be heard and taught while*

actually thinking. I had never met anyone like Dr. Yan, there are of course some slight exceptions. We really need more people like Dr. Yan in the university. I hope that when next year comes I will be given permission by our Dean, to have Dr. Yan as my graduation project leader (I am not quite sure how it is called, it is basically a professor that gives you the subject of your project, helps with materials hunt and so on). I am really impressed by Dr. Yan and the things we were taught. I hope that next generations will have the opportunity to experience something like that, even for one semester, with someone as passionate as Dr. Yan."

Remark to the above comment: We told the students that Dr. Yan would stay at TU-Sofia only for one semester. It was encouraging to hear that they liked PBL, and we felt confident that they would do well in the senior project with other faculty mentors, too.

"*I think the project should have been given in the beginning of the course, because it aligned with all of our exams and we did not have the time to fully execute it at the best we could*"

Remark to the above comment: This student might not realize that the earlier course lecturing on Arduino programming and 3D design was to prepare everyone in the class for the final project. It was probably because the students had different backgrounds, and some were more ready to take on the project than others.

"*What are the three most important things you learned in this course?*

- *Not to be afraid to try new things and experiment, Arduino language structure and to use all of our resources to the max"*
- *Team work, Brainstorming and Creativity*"

"*What do you think was the most valuable activity used to promote learning in this course?*

- *The questions given to us by our professor, during class time*
- *Team work*"

Conclusions and Future Work

As shown in both the quantitative survey results and the qualitative student comments, the PBL course was challenging yet enjoyable for the students to practice their technical knowledge and professional skills, especially in teamwork, creativity, and problem-solving. Although the sample size was small as this PBL course was an elective course, the response rate was reasonable (6 out of 13 in the pre-course survey among all the students and 5 out of 7 in the post-course survey among the groups who have finished their projects).

It took a significant amount of effort to obtain all the needed lab kits (such as vendor selection, alternative product model selection given different standards in the U.S. and EU, applying for the EORI document for customs clearance, beyond securing the funding), but it was worth the effort as the lab kits proved to be essential for the students to maintain hands-on activities at home when the course had to be transitioned online. The PBL course needed to be adapted to a new environment in the Fulbright Scholar project, and the pandemic had caused further challenges so that some of the intended high-impact practices beyond PBL such as vertical integration and COIL were not fully executed but both enhancement plans were attempted at a lesser degree.

The project topic was chosen to reflect the mission of the Fulbright program and the students were able to incorporate their technical skills and cultural awareness in their creations. Overall, it was a meaningful project to encourage the students to continue their pursuits to be engineers.

In the future, we could explore smaller-scale projects that could happen earlier in the semester at TU-Sofia then full-scale COIL might be feasible. Dr. Yan has planned a faculty-led trip to lead the U.S. students to visit Bulgaria in the summer (although the May 2022 trip had to cancel, the planning will be used in a future trip), and the students from both universities could meet and learn. If opportunities allow, the authors would love to continue inspiring PBL practices with potential enhancements such as vertical integration and COIL in a wider range of universities.

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