ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #38151

Lessons Learned from Collaborative Initialization of Machine Learning Class and STEM Contest with University and Industry Partnership

Hoo Kim

Hoo Kim, Ph.D., P.E., is an Associate Professor in the School of Engineering and Engineering Technology at LeTourneau University. He received his B.S. and M.S. degrees from POSTECH, Pohang, South Korea, and his Ph.D. from the University of Texas at Austin. His professional interests include teaching in the area of electromagnetics and RF, integration of faith and engineering, and entrepreneurship in engineering.

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Introduction

University and industry partnerships have been effectively providing mutual benefits to both participating universities and industries, and the real-world engineering problems and networking opportunities provided during collaboration give students unique learning experiences [1-4]. Various models and frameworks in university and industry partnership have been introduced with different collaborations [5-7]. Small-sized schools in particular benefit greatly from partnerships [8]. Some partnerships target not only higher education but also K-12 STEM education with diverse forms to impact more perspective students [9, 10]. This paper introduces the lessons learned from a three-year collaboration and partnership between LeTourneau University (LETU) and Qeexo, Inc. LETU is a small private institution in Texas, and Qeexo is a startup located at Silicon Valley in California. The partnership between LETU and Qeexo was initiated during the 1st year of a Silicon Valley mission trip with LETU students led by a faculty member. The successful partnership was established with a two-year collaboration to end with mutual benefits for the participating groups. Students experienced leading edge machine learning (ML) technology in their class term project and an embedded machine learning contest supported by Qeexo. Qeexo could test its pre-launch, new product before releasing and improve the product with valuable input and feedback from students and faculty with their user experience. In the 2nd year, the contest was expanded to include high school students who were in LETU's dual credit programs. With this growing partnership, both LETU and high school students experienced real-world engineering projects to develop engineering solutions using a hands-on machine learning platform with the support of engineers and marketing experts in the fairly new STEM area of embedded machine learning. Diverse STEM collaboration and partnership among university students, industry experts, and high school students and their teachers ended with successful and encouraging outcomes with the desirable partnership case between small university and start-up company.

Partnership Conditions

LETU is a small, private institution which has a hands-on legacy in its engineering curriculum and courses. The Electrical and Computer Engineering (ECE) Department of LETU wanted to introduce fairly new technology and knowledge such as machine learning and artificial intelligence. With this vision, a faculty member prepared to open the course Machine Learning for Engineers with designed hands-on experiences to maximize students' learning. The instructor suggested collaborating with Qeexo's leading-edge tools to apply to the class project structure. The timing was coordinated effectively with Qeexo's new product release timeline. Before launching its software (SW) product, Qeexo needed a beta product test which was important to receive users' feedback and input before the actual release. With LETU's small and flexible course setup driven by an instructor, Qeexo provided the software and technical support from designated staff who introduced the software and usage examples with potential applications which students

applied to their own project ideas. As a part of the collaboration between LETU and Qeexo, an embedded machine learning contest was also designed and conducted to encourage students' active participation and to bring more attention to developing valuable applications of the product. In the 1st year, the contest only included LETU student teams, while the 2nd year's contest included both LETU student teams and high school student teams. For the successful collaboration, the consideration of both LETU and Qeexo's timelines were critical with the appropriate distribution of available resources. Table I shows the overall timelines of the collaborative work, including the course names and their semesters which were aligned with the partnership. The semesters of the conducted embedded machine learning contests are shown as well.

Table I: Timeline – Partnership Aligned with Academic Setup

Year/ Semester	Course	ML Contest	Note
2019 Summer			Company visit / discussion for collaboration
2020 Spring	·ENGR 4963 (New) ML for Engineers		
2020 Fall	·ENGR 4913 (New) Intro to AI	Open to all LETU students	
2021 Spring	·ENGR 4963 ·ENGR 5963 (New) ML for Engineers		Graduate-level course extension
2021 Fall	·ENGR 4913 ·ENGR 5913 (New) Intro to AI	Open to all LETU students & high school students	Graduate-level course extension Dual credit associated school focus

The following are the chronological detailed program descriptions.

Pre-collaboration Year with Company Visit: As a part of the Silicon Valley trip, LETU students and faculty visited Qeexo to meet industry personnel and were introduced to the company's leading-edge technology. As part of the discussion over LETU and Qeexo's collaboration, the idea to develop a course applying Qeexo's beta software in the class term project setup at LETU was proposed.

Year 1 Collaboration: The instructor designed the class (ENGR 4963: Machine Learning for Engineers) to include a term project using the tool provided by Qeexo, and the project simultaneously asked students to recreate the exact same application using Python programming so that they could compare two different tools. The term project required students to identify an engineering problem that fit their interests and apply machine learning techniques to solve it. The term project included major components along with a typical ML project sequence. The term project was aligned with the ML contest in the following semester, Fall 2020, which was open to all LETU students and sponsored by Qeexo and Arduino. Arduino was introduced by Qeexo since Qeexo's software used the hardware (HW) platform of Arduino. During the term project and ML contest, students received educational guidance and support both from the course instructor and Qeexo. In the following semester, the instructor opened another course (ENGR 4913: Introduction to Artificial Intelligence), aligning with the departmental requests to develop more coursework in

the area of artificial intelligence (AI). With the formal experience of the first class's term project and more mature software release by Qeexo, the instructor and Qeexo decided to hold a machine learning contest based on the initial 1st semester's term project experience. As a 1st year trial, Qeexo and the instructor limited the contest's participants to only students of LETU which reduced the burden of managing unspecified groups and teams with more complicated logistics. This worked efficiently because of the limited resources from both Qeexo as a startup and LETU as a small, private institution. With this new course to cover broader topics in AI, the term project was limited to using only the software of Qeexo to find engineering problems and solve the problems by applying their embedded ML software and hardware platform provided by Qeexo. To ensure the contest participants had more direct support in using new ML technology and tools, students who took the course were required to participate in the contest as a part of their class term projects. The contest was open to all LETU students, publicized by advertisements and announcements. As a contest design, selected 10 teams were invited to enter the final round to demonstrate their works. All team's works were judged by judges from B and C industry and judges from LETU. Qeexo sponsored all prizes and technical guidance in the contest, and LETU's marketing team provided support by inviting local media and advertising the contest to the public [11, 12].

Year 2 Collaboration: With the 1st year experience, the ENGR 4963: Machine Learning for Engineers course was extended to include graduate-level students with a separate graduate-level course (ENGR 5963). The course used the ML software and its platform from the 1st year but was more matured and the course materials further developed. In the 2nd year, the term projects were conducted by students with the expectations of adding more application cases using Qeexo's software. This was designed to receive more specific feedback from student users regarding the newer SW release and modification. The following semester (Fall 2021, 2nd year), the instructor extended the course (ENGR 4913: Introduction to AI) to have a graduate-level course (ENGR 5913). Along with the extended coursework, Qeexo and the instructor discussed holding the ML competition with larger group of participants. A faculty member suggested using the network of LETU and its existing relationship with LETU's dual credit programs. Under guidance of the ECE department of LETU, high school students who were in LETU's dual credit program were added to the 2nd-year contest alongside LETU students. This was an experimental trial to engage more with high school students and connect them with STEM activities through the ML contest. During the ML contest, LETU students participated as three different groups: 1) contest participants who entered the ML contests, including the course-taking students; 2) mentors who were students in LETU's SWE (Society of Women Engineers) club; and 3) operational staff who were students in the IEEE (Institute of Electrical and Electronics Engineers) and SWE clubs.

Course Design and Structure

With the legacy of LETU, every ECE engineering course includes hands-on projects, and each 16-week course is designed to teach key knowledge along with the project ideation and practice. With this typical course expectation and design, the ENGR 4963 and ENGR 5963 Machine Learning

for Engineers courses were as designed to train students with both a manual approach from code building by Python and an approach using Qeexo software. In this way, students knew how fundamental concepts of ML and its line-by-line coding were applied into the UI/UX of Qeexo's software. This comparison was intended for their learning as part of their project assignment. In the ENGR 4913 and 5913 Introduction to AI courses, the term project was designed to be part of the ML contest, and the registered students for the course were required to participate in the contest. The ML contest support was carefully designed to provide thorough guidance for both in-class and out-of-class students. Table II shows the course timeline and setup of LETU course with a list of the logistical and technical supports from Qeexo.

Table II: List of LETU Course Design and Qeexo's Aligned Supports

LETU Course Setup	**Qeexo Staffing**
Week 1 – Week 5 Basic ML concept	SW registration, HW shipping
Week 6 and 7 – Term project announcement, software introduction	SW Introduction and use cases by Marketing Director of Qeexo
Week 8 - 15 Term Project (& ML Contest) ▪ Topic selection - presentation ▪ Hands-on project development ▪ Final presentation	Providing technical seminar and remote Q&A sessions by engineering staff of Qeexo in technical areas such as SW Installation and Issue Resolutions.

Term Project Description(s)

Class term projects requested students to search for and choose project topics which could apply embedded ML to solve the relevant engineering problem(s). Term projects included three main parts: Part I – ML Project Planning/Framing, Part II – ML Project Implementation, and Part III – Report and Presentation. Along with the course schedule, the major project timeline was arranged with the divided sections to guide students as illustrated in Table III.

Table III: Term Project Timeline and Major Missions

Project Timeline	**Major Missions**
Pre-Project weeks	Learning fundamentals about ML project, project descriptions
Project Week 1	Searching topic and getting approval by the course instructor
Project Week 2	Finalizing scope and preparing the dataset
Project Week 3	Implementation – design/build/test
Project Week 4	Demo and presentation

Pre-project weeks included the students' learning and training to be ready to conduct their own project within the six-week class timeframe. Students studied basic ML knowledge with guidelines and example projects using ML SW and the HW platform. Each student or team opened an account for the SW usage and installed the SW. Moreover, the HW platform was provided with the guidance to understand and use embedded sensors in the platform. In Week 1 of the term project, students had to find unique and novel ways to apply the tools based on the examples given from Qeexo and class materials. Week 2 required students to build their own dataset using the hardware

platform and its available sensors. In Week 3, individual or team participants designed and built their ML solutions to solve the problems. Participants were required to test and validate their ML solutions. In Week 4, each student or team demonstrated their solution and presented their results.

Connecting the Term Project and ML Contest

To provide more motivation and maximize students' learning, the 1st year Intro to AI course was designed to include the term project, which required students to enter the embedded ML contest. The embedded ML contest included both in-class and out-of-class participants, and tutorial sessions and support were provided by both an instructor and Qeexo staff. The contest had a more dynamic setup with the out-of-class contest participants. The sessions and seminars were open to any participants to provide a fair environment to every participant. All sessions were recorded and shared with every participant. In the 1st year's ML contest, the participants were only LETU students, and any participant could join the class or access the competition-related materials such as video lectures, seminars, and Q&A sessions. Qeexo staff provided the live tutorial and mentoring sessions to encourage the teams with more personal guidance for their successful contest participation. In the 2nd year's ML contest, which included high school participants, the contest contents and tutorial sessions for high school students were provided to better support the local high school teachers and students who were mainly remote participants for the contest.

ML Contest Program and Collaborations

The 1st ML contest was designed for only LETU students, and the Qeexo staff provided the seminar and technical help sessions. 10 teams out of the 15 participating teams were selected to present their demonstrations in person at the LETU's engineering lobby. The five judges were composed of Qeexo and Arduino representatives and LETU faculty and staff. The 2nd ML contest was designed to support high school participants, receiving the applications from more than 30 teams in different states in U.S. and one team from Brazil. Eight teams from LETU entered the contest in this 2nd year. The contest was redesigned and modified to support the high school teams who participated remotely and did not have much background about ML. Table IV shows weekly events and missions throughout the period of the 2nd ML contest.

Table IV: Weekly Events and Missions in the 2nd-Year ML Contest

ML Contest Weekly Events	Activities and Missions
Week 1: Kick-Off	▪ Qeexo SW sign-in ▪ Mentor assignment
Week 2: Ideation Week	▪ Call for idea with '20 Giveaway' boards ▪ Submission for project ideas
Week 3: Mentor Day	▪ Meeting mentors with Zoom/video chat
Week 4: Mock Project Day	▪ Example project building ▪ Practice project
Week 5: Lab Day	▪ Remote sessions with Q&A ▪ Issue resolution – 1-on-1 coaching
Week 6: Mock Demo Day	▪ Seminar on good presentations, generating video demos, video preparation, and practice demos
Week 7: Submission	▪ Preliminary judging (for final round entry)
Week 8: Final Demo Day	▪ In-person + remote final presentations ▪ Final judging / awards

In the 2nd-year contest, two student clubs, SWE and IEEE of LETU, served the contest. SWE mainly served by providing their mentorship to high school participants. Representatives of each student club participated in the contest events to introduce LETU's engineering program and what engineers do in general, not only focusing on the contest itself but also encouraging high school students to learn about careers in STEM fields with the voices of undergraduate students who were close to their ages. Also, student volunteers engaged with several events as they led sections of the events, such as icebreaker time in the kick-off meeting. Each SWE student was matched with a team as a team mentor to communicate and encourage the high school teams. Mentors provided the remote helping sessions as communicators and bridges between the high school participants and contest runners who could report on each team's various needs. Mentors encouraged the team not only by providing remote sessions but also sending cards with encouraging words along with the shipped parts. IEEE students mainly resolved the technical issues and prepared the contest kits. The IEEE student group provided technical support for the contest HW board modification and managed logistics of the contest. Furthermore, students of the IEEE and SWE clubs were involved with the judging process, and the 2nd-year contest judging was done with more various judges from different parties.

Assessment / Rubric

The assessment was carefully designed for both the class term projects and the contest judging process. The class project criteria were aligned with the ML contest rules to measure the project's performance in the following six categories: 1) originality and creativity, 2) functionality and technical qualities, 3) demo video, 4) presentation, 5) participation in live sessions and mission, and 6) popularity according to people's votes. For each category, teams could earn points or lose points, meant to guide and encourage the participating teams. This assessment was specifically

designed to not only reflect students' learning but also Qeexo's technical and marketing purpose after the discussion between the instructor and Qeexo staff. First, for originality and creativity, each team was challenged to convince judges of their problem statement and to address the benefits of their innovative ML solution. Second, functionality and technical qualities were set to achieve industrial acceptance for ML solutions with 95% of live-testing results, and teams were required to investigate the limitations with the future plan if current limitations were resolved. In addition, the justification of the use of Qeexo's software was included to narrow down teams' solutions. Third, regarding demo videos, this criterion required the generic rubric to reflect successful demonstrations, including team introductions, high recording quality, and good textual or voiceover explanations. Fourth, presentations required both technical and business details so that teams could consider not only the engineering perspective but also the business perspective with their project. Fifth, the participation in the provided events, such as live tutorial sessions and missions during the contest, was included to encourage the teams' successful participation and corresponding success in their project's progress. Last, a popularity vote was added as a part of the judging. With this popularity vote, the contest final demo could reflect the audience's perspective.

Outcomes through the Partnership

The partnership was mutually beneficial between a small university and a startup. As a startup, Qeexo could use this partnership to collaborate to test their unreleased new technology and products through the experimental class term project and ML contest. Moreover, Qeexo could receive the opportunity to develop a relationship with higher and STEM education and showcase applying their product which could be used in developing the market with other institutions. Participating as a sponsor for the class project and contest, Qeexo could receive valuable feedback from the student users in its beta SW version development. With the submitted term projects and contest results, Qeexo could use these outcomes as well as its educational collaboration with LETU to advertise its product. On the other hand, as a small university, LETU could collaborate with a Silicon Valley company to develop courses that adopt new topics from leading industries into its curriculum. LETU students received more motivation with the ML projects and contest by communicating and engaging with actual engineers and staff of a leading Silicon Valley company. Unlike in a massive competition or program, students felt they were more cared for and supported with the prestigious learning opportunity and networking opportunity with the marketing director, ML engineering and application director, and engineers of Qeexo. Students could learn about ML and build relationships with industry personnel for their future job networks. Students had a unique learning experience with novel SW which was not in the market yet. With trial and error during the class project, students could engage with the Qeexo staff, and students' inputs and experiences directly contributed to developing and improving the product of Qeexo. Through the extended ML contest with dual credit high school students, LETU students received the opportunities not only to learn the new technology but also to serve and lead high school students with active mentoring and staffing during the ML contest. With the extended contest and university-high school-industry

wide collaboration and participation, students benefitted from learning and developing not only their engineering hard skills but also soft skills.

Reflections

Evaluations and surveys were collected from all participants, and the following is a summary of these results with major reflections.

Reflections: LETU

1) 1st Semester Course Students (who used the beta version SW of Qeexo)

LETU students expressed how easily ML could be applied compared to Python and other tools, which require fairly good programing skills and an understanding of ML algorithm implementation, with comments like the following:

"Qeexo SW provided confidence to work with machine learning algorithms and an outlet to learn more about how they work. Qeexo SW provided a familiarity with the outer working of machine learning. Through pushing forward and learning to work with the materials given, confidence and interest toward machine learning increased."

2) ML Contest Participating Students

Students addressed how easy it was to apply ML with the platform provided by Qeexo.

"Qeexo SW was very easy to apply ML concept and students also learned valuable skills."

LETU students had more motivation with the support of Qeexo as a partner. Students felt that the opportunity directly connected with Qeexo and Silicon Valley engineers through the course setup because of the focused support provided to LETU students. The following was the direct comment from the participant:

"Are there no other teams from other schools to compete with us? Is this contest designed only for us (LETU students)? Wow! This is a great opportunity for a very selective and privileged experience which cannot be provided from any other place."

3) Students Mentors and Staff

Student mentors and staff had positive experiences serving the contest participants and guiding high school students. As students participated as mentors and staff, they experienced the growth of their communication and leadership skills, and they also expressed joy in serving the high school students and managing contest logistics. Overall, students expressed satisfaction with their serving roles.

4) Faculty (course instructor)

The instructor received three major benefits partnering with the industry. First, the instructor was able to design the course efficiently with the resources and support of Qeexo which saved the

instructor's time to investigate and select the appropriate course materials. Second, the instructor saw students' active learning with more motivation and fun, especially having hands-on projects with direct supports from industry partner experts during the project and contest. Last, the instructor gained experience coordinating diverse groups in a STEM contest setup with a broader educational impact.

Reflections: Qeexo CEO and Staff

The CEO of Qeexo was very satisfied with the university partnership. The 1st year class project provided valuable input to improve the user interface of the beta version software, finding inconvenient components and debugging issues in it. Moreover, after having two ML contests, Qeexo staff better understood their potential users, especially with the experience of supporting university students and high school students. Their manual and instructional documentations were improved significantly as a result of contest participants' questions and requests. In addition, the CEO invited the winning teams of the 2nd-year contest to participate in a separate video conference with Qeexo's major staff. The CEO mentioned that the contest presentations and inputs from the video conference were very helpful for their staff to see how actual customers or users could experience the product differently from what the developers intended. Moreover, Qeexo's marketing department was glad to benefit from advertising their product efficiently through the partnership with University A, creating advertisements with stories about Qeexo's product and sponsorship of the contest.

Reflections: High School Participants

The high school teams from the final round provided very positive feedback about their learning experience with the contest. Both teachers and students were impressed with LETU's kind guidance from mentors and faculty, and the events during the ML contest helped students follow the steps to finish their contest submissions. The invited teams had a chance to have a guided tour of LETU which provided the great opportunity for high school students to learn about university STEM education. One of the teachers who led a local robotics program in Mississippi commented that the contest program was well structured, and the judging criteria was well designed. Moreover, the teacher was very glad to learn and experience the hands-on ML project through the ML contest because it was very new to the teacher and other teachers in his region, which does not have many ML hands-on educational resources.

Recommendations for Better Collaboration

There were several challenges to this collaboration as well. Regarding timeline and contents of the course, the course instructor should be flexible and open to accept uncontrollable conditions in teaching and running the term project. Practically, it is recommended to have extra hours to coordinate the term project along with the timeline and product cycle of the partnership company.

In logistics, it was still difficult to support the remote participants, especially with high school students from various regions. The events were carefully designed and conducted with multiple events which were expected to be live sessions; however, some high school participants had difficulty joining due to conflicts with their own school schedules. Although the recorded video was provided, it was not very productive when the team needed to make up the live sessions with a hands-on demonstration. Moreover, the contest setup was limited for some high school students who did not have much experience to bring their own ideas. We also realize that local teachers were very important for high school teams' successful contest submissions. Since the ML concept was new to most students, it was necessary to make sure that local teachers understood the ML concept and process so that the teachers could encourage and lead their students. One of the challenges was the manuals and tutorials provided by Qeexo were not easy enough for high school participants to understand, although the help sessions and guided events covered most of the major components for the contest submission. It is recommended to create a separate tutorial to introduce the ML education project rather than using the company's user manuals and generic documents. Lastly, communication was critical, and the communication and sharing project work were done via the cloud environment of LETU. However, sharing files and tracking the progress of each team was not straightforward with complicated security steps and required access permission for people outside of LETU. It is recommended that the contest have a designated system to manage teams' activity and progress; however, this issue would be also improved by clear guidance and communication with diverse participating groups ahead of the contest.

Conclusion

Overall, this experimental partnership between LETU and Qeexo was successful, with much positive feedback from all participants including industry personnel, university instructors, high school teachers, coordinators, and participating students. In the course of partnership with LETU and Qeexo, typical advantages of the collaboration between a small university and a startup were observed and experienced. With an agile and flexible setup, the collaboration made it easier for LETU to adopt new ML contents with the course term project and contest along with Qeexo's support. Although it was challenging to apply a fairly new product and technology into the course term project and contest setup, partnership with the industry may reduce the burden on an instructor to develop a whole new course and project as well as allow them to motivate students with valuable experiences connecting with industry experts through the partnership program.

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