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Case study

Inspiring and engaging high school students with science and technology education in regional Australia

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Abstract: In the last two decades, there was a continuing declining participation rate in STEM education, especially in secondary schools in regional Australia. To reverse this trend and inspire rural school students with science and technology education, both federal and state governments identify the new strategies to promote STEM engagement of school students. In this study, with Queensland government's Engaging Science funding support, Central Queensland University researchers collaborated with rural school to deliver a demonstration with hand-on experiences of drone technologies to students. The activity led students to understand the application of drone technologies in daily life, especially agriculture sector. These activities impressed local communities including both teachers and students by demonstrating real-world problem-solving skills, with increasing over 25% participating students' interest in STEM education. This also leads more future collaboration opportunities to deliver other projects to supporting rural schools' STEM education. Future challenge for conducting these activities would be preparing the activity materials that fit the learning style and time schedule for different knowledge levels of students.

Keywords: engagement with secondary school, science and technology education, drone, agriculture

1. Introduction

Scientific and technological advances significantly shape our daily lives and influenced the world we live in [1]. Science and technology education in schools will benefit students with deep understanding of the disciplines and skills to succeed in a world of technological change. However, in the last two decades, there was a continuing decline of the participation rate in STEM education, especially in secondary schools in Australia [2-4]. This is resulting a growing 'knowledge generated' gap where the number of students developing STEM skills through the education system is not meeting growing demands from industry [4]. Thus, there is an urgent need to reverse this trend to overcome the limitations.

Australian governments (both federal and state) have identified some new strategies to promote STEM engagement of school students for the next 10-20 years. The national STEM school education strategy 2016-2026 proposed some actions such as facilitating effective partnerships with tertiary education providers and increasing student STEM ability, engagement, participation and aspiration. In response to this strategy, the Queensland government also released suggested actions such as increasing student engagement through STEM strategies by implementing the Digital Technologies curriculum and STEM academies, and by targeting under-represented groups.

As one critical national event to promote public interest to STEM, National Science Week was funded by Australian government as an annual celebration of science and technology since 1997. It runs each year in August and hosts over 1000 events with over one million participants across the nation. National Science Week engage and inspire people of all ages with science, engineer, and technology, with specific aims including: (1) highlighting Australian scientists' contribution to the world of knowledge; (2) encouraging the interest in science pursuits among the general public, and (3) encouraging younger people to be fascinated by the world we live in [5]. During National Science Week, many activities are delivered by universities, schools, research institution, libraries, and science centres. The participants and audiences cover a wide range of age group from children to adults. Survey suggests that a majority of the participants learn new knowledge through the events, are more interested in science, and intend to find more about the topic [6].

As part of the effort of Queensland government to promote STEM education and scientist engagement with the public, the funding scheme of Engaging Science Grant was established in 2016, aiming to improve STEM participation, public engagement, scientist engagement and public awareness of scientific research achievements in Queensland [7]. During 2018 to 2019, agriculture researchers of Central Queensland University (CQU) Bundaberg Campus received an Engaging Science grant to deliver STEM Education activities for students from local schools in Bundaberg as a regional city. The project instructed students of year 8 to 10 to explore the applications of consumer sensor products including smart home sensors, mobile devices, and consumer drones, in agriculture sector. CQU scientists delivered STEM courses, extracurricular activities and National Science Week events, bringing state-of-the-art STEM learning experience to inspire students in the region.

As a cutting-edge technology and a hot topic in media, drone is recognized as a tool that can potentially enhance learning and teaching effectiveness [8], especially to inspire students' interest in STEM and innovation. Queensland government has made strategy to investigate ways to build drone element upon existing school STEM programs, and options for linking universities and educational institutions [9]. As an attempt to contribute to this goal, this case study described a drone aerial mapping demonstration as a National Science Week 2019 event ran at Bundaberg Christian College (BCC) in CQU's Engaging Science project. As Bundaberg is one of the largest horticultural production regions in Australia [10], the activity highlights potential applications of drone aerial mapping in agriculture for local students as a part of a regional agricultural community. This paper introduced the aims and design of this National Science Week event, described the activity process, and discussed the learning outcome and impact.

2. The aims and design of this project

2.1. Background and aims of the project

Since 2010, it has been mandatory in all States and Territories for students to complete Year 10 and participate full time in education, training or employment, until they are at least 17 years old. Students generally make their senior secondary subject choices in Year 10, which is the critical year for students to make their future planning. Science is compulsory in Year 10, while in Years 11 and 12 students select at least one science as an elective subject to continue the subject. Therefore, nurturing student interest in STEM disciplines in Year 10 is a key point of interest in senior secondary school, which increases the enrolment in STEM subjects for more advanced development of related skills. In the world, many other countries (e.g. UK, Japan) emphasize the importance of science and mathematics at secondary school [11]. For example, science and ICT are compulsory in Years 10-11 in UK.

Drones are capturing headlines in the media and have many applications such as aerial photography and filming, land survey, crop monitoring, package delivery, rescue etc. As a cutting-edge technology with wide use in daily life, drones are excellent tools to provide state-of-the-art learning experience and stimulate student participation in STEM subjects. Providing Year 10 students with tangible and hands-on activities with new technology like drones therefore will potentially stimulate student interest and engage more students with science and technology education in senior secondary subject choice toward STEM pathway.

Both international and national testing suggests that students in rural schools perform at a lower level than their urban counterparts in STEM [12, 13]. The National STEM School Education Strategy [14] clarifies a need for research into effective STEM education practices in rural schools. In this case study, CQU researchers collaborated with BCC to conduct a drone aerial mapping demonstration for Year 10 students in Agricultural Science, as a part of National Science Week school activities. BCC is an independent P to 12 rural school located on the outskirts of Bundaberg in the centre of a thriving and innovative agricultural region. It has a proud history of quality agricultural education and seeks to broaden this by providing greater opportunities for students in the use of digital technology for monitoring and managing real life agricultural situations. Recent efforts include the introduction of smart environmental sensors and monitoring cameras enhanced with computer vision for detecting pests (with the assistance of funding from the Agribusiness Gateway to Industry Schools Program).

The aims of this project were for Year 10 students, through completing the demonstration and hands-on activities using drones,

1. To acquire the basic knowledge of drone aerial mapping process including safety requirement and regulation, drone flight route planning, the operation procedure, and the concept of stitching individual images to a map;
2. To understand the concept of normalised difference vegetation index (NDVI), as a critical remote sensing index, and its relationship to vegetation status;
3. To recognise the application value of aerial RGB (orthomosaic) and NDVI maps for vegetation assessment in a real-world case.

2.2. Design of the project

The project was collaboratively developed by CQU agriculture researchers and BCC STEM teachers. To achieve the aims of this project, following activities were designed as below:

To achieve Aim 1, a drone aerial mapping demonstration was planned to examine the lawn development in BCC's oval. The demonstration included three sections: (1) a pre-flight introduction to basic knowledge of drone, safety requirement and regulation, procedure of drone aerial mapping, field operation procedure, and drone flight route planning; (2) the demonstration field flight including the implementation of drone flight route planning, drone aerial mapping, and execution of the field operation procedure; and (3) a post-flight introduction of initial processing and assessment of drone aerial images including basic knowledge of stitching individual images to a map.

To achieve Aim 2, a brief lecture session was provided to students in the class after drone aerial demo flight for an introduction to image analysis. The lecture introduced basic concept of NDVI as a widely used remote sensing index, as well as the relationship between NDVI and ground vegetation status. Then a few typical examples of drone aerial images, including those collected during the demonstration were shown to students.

To achieve Aim 3, students were led to discuss the real-world case study of drone applications in the class. Students were also guided to analyse the obtained drone aerial images during the demonstration, discuss the indication of NDVI map to the lawn development in the oval, and identify potential areas of problem. New tasks, such as ground examination/survey, were set to examine the identified areas and further results were obtained from the examination.

3. Implementation of the project

3.1. Background information

The activity was carried out during Australia's National Science Week of 2019 in BCC (Bundaberg, Queensland). A drone aerial mapping demo was run to assess the lawn establishment of BCC's oval. The demonstration targeted Year 10 students enrolled in agriculture subject, but also attracted other student in the oval to attend, especial some Year 8 students (in Sustainable Solutions course) who participated in another activity supported under the same Engaging Science project. The activity venue included three sections:

1. Site preparation and pre-flight introduction (20 minutes): drone take-off/landing site was set following CASA regulation and professional drone operation standard, and students were provided an introduction of the purpose of the demonstration flight, the equipment, safety regulations of drone operation, and the basic principles of flight route planning.
2. Drone aerial mapping (20 minutes): drone flight and aerial mapping was implemented to show students a demo.
3. Data presentation (20 minutes): drone aerial maps were processed and results were discussed with students in a class session on the second day. The basics of image stitching and remote sensing were introduced to students.

3.2. Hardware and software

A small quadcopter drone (Phantom 3 Advanced, DJI, Shenzhen) was used for drone mapping demonstration. The drone has an OEM RGB camera that captures images of 4000x3000 (pixels) resolution. To provide more vegetation information, the drone was also modified to load an additional multispectral camera (MicaSense RedEdge, MicaSense, Seattle) in the back of the drone body on a 2mm carbon fibre mounting plate. To balance the drone, the OEM RGB camera was moved forward. The multispectral camera has a horizontal angle of view at 47.2°and captures images of 5 narrow spectral bands (blue, 465-485nm; green, 555-565nm; red, 663-673nm; red edge, 712-722nm; and near-infrared 820-860nm) with the resolution of 1280x960. Equipped with a GPS antenna to record geo-coordinates, and a light sensor to record environment radiation intensity, the camera is self-contained for most functions except using 5V DC power output from the drone.

The drone flight mission including the route and OEM camera triggering was controlled by DroneDeploy iOS App, a 3rd party App designed for mapping applications of DJI drones. This App allows to set flight height, direct, speed, image front and side overlap (of the OEM camera), and starting point for automatic planning of the mapping flight route.

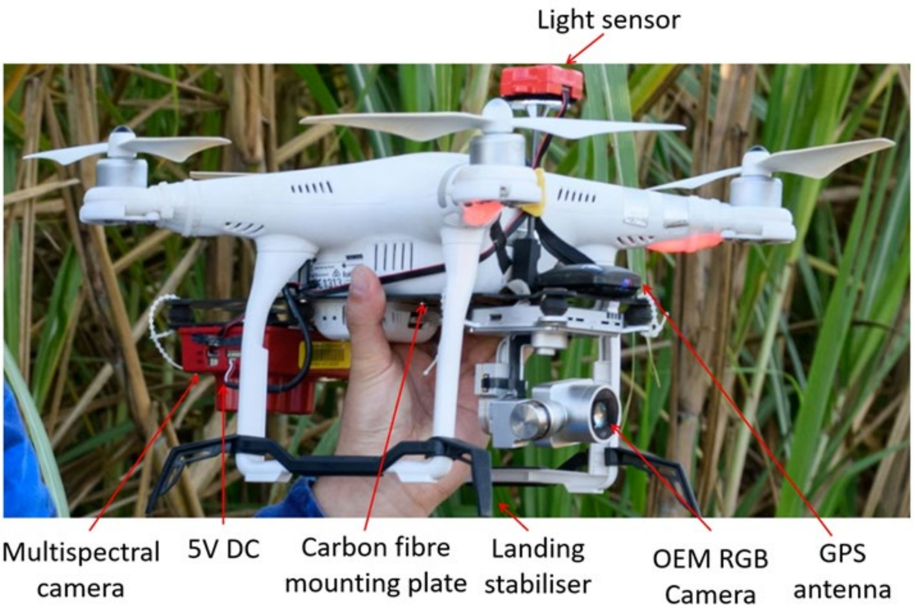

Figure 1. The drone used for aerial mapping demonstration in this case study (modified from DJI Phantom 3 Advanced).

3.3. Flight protocol

The drone was flown at an altitude of 50 m, providing a ground sampling distance (GSD) of 2.1 cm for RGB camera and 3.4cm for the multispectral camera. The flight route was set to be 80% side overlap based on the specification of the OEM RGB camera, which is equivalent to 60% for the multispectral camera. The front overlap of RGB and multispectral camera was set at 70% and 90%, respectively. The flight speed was set at 6m/s. The flight route covers the oval and a trial block of the school farm.

Figure 2. Flight route for aerial mapping in DroneDeploy software interface

3.4. Field demonstration

A lunch time activity was arranged during the National Science Week of 2019 to run the drone aerial demonstration at the oval of BCC to assess the lawn development, following steps below. A CQU researcher implemented drone demonstration flight and delivered lecture as an external instructor. BCC teachers organized activity and facilitated the interaction between the instructor and students and other BCC staff.

3.4.1. Site setup

The instructor attended the site about 30 minutes in advance to set up the flight site. A taking off/landing zone was set, and safety cones were used to assure 30m distance from any non-operational personnel, as regulated by CASA's RPAS operation compliance requirement. School teachers also helped to prevent students entering the taking off/landing zone. When the activity started, the instructor first explained the basics of CASA regulation of drone operation to the students and highlighted the necessity of all the safety measure. He also showed students the package of operation gears (first aid kit, fire extinguisher, fire blanket, reflective safety edge etc.), and answered questions raised by students and school teachers.

3.4.2. Hardware and software explanation

The instructor showed students pre-planned DroneDeploy mapping flight route on ipad and explained the basic principles of designing the map ping route (requirement of image overlap, flight time estimation, flight speed choice, flight route angle etc.). The instructor also showed the students the modification of the DJI Phantom 3 Advanced drone to load an additional Micasense Rededge multispectral camera, and briefly introduced the camera (spectral bands the camera capture, light filter, etc.). Student's questions about the drone hardware and software were answered.

3.4.3. Drone aerial mapping

The instructor then took off the drone and started image capture. When the drone was capturing images, the instructor showed students the operation interface of DroneDeploy on ipad, which made real-time update of drone movement and image capture. Due to the safety requirement of CASA drone operation regulation, instructor-student interaction in this step was limited and students were not allowed to make hand-on operation of the drone.

3.4.4. Landing

The instructor landed the drone after completing the aerial image capture and then explained the importance of pre- and post-flight check of the drone for safe operation to students.

Figure 3. Instructor interacting with students to explain safety regulation, operation gears, and flight procedure.

Figure 4. Aerial image of Bundaberg Christian College's oval.

3.5. In-class image processing and data visualisation

3.5.1. Image processing

The acquired RGB and multispectral images were initially processed using Pix4Dmapper, a benchmark software for drone image processing, to generate the RGB orthomosaic map and reflectance maps for each spectral band. The default setting in Pix4Dmapper '3D Maps' and 'Agricultural Multispectral' were used to process RGB and multispectral images, respectively.

Reflectance maps were calibrated with images taken on a standard reflectance panel under the same light condition and a light meter mounted on the top of the drone. Red and near-infrared (NIR) bands were used to calculate Normalized Difference Vegetation Index (NDVI) in Pix4Dmapper. using the following formula [15]: NDVI = (NIR−RED)/(NIR+RED); where the NIR and the RED are reflectance of the near infrared and the red bands. Colour imaging was classified into 20 steps with equal space across the NDVI range of 0 to 1 (i. e. each colour step represents NDVI range of 0.05). As a remote sensing index, NDVI theoretically range between 0-1, with higher value indicates more thriving vegetation coverage.

3.5.2. Data visualisation

A class session was delivered in the following day of the drone flight demonstration. In this session, the instructor:

- Showed the 3D reconstruction model of the mapped campus area to demonstrate the capacity of drone aerial images for 3D mapping and modelling. The very basic principles of 3D reconstruction and image stitching was introduced.
- Showed the RGB orthomosaic map and NDVI vegetation map of the oval, and asked the students to compare the two maps, finding the correlation between NDVI distribution pattern and ground vegetation image.
- Discussed the indication of aerial maps about lawn growth, and raised a number of questions for students to think. For example, why there were vertical rows of gap? In which area the lawn growth was limited? What can be the possible reason of spatially uneven development of the lawn?

The teachers from Science and Technology sectors of BCC facilitated the session and discussion. After the class, students got opportunity to have hand-on operation in Pix4DMapper software to examine 3D model and drone maps.

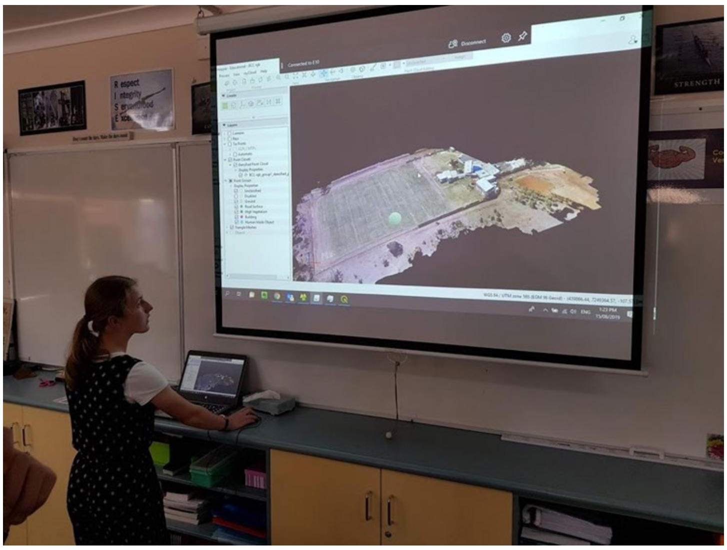

Figure 5. Student making hand-on operation of Pix4DMapper software to examine the 3D map.

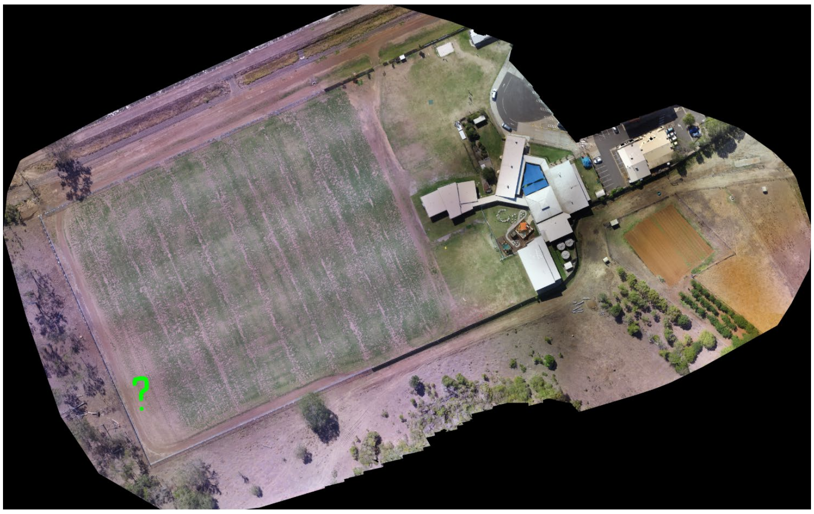

Figure 6. RGB orthomosaic map of Bundaberg Christian college. The green question mark highlights the oval area showing abnormal lawn development.

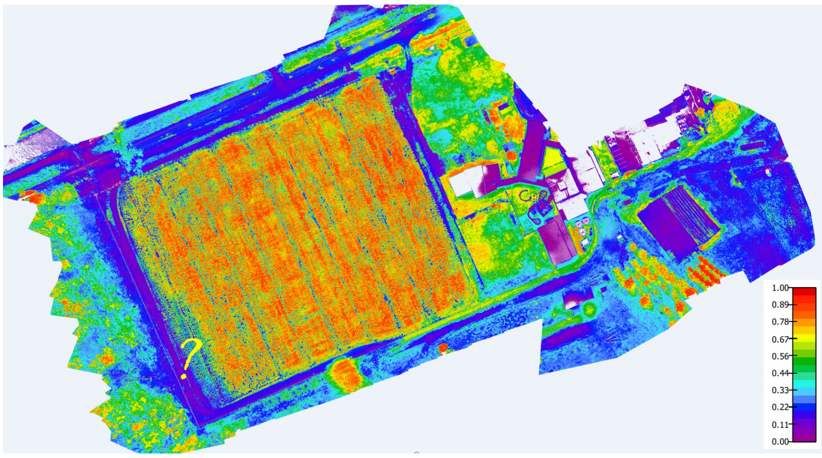

Figure 7. Normal Difference Vegetation Index map of Bundaberg Christian college, with red indicating high grass biomass and blue-purple color indicating poor vegetation coverage. The yellow question mark highlights the oval area showing abnormal lawn development.

3.6. Follow-ups post the main activities

The aerial maps were forwarded to BCC's school facility management team for their reference to assess the development of oval lawn.

Both RGB and NDVI map identified underdevelopment of lawn in the south west corner of the oval. The school facility management staff went to check the irrigation facility and found that the water pressure of pop-up sprinklers in the west end of the oval was substantially lower than the normal level (since they were the farthest from the pump), especially for those in the south west corner. Due to the low water pressure, the sprinklers in that area did not fully pop-up. Thus, the lack of irrigation and water was the main reason causing the uneven development of the lawn. The school facility staff then fixed the problem of lawn irrigation system. This result of ground examination was then fed back to students who participated in the activity.

4. Discussion and concluding remarks

4.1. Highlights

The two highlights of this project are (1) leading students to understand the application of drone technologies in daily life, and (2) delivering combined demonstration and hand-on experiences with drone technologies to school students. In the feedback survey, these two points were nominated by students as the aspects they like most about this activity.

The technologies presented in this project impressed school community by demonstrating efficient solutions to real-world problems. For example, the aerial map taken during the Drone Mapping Demo at BCC identified an area with poorly developed lawn in the Oval. School staff then checked the area and fixed an irrigation defection causing the problem. Both the teachers and students were impressed by the solution brought by drone technologies in this real application case. This greatly raised the awareness and interest of the community to great science taking place in Queensland.

Although this drone demonstration project brought some hand-on experience for students, such as operation of Pix4DMapper to examine 3D models and drone maps, the scope was limited due to CASA regulation on drone operation. In future activities, smaller, safer drones exempted from CASA regulation (<250g), such as DJI Tello EDU, could be adopted for students to operate and gain hand-on experience of drone aerial mapping. This is expected to further stimulate student's interest.

4.2. Feedbacks

The project satisfactorily increased student participation in STEM subjects. Among 24 respondents from students, 26% of students participated in the project stated that the activities increased their interest in STEM, and 32% of participating students hoped to be involved in similar activities in the future. About 2/3 of the respondents learned new knowledge and skills in these activities. About 46% students well enjoyed the activities and about 40% of the students believed that the instructor, as a researcher from CQU, delivered clear lectures and were helpful to support them understanding scientific questions. It is notable that considerable proportion of respondents (23% to 60% across different questions) provided neutral score to our questionaries. The activities also increased STEM class enrolment, e.g., the enrolment in Agriculture Science class increased 50 in the following term in BCC.

Here is a selection of narrative feedback from BCC teachers involved in the activity:

"It is refreshing for students to find that the science they are learning in school has a real purpose. It is also something quite achievable, anyone can test something if they do it in an unbiased way. Agriculture is an excellent context because it is so important for life in the 21st Century. This project has shown young people that they can take some measure of responsibility in improving the provision of food and fibre in the future, in a sustainable way."

"Often, teaching students about data involved very dry activities like conducting surveys on demographics or something that has little impact in the real world. The agricultural sensor project engaged students in the emerging industry of smart farming where they were able to experience first-hand how data can lead to improvements in profit, yield, and sustainability."

"It was fantastic for students to hear first-hand from experts in the field about some of the sustainability problems faced in agriculture today. Students had the opportunity to use sensor technologies and collect on-going data. As a result, they engaged in an authentic experience which allowed them to consider the innovative ways technology could be used to help solve some of these problems for future generations."

This drone demonstration, together with other activities in the Engaging Science project, have also been reported by ABC, 7NEWS and NewMail and therefore increased the public awareness of school STEM education in Wide Bay communities.

4.3. Further collaboration

This project helped local rural schools to build trust and relationship with CQU researchers. This has led to several future collaboration opportunities that will deliver projects supporting rural schools' STEM education. A few directions identified include:

1. STEM education program with small programmable drones: BCC teachers and CQU researchers identified DJI Tello EDU could be a good tool for future STEM learning activities. DJI Tello EDU was developed for STEM education. It is affordable (AU $219), with aerial photography capacity, and small enough to be exempted from CASA regulation (89g), so it can provide students hand-on operation experience. Tello EDU also supports several coding tools fit different level of students (Scratch, Swift and Python), so that students can learn coding to manipulate the drone. Adoption of this tool in the future will significantly expand the scope of STEM learning with drone technologies and applications.
2. Working with local schools to build Professional Development (PD) programs for Science/ Technology teachers. Recent school syllabus amendment aimed to include more data analysis and use in science subjects, so there is an imperative need of PD programs to update the data analysis knowledge and skills of science teachers. CQU researchers would work with schools on developing PD workshops to fit this purpose.
3. Running research trials on school farm. CQU researchers worked with BCC to run microplot research experiments on school farm. Such school farms are great resources for researchers to use and the trials are also used for education in classes like Agriculture Science, Biology etc., creating win-win solution for both the school and researchers.
4. Involving in Student School Holiday Work programs. CQU researchers further worked with BCC to recruit students to work in STEM research projects during school holidays, providing the youth hand-on working experience in a real research environment. Two BCC students were recruited in 2020 to work in a pest project at CQU.

4.4. Self-reflection

The greatest challenge researchers encountered was to prepare activity materials that fit the learning style and time schedule of school students at different levels. Student feedback reflected a few issues with the activity, including that the lecture content was not fun and enjoyable enough; there were too many lectures and not enough interaction; and some content was difficult and hard for high-school students to understand. In addition, it was identified that the activity must follow strict timeline so that normal classes at the school would not be interrupted. In the future, it is recommended to keep the general structure of the activity but fine tune its design. Also, the time allocation of lectures could be reduced while more hand-on experiences for real-world problem solutions could be included. The activities also need to be made easier to fit students' knowledge level.

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