Project Title: STEAM@soybean - Promotion of STEAM education through investigations of soybean cultivation (STEAM@soybean 透過大豆種植的探究推動 STEAM 教育)

Project Number

Name of Organisation: Department of Curriculum and Instruction, The Chinese University of Hong Kong

Project Leader: , **Co-Leader:**

(1) Goals: Promote STEAM education in secondary schools through investigations of soybean cultivation

Objectives:

a. Students learn and apply (i) biology concepts in relation to soybean cultivation; (ii) science and engineering practices for science and engineering inquiry; (iii) skills of using DNA markers and cross-breeding soybeans
b. Students realize and appreciate (i) the roles of various STEAM elements in smart soybean cultivation and soybean- industry; (ii) the importance of soybean as protein food and feed and its economic significance to China and the world
c. Develop teaching and learning resources using frontier research in soybean cultivation
d. Develop a framework for STEAM teaching and foster the competency of secondary teachers in designing and conducting STEAM education, especially for senior level biology

(2) Targets and Expected Number of Beneficiaries:

- Project participants: 30-40 secondary schools, 30-40 biology/science teachers, 900-1200 S3-S5 students;
- Participants of public school seminars and exhibition: 300 teachers, 1000 students

(3) Implementation Plan: (i) Duration: Jan 2020 to Jun 2022 (30 months)

(ii) Process/Schedule:

Round 1: Phase 1: Soybean cultivation at school	Feb 2020 – Jun 2020
Phase 2: Visits to experimental soybean fields in NW China and soybean food factory	Jun - Jul 2020
Phase 3 – Scientific investigations and design projects about soybean cultivation at school e.g. Using DNA markers to identify soybean with salt-tolerant gene	Sep -Dec 2020
Round 2: 3 phases identical to round 1	Jan 2021-Jan 2022
Evaluation and production of deliverables	Jan-Jun 2022

(iii) Collaboration parties:

(4) Products:

(i) Deliverables/outcomes: framework of STEAM teaching, teaching and learning materials for soybean-related investigations and design projects, DNA marker kit for soybean identification, VR video of soybean field

(ii) Dissemination of outcomes: website, teacher seminars, project exhibition, conference presentation

(iii) Commercialization potential of outcomes: DNA marker kits for soybean identification

(5) Budget: (a) staff cost: HK$1,041,000 (b) services: HK$70,000 (c) equipment: HK$380,000 (d) visit: HK$434,000 (e) general expenses: HK$335,949 (f) contingency: HK$27,751 **Total = HK$2,288,700**

(6) Evaluation:

- Teacher and student surveys on the target skills, knowledge and attitudes for seminar, workshop, visit and the whole project. (Success criteria: an average of 3 or above in the 5-point Likert scale)
- Interview of selected teachers and students (Success criteria: 70% or above of the interviewees satisfied)
- Test of students on knowledge and skills about soybean cultivation, DNA marker and cross-breeding (Success criteria: Scores of students joining the project are significantly higher than those not joining the project.)
- Student investigation report, design models and worksheets (Success criteria: 70% or above are rated to be Good or above by external assessor in the scale of Sufficient/Satisfactory/Good/Very good/Excellent)

STEAM@soybean - Promotion of STEAM education through investigations of soybean cultivation (STEAM@soybean 透過大豆種植的探究推動 STEAM 教育)

Introduction

The project is aimed at promoting STEAM education in secondary schools through investigations of soybean cultivation. The project not only builds on the expertise of university scientists, educators, and secondary teachers, but also integrates frontier soybean research with STEM technology and teaching models. Since the publication of *Report on STEM Education – Unleashing Potential in Innovation* in 2016, STEM education has been widely embraced by Hong Kong schools and become one of the major initiatives in teaching and learning. However, STEM education practices in Hong Kong tend to be more about computer coding and engineering in form of cocurricular activities, whereas classroom science learning, in particular at senior levels, are not often involved. To address the issues, this project specifically targets the senior biology curriculum and attempts to make the STEM activities an integral part of classroom teaching.

Investigation of soybean cultivation is chosen as the theme of the project because of its importance in many aspects. First, it is an important protein source to the world population, particularly to China. Its importance has been highlighted in the recent trade disputes between China and the US, where China needs to import more than 100 million tons of soybean each year from the US and other countries to feed the livestock and poultry. In addition, soybean related products, such as soy sauce, tofu and soy milk, are indispensable traditional foods in Hong Kong and China. Environmentally, soybean could reduce the use of nitrogen fertilizers via its nitrogen fixation ability. Educationally, soybean can provide theme-based learning on many parts of the secondary biology curriculum and other subjects, for instance, plant biology, reproduction of flowering plants, nitrogen cycle, biotechnology, agriculture, sustainable development, famine, etc. Soybean as a theme also allows for the integration of knowledge from biology, geography, liberal studies and humanities. Soybean investigations that involve the use of genetic crossing and DNA markers will perfectly complement the classroom teaching of biology, and provide opportunities for the students to perform hands-on activities on genetics and biotechnology, with a final goal of actual applications.

Objectives

To allow students to learn and apply:

- the biology concepts in relation to soybean cultivation and investigation e.g. photosynthesis, reproduction, growth and development of flowering plants, nitrogen cycle, etc.
- the science and engineering practices for science and engineering inquiry e.g. asking question, defining problem, observation, experimental design, prototype testing, data processing and presentation, communication of ideas, etc.
- skills of biotechnology e.g. micropipetting, gel electrophoresis, PCR.
- the concepts and skills of genetic cross-breeding between two varieties of soybeans
- the concepts and skills of using DNA markers to assist breeding

To foster the following understandings and attitudes among students:

- Understand the roles of various STEAM elements involved in smart soybean cultivation and soybean-related industry: science, technology, engineering, entrepreneurship, innovation and social responsibility
- Appreciate the contributions of STEAM to the economy and society of Hong Kong and China e.g. stress-tolerant

soybean grown in arid lands of NW China, soybean-related industries in Hong Kong

- Be aware of the importance of soybean as protein food and feed to China and the world
- Be concerned about the challenges of sustainable agriculture and poverty in NW China

To contribute to STEM education in Hong Kong by:

- Developing teaching and learning resources for STEAM education based on frontier research in soybean cultivation e.g. DNA marker for soybean identification, cross breeding of two soybean varieties
- facilitating collaboration between university scientists and secondary teachers
- developing a STEAM teaching framework
- fostering the competency of secondary teachers in designing and conducting STEAM education, especially for senior level biology

Unique Features of the project:

There are numerous frameworks proposed for STEM education. The most important aspect is to link frameworks with meaningful context and contents that facilitate the sharpening of 21st Century skills and the enrichment of knowledge in STEM disciplines, as well as the nurturing the values of students who are the potential participants of future STEM related enterprises. This project put STEM education in the context of agriculture, world food supply and safety, food industries, biological science and frontier research, biotechnology, environmental concerns and related social issues, value education through soybeans cultivation and related studies. Such ***innovative*** approach to STEM education will bring great impacts to student learning and teachers' professional development. This project brings in collaborations among academics, educators and experts from industries. is an eminent scholar in soybeans research, and is an expert in biology education. Their collaboration, with the support from other experts, bring out the unique feature of this project:

(1) Through the support of , students and teachers can have the chance to experience his high-end, frontier science researches e.g. the cultivation of salinity-tolerant soybean and its genetic cross-breeding with S. African soybeans. These frontier researches are simplified and adapted into teaching and learning materials suitable for secondary student by the research team of and the education team of . The project thus not only provides innovative, research-based investigations to secondary schools, but also realize knowledge transfer from university research to high school STEAM learning.

(2) STEM is expanded into STEAM. 'A' denotes Arts, which not only refers to artistic design, but liberal arts and humanity values embedded in the broader sociocultural contexts of any STEM-related problems (Zeidler, 2014). , together with other researchers, will deliver a series of seminars and workshops on the science, social and environmental aspects of agriculture e.g. trade, famine, food security, water resources, sustainable agriculture and poverty. These seminars, together with the visits, will let teachers and students realize that STEAM education is not just about innovation or problem solving, but must be guided by human values and virtues. It aims to foster students' care and concerns for the developmental issues in HK, China and the world.

(3) This project aligns with the emphasis of science process skills in the new F1.-3 IS curriculum. Students in this project start from observing the growth of soybeans, interpreting the observation and results, asking questions from the observation, designing further experiments, and communicating their results to other students. The more advanced investigations e.g. DNA marker and genetic cross-breeding, can become important part of school-based assessment (SBA) for biology at senior levels. The project will support schools with the materials and equipment

for these high-tech experiments.

(4) Students participated in this project can have a chance to see how 'STEM AT WORK' through visiting farmlands in NW China, State Key Agricultural Laboratory, and the industry (e.g.   ). Students can understand how knowledge of science, technology, engineering and mathematics are integrated and applied in real world contexts to contribute to the society.

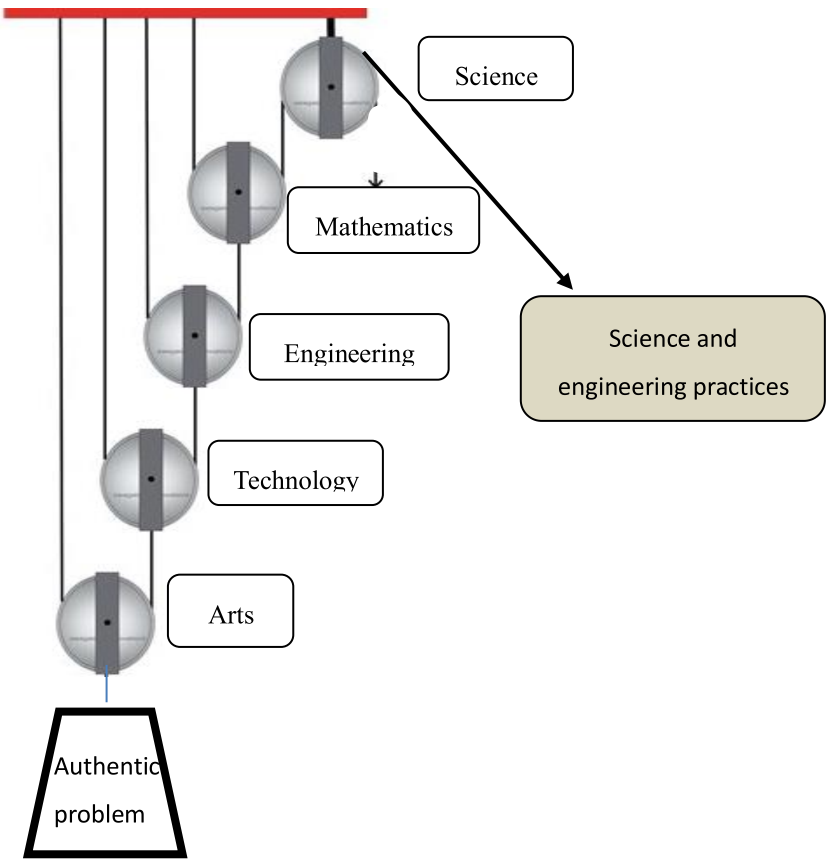
(5) This project puts much emphasis on the career aspirations of students. Students in HK are generally remote from agriculture and unfamiliar with food industry and other STEM careers. This project will provide teachers and students with personal experiences on how scientific research can contribute to agriculture and food production in HK and China. Through realizing the transformation of research into agricultural products and further into food products, students will see the potential and values of pursuing STEM-related study and careers in HK and China.

(6) This project, besides providing teachers with professional development on STEAM-related pedagogies, also aims to foster teachers' interest in STEAM through collaboration with frontier scientists and involvement in real scientific research. This is our belief that dedicated STEAM teachers must themselves be interested in STEAM disciplines, thus nurturing teachers' interest is key to the sustainable development of STEAM education.

Conceptual framework for STEAM teaching

A conceptual framework for STEAM learning (Fig 1) was developed to guide the design of the teaching and learning activities in the project, which is modified from the STEM learning framework proposed by Todd and Geoff (2016).

Period Activity   PeriodAu



In this pulley framework, the five pulleys denote the five disciplines: science, engineering, technology, mathematics and arts. They form an integrated system to elevate a weight – authentic problems. Connecting the pulleys is a rope, which represents the science and engineering practices as suggested in the Next Generation Science Standards (NGSS Lead States, 2013). These practices are the ways scientists and engineers solve problems and have similarities and differences:

The **science and engineering practices** (NGSS Lead States, 2013) includes:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models (pictures, physical, math, analogy, computer)
3. Planning and carrying out investigations
4. Using mathematics and computational thinking (decomposition, pattern recognition, abstraction, algorithm)
5. Analyzing and interpreting data
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Arts here not only refers to artistic design, but the needs to consider the broader sociocultural contexts of the problems (Zeidler, 2014), including liberal arts and humanity values. Agricultural problem is a case in point where solutions cannot be informed solely by science and engineering. The pulley of Arts is thus placed at the lowest of other disciplines to highlight its importance in solving authentic problems.

The different parts of a pulley system work as a whole, where it highlights the importance of integration in STEAM learning. Science inquiry can be connected with engineering in solving a design problem: science experiments can provide the information to construct a design, which can then be tested and refined by the engineering practices (Todd and Geoff, 2016). In addition, teacher needs to help students make explicit translations across the various disciplines and practices in STEAM learning (Glancy & Moore, 2013). For instance, the irrigation problem of agriculture can be dealt with by science inquiry, technological design and mathematical modelling, which needs to be drawn on and integrated deliberately in the learning process.

Authentic problems are key to the framework. STEAM learning has to be situated in complex, realistic problems that students have personal connection to (Glancy & Moore, 2013). That's why the project requires students to visit the soybean fields in poor NW China and the food industry so that they will be personally connected with the problems and motivated to find a solution.

Two examples are given below to illustrate how the framework guides the investigation and design process and the integration of content knowledge from various STEAM disciplines:

Example of an investigation problem

Science and engineering practices	Investigation process	Contents drawn on
1. Asking questions	Do Rhizobia enhance growth of soybean?	**Science** • Conditions for plant growth • Nitrogen-fixation • Pest control • Measurement of growth • Seed germination, flowering, self-
2. Developing and using models	Based on the model of symbiotic nitrogen fixation, it is predicted that soybean will have additional supply of nitrogen from Rhizobia and thus will grow better.	
3. Planning and	Grow soybean in soil inoculated with	

carrying out investigations	Rhizobia, compared to a control without Rhizobia. Control other variables of the environment, e.g. pot density, light, soil, water, sunlight and pest.	pollination and fruit formation **Mathematics** Means, standard derivation, ratio, curves, data table, **Technology and engineering** Students try out different technological designs to solve the problems encountered in the process of cultivation: pest, wind, water supply, fungal infection, etc. For instance, students irrigate the soybean pots with a dripping air conditioner, protect the soybean from birds with nets, treat fungal infection with pesticide. The designs are tested and continually improved according to their effectiveness, e.g. snails removed initially by hand but later by a cup of beer drowning the snails. **Arts** Cherish food and appreciate efforts of farmers through experiencing the hardship of growing crops; Appreciate the value of Rhizobia to agriculture by reducing the costs and environmental damages caused by the use of nitrogen fertilizer; Be aware of the challenges of agriculture in reaching a balance between yield, costs and environmental damages; Realize the importance of soybean as an important protein source to humans, in particular in the poor regions
4. Using mathematics and computational thinking	Identify various parameters of growth, e.g. length of stem, number of leaves, time of flowering, time of pod formation, number of pods and seeds Use mathematical representations to present the results Write down detailed procedure of cultivation and measurement.	
5.Analyzing and interpreting data	Identify any quantitative and qualitative differences between soybeans grown with and without Rhizobia Interpret the data by drawing on relevant theories, e.g. conditions needed for soybean growth, nitrogen-fixation, etc.	
6. Constructing explanation	Based on the data, construct an explanation for the role of Rhizobia in soybean growth. The original model needs to be revised: Whether Rhizobia can enhance growth depends on many factors, e.g. the successful formation of root nodules, appropriate soil nutrients, soil water, soil aeration, temperature, etc.	
7. Engaging in argument from evidence	Each group need to present their results and defend their explanation with evidence-based arguments.	
8. Obtaining, evaluating, and communicating information	Write up a report for the investigation to describe the experimental design and procedure, present the results, interpret the analysis and argue for the conclusion.	

Example of a design problem

Science and engineering practices	Design process	Contents drawn on
1. Defining a problem	In the visit students identify the problems of water scarcity for irrigation in NW China.	**Science** Role of water for plant growth **Mathematics** Mathematics used in
2. Developing and using models	Students learn different methods of saving water in irrigation e.g. drip irrigation, sprinkler irrigation, plastic film mulching,	

	non-full irrigation, drought crops. Students choose a method suitable for the NW China and construct a model system.	programming and the control system **Technology and engineering** Use of Arduino hardware and software to control an irrigation system; Design of an automated irrigation system **Arts** Problem of water scarcity for irrigation in China; The important roles of STEM in tackling the problem of irrigation and thus improving the livelihood of the poor farmers
3. Planning and carrying out investigations	Students construct the water-saving irrigation model and test its effectiveness against the traditional method.	
4. Using mathematics and computational thinking	Draw block diagram to show the feedback control of soil moisture by the system Program the software for the system Explicitly connect the programming with relevant mathematics	
5.Analyzing and interpreting data	Assess the performance of the system in water saving and identify any weaknesses of the design and technology	
6. Designing solutions	Based on the test results, improve the design for several rounds until a design that is the best within the constraints.	
7. Engaging in argument from evidence	The final design is justified with evidence when compared to the alternatives	
8. Obtaining, evaluating, and communicating information	The design system is presented as a physical model with diagrams and data. The advantages and limitations of the system are communicated clearly and its applicability to real agricultural fields is critically evaluated.	

Project activities and expected learning outcomes

The project has **two rounds** of the following **three phases**:

1. Soybean cultivation;
2. Visits to the soybean fields and soybean food industry;
3. Scientific investigations and design projects about soybean cultivation

Activity	Learning outcomes
Phase 1: Soybean cultivation	
In classes of biology or junior IS, students grow cultivated and wild-type soybeans from seeds to seeds. Students need to observe and record the growth of soybean and solve any problems encountered during cultivation.	Students are able to: 1. Understand and apply the following concepts in DSE biology: • Essential life processes in plants – *Photosynthesis; Need for minerals; The concept of fertilizers. • Reproduction, growth and development of plants - Floral parts; self and cross-pollination; concepts of growth and development; germination of seeds; stages of growth in annual plants; • Ecosystems - Nitrogen cycles (nitrogen fixation)

	• Use of microorganisms - Rhizobia in soybean production. • Significance of seed - seeds as food for human and feed for animals. • measurement of growth in plants. 2. develop skills of scientific investigation: observation, measurement, data recording, processing and presentation, etc.
Phase 2: Visits to soybean fields in China and soybean food industry	
Teacher and students will visit and do field work in soybean fields in Northwest China, where stress-tolerant cultivars developed by is growing. school Teachers and students will also visit food factory e.g. at Taipo and Xinhui. **VR videos of the visits** are produced. This, together with the sharing seminar of the visits, allow students not joining the visits gain similar experiences to enter phase 3.	Students are able to: • Realize how a scientific discovery, the stress-tolerant soybean, makes real impacts on the poor local community in NW China • Understand how large-scale crop cultivation is different from school cultivation. • Be aware of the importance of soybean to China and the world • Understand the roles of various STEAM elements in the manufacturing of soybean foods: science, technology, engineering, entrepreneurship, innovation and social responsibility. • Appreciate the contributions of STEAM to the economy and society of Hong Kong and China
Phase 3 – Scientific investigations and design projects about soybean cultivation	
In classes of biology or junior IS, groups of students conduct scientific investigations or design projects about soybean cultivation using the knowledge and skills they learned in phases 1 and 2. The types and formats of the investigations or projects are decided by the teachers according to their school and student characteristics. The process integrates various STEAM elements, which is illustrated in the two examples in the section of *Conceptual Framework*. Some topics of the investigations and projects are: • *Use of DNA markers to identify soybean varieties with salt-tolerant gene, or GM soybean • *Development of new varieties of soybean by cross-breeding stress-tolerant varieties with African fungal resistant varieties.	Students are able to: • Develop the competencies in conducting scientific investigations • Develop the ability to solve authentic problems using technology and innovation • Acquire the basic skills of biotechnology, i.e. micropipetting, gel electrophoresis, PCR. • Understand the concepts and acquire the skills of genetic cross-breeding two varieties of soybeans • Understand the concepts and acquire the skills of assisting breeding by DNA markers

• Roles of nitrogen fixing bacteria in soybean cultivation • Design of an irrigation system for soybean cultivation in NW China *These investigations are uniquely developed for this project by based on his frontier soybean research. The outcomes of students' investigations may have real impacts to the world, for instance, the new soybean variety from genetic cross-breeding contributing to Africa agriculture.	

During the three phases, the five elements of STEAM will be infused and integrated in the learning activities. The purposes of phase 1 are to develop the knowledge and skills of the teachers and students in soybean cultivation and motivate them to take part in the subsequent activities. Phase 2 will give students opportunities to personally experience the stressful environment in arid regions of North-West China, and realize how science and technology can play a role in alleviating the agricultural and poverty problems there. The story of the food factory, e.g. , would let students understand how traditional and modern technologies are integrated to serve the society, in particular the Chinese community over the world. These visits can help students develop connections with the problems so they will solve the problems in authentic context. The problems that students identify in phase 2 will lead them to phase 3, where students are required to design and conduct scientific investigation and design projects related to soybean cultivation at school. They use the knowledge and skills learned in the previous phases to address the issues of soybean cultivation faced by the farmers in China.

Phase 1: Soybean cultivation from seed to seed at schools

Each participating school will receive seeds from one cultivated soybean line and one wild-like soybean line. Nitrogen fixing bacteria, Rhizobia, are provided to promote the formation of root nodules. As supervised by the teachers, the students grow the soybean from seed to seed, which will take about four months from Mar to June. During this period, students need to record all the growth characteristics and tackle any problems encountered, including control of pests and adjustment of environmental parameters like sunlight, water and temperature. Students can also investigate the different growth patterns of the two soybean lines and the effects of Rhizobia.

Many parts of the DSE biology curriculum are relevant to this phase (see Learning outcomes of Phase 1 in the above Table) so teachers are suggested to conduct the activities as **whole class learning**. Teaching and learning materials will be developed to facilitate the teaching (See Appendix). Technical supports on soybean cultivation will be provided by and other researchers by workshops, WhatsApp group and online platform. Teachers and students will also share their experiences and exchange resources continually in the period. A presentation seminar will be held at the end of the phase 1.

Phase 2: Visit to the soybean fields in China and soybean food industry

Some of the participant teachers and students will visit Gansu, China. Leaded by , students will visit a large-scale soybean experimental field growing the new stress-tolerant soybean cultivars co-developed by and his collaborator . The tentative itinerary of the visit is:

Day 1	Flight from HK to Gansu
Day 2	Visit joint field station on water saving technologies and discuss with local scientists
Day 3	Visit soybean experimental fields for water stress cultivar developed by and his collaborator
Day 4	Visit Lanzhou university and attend seminar by local scientists Do field research on experimental soybean field
Day 5	Flight from Gansu to HK

The above activities will let students

- realize how a scientific discovery in laboratory could become a real product on the field and benefit the local people
- experience as researchers in the soybean field
- apply the knowledge they gained in previous soybean cultivation
- learn how technologies are applied in cultivation, in particular water saving on the arid lands
- aware of the importance of soybean to China and the world

Reflection worksheet is developed for the visit to guide students to raise questions and do reflections, including "What questions you will ask? What you have learned?". At the night of each day, students are having group reflection led by their teachers. At the end of the tour, the whole group will gather to have a reflection of the whole journey regarding to the above learning objectives.

Some of the participant teachers and students will visit HK food industry e.g. at Taipo and Xinhui, China. The tentative itinerary of the Xinhui visit is:

Day 1 – from HK to Xinhui, Visit factory
Day 2 – visit local industry and school in Xinhui

Visits to food industry can let students:

- understand how science and technology can be applied in making soybean food products
- understand its contributions to the economy in HK and China
- understand the emphasis of social and corporate responsibility of the company- role of 'A' in STEAM.

Reflection worksheet is developed for the visit to guide students to raise questions and do reflections, including "What questions you will ask? What you have learned?". The teacher will guide their students to do group discussion on their learning.

The safety of the participants in the trips are taken with due consideration. The students from the schools will be taken care by their teachers in a ratio of 3-5 to 1. The Guidelines on Outdoor Activities, Guidelines on Study Tours Outside the HKSAR and other related safety measures are observed.

Before the visits, and other researchers will conduct seminars on the global challenges of food security and water resources in China and the world, and the beneficial roles of legumes in human health and sustainable agriculture. These seminars will provide students with the background knowledge for meaningful learning and deep reflections in the visit. Education 2.1 and the food industry will provide financial and logistic supports to the visits.

Since only selected students are able to join the visits, particularly the visit to China, VR videos are produced for the visits to let other students gain comparable experiences. In addition, a seminar sharing the experiences of the visits will also be conducted. These allow those students who have not joined the visits to participate in phase 3.

Phase 3 – Scientific investigations and design projects about soybean cultivation at school

In this phase, participant teachers will supervise their students to design and conduct scientific investigations or design projects related to soybean cultivation at school. The teachers are encouraged to make these investigations a part of whole class learning and even the School-based Assessment (SBA) of DSE biology. More able and interested students can do more extensive investigations over months, which can even be used for science competitions. Instead of an ordinary school biology investigations, students are suggested to apply the knowledge and skills learned in the previous phases to address the authentic issues of soybean cultivation faced by the farmers in NW China, or tackle the challenges of manufacturing soybean foods after visiting the food industry. The solutions are STEAM based: it will integrate knowledge from science, technology, engineering and mathematics as well as their understandings of the sociocultural conditions in NW China. The investigations/projects can be, but are not limited to, the following:

- Identification of salinity-tolerant soybeans using DNA markers
- Cross breeding of salinity-tolerant soybeans with African fungal resistant soybeans to obtain progenies having all these desirable characters
- Investigation of the optimal environmental parameters for soybean growth
- Design of 'smart' greenhouse for soybean growth
- Design of irrigation system for soybean cultivation in arid regions
- Analysis of the nutritional values of soybean varieties
- Design of pest control methods for soybean cultivation
- Investigation of the role of nitrogen fixing bacteria in soybean growth
- Investigations of the optimal conditions for fermentation of soybean in the production of soy sauce
- Investigations of the qualities of soy sauce, e.g. salinity, composition, concentration of soybean.

Various STEM workshops are conducted to support the investigations, including the use of DNA markers for identification of plant, skills of cross-pollinatiing soybean flowers, design of biological investigation and various IT technologies such as , , 3D-Printing, virtual reality. Teaching and learning materials will be developed to facilitate the investigation. Amgen Biotech Experience Hong Kong (ABEHK) will assist the training and development of T&L materials based on their extensive experiences in implementing biotech education in Hong Kong. Supports are also provided by and other researchers through various workshops, WhatsApp group and online platform. Teachers and students will also share their experiences and exchange resources continually in the period. A presentation seminar will be held at the end of the phase 3.

Targets:

- Secondary students, mostly S3-S5 studying biology or science
- Secondary teachers, mostly biology, science or geography teachers

Expected Number of Beneficiaries:

- Project participants: 30-40 schools (15-20 each around), 30-40 teachers, *900-1200 students;
- Participants of public school seminars and exhibition (In addition to the project participants): 300 teachers, 800 students
- Project webpage and Teaching Packages (Teacher's guide and task sheets of all the investigations and design projects): all schools and teachers
- DNA marker kit: 30-40 enrolled schools for two more rounds of the labs after the project period and up to 20 non-enrolled schools

* Assuming each school having one class of 30 students to join the project, 15-20 enrolled secondary schools in two rounds will have a total of 900-1200 students involved.

Implementation plan

Period	Activities	Targets
Jan 2020	Public school seminar at to introduce the project and the role of soybean in food supply and health	100 to 200 secondary teachers (priority given to biology and science teachers)
Jan 2020	Open recruitment of participating schools (by drawing lots in case of over-enrollment)	All secondary schools
First round		
Phase 1 - Soybean cultivation		
Feb and Apr 2020	**Two teacher workshops** ● Held by and other researchers at ● skills and knowledge of soybean cultivation ● handing over soybean seeds, Rhizobium and other resources	**15-25 biology or science teachers** from 15-20 enrolled secondary schools for each workshop
Mar–Jun 2020	Students growing cultivated and wild-like soybean from seed to seed at school as supervised by teachers. Continued and instant support is provided by staff through WhatsApp groups	**15-25 biology or science teachers** and **450-600 students** from 15-20 enrolled secondary schools (assuming each school having at least one class of 30 students to join the project)
Phase 2 - Visit to soybean fields and food industry		
May 2020	Public school seminar by - food security, water scarcity and sustainable agriculture	**50-70 teachers and 150-200 students** from the enrolled and non-enrolled schools
Jun 2020	2-day visit to food factory in China, e.g. at Xinhui, China Day visit to food factory in HK e.g. at Taipo, HK	2-day visit to Xinhui: **10-15 teachers and 30-40 students** from the enrolled schools Day visit to Taipo: **10-15 teachers and 30-40 students** from the enrolled schools

Jul 2020	5-day visit to the soybean fields in NW China	**10-15 teachers and 30-40 students** from the enrolled schools
	Selection criteria for the visit: For each visit, there are quotas for 8-10 schools with 1-2 teachers and 3-5 students from each school. Each school completing phase 1 is eligible for at least ONE visit. In case of over-enrolment, schools will be selected according to their attendance rate of workshops and performance of soybean cultivation at school, as judged by and .	
Phase 3 – Scientific investigations and design projects about soybean cultivation		
Aug 2020	Two teacher and student workshops held by : DNA markers, PCR, gel electrophoresis, cross-pollination techniques, greenhouse design, experimental design, etc.	**15-25 teachers and 75-100 students** from the 15-20 enrolled schools Priority is given to the students who have participated phases 1 and 2.
Sep–Dec 2020	In classes of biology or IS, students conduct scientific investigations or design projects about soybean cultivation (Two examples provided in *Conceptual Framework*). Continued and instant support by staff is provided through WhatsApp groups	**15-25 biology or science teachers** and **450-600 students** from 15-20 enrolled secondary schools (assuming each school having at least one class of 30 students to join the project)
Dec 2020	Exhibition displaying outcomes of the soybean investigations and design projects. Awards will be given to student groups with outstanding performance.	**15-25 biology or science teachers** and **450-600 students** from 15-20 enrolled secondary schools. Other teachers and students are welcomed.
Mid-term evaluation to fine tune the next round implementation		
Second round		
Jan 2021	Public school seminar at to introduce the outcomes of first round and the role of soybean in food supply and health Open recruitment of schools (by drawing lots in case of over-enrollment)	All secondary schools
Phase 1 - Soybean cultivation		
Feb and Apr 2021	**Two teacher workshops** ● Held by and other researchers at ● skills and knowledge of soybean cultivation ● handing over soybean seeds, Rhizobium and other resources	**15-25 biology or science teachers** from 15-20 enrolled secondary schools for each workshop
Mar–Jun	Students growing cultivated and wild-like soybean	**15-25 biology or science teachers** and

2021	from seed to seed at school as supervised by teachers. Continued and instant support is provided by staff through WhatsApp groups	**450-600 students** from 15-20 enrolled secondary schools (assuming each school having at least one class of 30 students to join the project)
Phase 2 - Visit to soybean fields and food industry		
May 2021	Public school seminar by - food security, water scarcity and sustainable agriculture	**50-70 teachers and 150-200 students** from the enrolled and non-enrolled schools
Jun 2021	2-day visit to food factory in China, at Xinhui, China Day visit to food factory in HK e.g. at Taipo, HK	2-day visit to Xinhui: **10-15 teachers and 30-40 students** from the enrolled schools Day visit to Taipo: **10-15 teachers and 30-40 students** from the enrolled schools
Jul 2021	5-day visit to the soybean fields in NW China	**10-15 teachers and 30-40 students** from the enrolled schools
Phase 3 – Scientific investigations and design projects about soybean cultivation at school		
Aug 2021	Two teacher and student workshops held by university staff at : DNA markers, PCR, gel electrophoresis, cross-pollination techniques, greenhouse design, experimental design, etc.	**15-25 teachers and 75-100 students** from the 15-20 enrolled schools Priority is given to the students who have participated phases 1 and 2.
Sep–Dec 2021	In classes of biology or junior science, students conduct scientific investigations or design projects about soybean cultivation. Continued and instant support by staff is provided through WhatsApp groups	**15-25 biology or science teachers** and **450-600 students** from 15-20 enrolled secondary schools (assuming each school having at least one class of 30 students to join the project)
Jan 2022	Exhibition displaying outcomes of the soybean investigations and design projects. Awards will be given to student groups with outstanding performance.	**15-25 biology or science teachers** and **450-600 students** from 15-20 enrolled secondary schools. Other teachers and students are welcomed.
Evaluation and production of deliverables		
Jan– Jun 2022	Construction of webpage for the delivery of the project outcomes Write up of lab manuals and teacher's guide for the investigations and design projects Evaluation of learning outcomes Production of DNA marker kits and soybean cultivation kits for the enrolled schools for **two** more rounds of investigation. To make the project sustainable, schools will be provided with the necessary materials to conduct the investigations at their own costs after that.	

Feasibility

The three phases of the project had been tried out with students and teachers from ten secondary schools in 2018. The participation was active with highly desirable outcomes. The experiences from the tryout give valuable information for the planning of this proposal. More details of the tryout are attached in **Appendix.**

Budget

Total grant sought: **HK$ 2,288,700**

Categories	Item	Amount (HK$)	Justifications
a. Staff	one Project Assistant and one Research Assistant from Jan 2020 to Jun 2022	Project Assistant HK$14,500 x 30 months x 1.05 (MPF) Research Assistant HK$17,500 x 30 months x 1.05(MPF) **Total = HK$1,008,000**	One Project Assistant is needed for administrative work: arrangement of seminars, workshops and visits, coordination with teachers and students, and production of deliverables. One Research Assistant is needed for the development of DNA marker kits, cross-breeding experiments and other investigations, provision of technical supports to teachers and students, and production of teaching and learning materials
	Student helpers	**$55/hour x 20 hours x 30 months** **HK$33,000**	Employ undergraduates to assist the conduction of seminars, workshops and visits
b. Services	Three public school seminars	**HK$3,000 x 3 = HK$9,000**	Venue, speaker honorarium,
	Eight workshops for students and teachers	**HK$4,500 x 8= HK$36,000**	Venue, speaker honorarium, photos, lab materials (e.g. DNA, enzymes, gel)
	Webpage construction	**HK$15,000**	Webpage constructed to disseminate the project outcomes
	VR video production	**HK$10,000**	Recording and production of the VR videos
c. Equipment	6 sets of biotech equipment (each set includes 1 PCR machine, 8 electrophoresis gel systems, 8 micropipette and 2 microcentrifuges) and 8 Plant cross	**HK$300,000**	The biotech equipment is needed to do the DNA marker test. Six sets of equipment are to be borrowed by the schools without the equipment.

	breeding kits		
	DNA marker kits	**HK$1,000 x 20 schools x 4 rounds = HK$80,000**	Manpower and materials costs to prepare the kits for all participating schools
d. Visit (see remark)	5-day visit to soybean field in NW China	**HK$3,250* x 60 participants x 2 visits =HK$390,000** **Full costs are HK$7,000**	Costs for transport, foods, accommodation, insurance for 15 teachers, 40 students and 5 project staff each visit Additional funding will be sought through Education 2.1 and the food industry
	2-day visit to food factory in China, e.g. at Xinhui, China	**HK$300* x 60 participants x 2 visits =HK$36,000** **Full costs are HK$600**	Costs for transport, foods, accommodation, insurance for 15 teachers, 40 students and 5 project staff each visit Additional funding will be sought through Education 2.1 and the food industry
	Day visit to food factory in HK, e.g. at Taipo	**HK$4000 x 2 visits =HK$8,000**	Costs for 2 coaches for 15 teachers, 40 students and 5 project staff each visit
		For the two trips outside HK, the amount of subsidies will depend on the social economic status of the students as stipulated in para 23-25 in Annex I of the QEF Priority Themes Guide to Applicants.	
e. General expenses	Conference fees	**HK$12,000 x 2 = HK$24,000**	Disseminate the project to the wider STEM education community
	Printing costs	**HK$2,043**	Workshop, seminar and other materials
	Audit fee	**HK$15,000**	
	Overhead	**HK$294,906**	will provide office desk, computer facilities, venues of seminars and workshops and other utilities
f. Contingency		**HK$27,751**	
	Total	**HK$2,288,700**	

Remark

The Quality Education Fund will sponsor half of the cost/fee of students participating in the activities outside Hong Kong and provide additional funding support to social-economically disadvantaged students enrolled in the activities.

For students in receipt of the Comprehensive Social Security Assistance (CSSA) and full remission under the Student Financial Assistance Scheme (SFAS), they will receive 100% support of the costs/fees involved in their overseas trips or the funding ceiling of the respective destination, whichever is the lower.

For students in receipt of half remission under the SFAS, they will receive 75% support of the costs/fees involved in their overseas trips or the funding ceiling of the respective destination, whichever is the lower.

For general students, they will receive 50% support of the costs/fees involved in their overseas trips or the funding ceiling of the respective destination, whichever is the lower.
The project will be funded by 50% first and the balance will be calculated based on the actual number of students and the percentage of funding support.

All procurement of goods and services is conducted on an open, fair and competitive basis with measures taken to avoid conflict of interests in the procurement process.

Evaluation

The process and outcomes of the project will be evaluated by mixed methods both formatively and summatively :

- The teacher and student participants will be surveyed with closed and open questions on the target skills, knowledge and attitudes as stated in *Objectives* after each seminar, workshops, visit and the whole project. (Success criteria: an average of 3 or above in the 5-point Likert scale)
- Selected teachers and students will be invited for interviews to further solicit their feedback after each seminar, workshops, visit and the whole project. (Success criteria: 70% or above of the interviewees are satisfied with the activities)
- A test is constructed to assess students' knowledge and skills about soybean cultivation, DNA marker and cross-breeding after the project. The results are compared with a similar cohort not joining the project. (Success criteria: Scores of students joining the project are significantly higher than those not joining the project.)
- The student products of the project, e.g. school investigation report, design models, worksheets, will be sampled for evaluation according to the STEAM framework by external experts (Success criteria: 70% or above are rated to be Good or above in the scale of Sufficient/Satisfactory/Good/Very good/Excellent)
- A progress report is made after round one of the project to summarize and reflect on the experiences, based on which round two activities are adjusted. External evaluation is done upon the completion of the project. STEM educators from university and professional bodies are invited to examine all the outcomes, products and processes and write an independent report.

Products and deliverables

- A framework of STEAM teaching is developed, which is not only applicable for senior biology but also for other subjects and levels including junior science. The framework is revised and finalized based on the experiences of the project tryout and feedbacks from the participant teachers. A public dissemination seminar will be held after the completion of the project to introduce the framework to all secondary schools.
- The teaching and learning materials for the soybean-related investigations and design projects are produced. These include lab task sheet and teacher's guide, which are revised and finalized based on the feedback from the tryout schools. It is estimated that 20-30 tasks will be developed, such as identification of GM soybean using DNA markers, cross-breeding of soybean lines, effect of Rhizobia on soybean growth, smart irrigation system for soybean cultivation
- DNA marker kit for soybean identification is developed. Extra kits are provided for the enrolled schools for two more tests after the completion of the project. A limited number of kits can also be provided to the non-enrolled schools if they have the expertise to conduct the test.
- Experiences of the visits to soybean fields in China and food industry will be reproduced using virtual reality

technology. All teachers can download the video for classroom use. Worksheets are also developed for the visits, which, together the VR videos, provide simulated learning in for students in classroom.

- An electronic platform will be constructed for sharing of the resources and experiences.
- Two conference papers will be written and presented at international conferences.

Dissemination

A webpage with all the resources and outcomes of the project is constructed and open to all teachers. All secondary schools are invited to join the school seminars and the final exhibition of project products. Experiences of the project will also be shared at SBA biology teacher conference, international and local conferences and teacher professional development workshops.

Sustainability of the project

The products of the projects, including lab manuals, teacher's guides, VR videos, reflections of visit, will be archived in an online platform open for all teachers and students after the completion of the project. The online platform will allow teachers and students to keep sharing ideas and resources for the investigations and projects they conduct after this project. Continued supports will also be provided by the project team. A few years after the project, the biotech equipment and related materials for the DNA marker test will continue to be provided to secondary schools upon request. In the long run, schools are assisted to purchase the materials and equipment using their own funding.

The Product and the records, database and materials developed and the copyright and other intellectual property rights in such items shall be and shall remain the exclusive property of the Grantor and shall vest in the Grantor at the time they are created. Upon receipt of any request from the Grantee for the use of any copyright or other intellectual property rights in relation to the Product and the records, database and materials developed outside the bounds of the Project, the Grantor may at its sole discretion determine whether or not to grant its approval.

Capability of the applicants

The project has combined the expertise of frontier scientist and science educator. is a world-renowned plant biotechnology scientist and the at . will provide the materials and expert support to soybean cultivation and the investigations and incorporate his frontier soybean research into the DNA marker kits and cross-breeding experiments. The visits to soybean fields in China are made possible through arrangement. is an experienced educator in science and biology at . He has extensive experiences in providing professional development to science and biology teachers as well as development of teaching and learning materials for biology. As the SBA biology supervisor for many years, has strong expertise in school science investigation. He is also the co-supervisor of two STEM projects including . Both and are the Director of in Hong Kong, which has trained over 130 biology teachers and lab technician and supported 1600 students to conduct state-of-the-art biotech experiments in 60 secondary schools. They thus have strong background in promoting STEM and biotech education in Hong Kong.

Assets Usage Plan

Category (in alphabetical order)	**Item / Description**	**No. of Units**	**Total Cost (HK$)**	**Proposed Plan for Deployment** *(Note)*
Lab equipment	PCR machines to make copies of DNA fragments	6	6x7,000=42,000	For participating schools of the project to borrow the equipment to continue doing the experiments of this project or other biotech experiments after the project period
	Gel system for electrophoresis	48	48x2,500=120,000	
	micropipette	48	48x1,500=72,000	
	microcentrifuge	12	12x1,500=18,000	
	Plant cross breeding kit	8	8x6,000=48,000	
		subtotal	300,000	
DNA marker kit	DNA, reagents, enzymes	80	80x1,000=80,000	Most are consumables. The materials remained will be provided to the participating schools to continue the experiments

Report Submission Schedule

The grantee commits to submit proper reports in strict accordance with the following schedule:

Project Management		**Financial Management**	
Type of Report and covering period	Report due date	Type of Report and covering period	Report due date
Progress Report 1/1/2020-30/6/2020	31/7/2020	Interim Financial Report 1/1/2020-30/6/2020	31/7/2020
Progress Report 1/7/2020-31/12/2020	31/1/2021	Interim Financial Report 1/7/2020-31/12/2020	31/1/2021
Progress Report 1/1/2021-30/6/2021	31/7/2021	Interim Financial Report 1/1/2021-30/6/2021	31/7/2021
Progress Report		Interim Financial Report	

1/7/2021-31/12/2021	31/1/2022	1/7/2021-31/12/2021	31/1/2022
Final Report 1/1/2020-30/6/2022	30/9/2022	Final Financial Report 1/1/2022-30/6/2022	30/9/2022

Appendix 1 - Experiences of the tryout

Participants: 14 secondary schools and 14 teachers, over 300 students

Period: Dec 2017 – Dec 2018

Phase 1 : Soybean cultivation from April to June

Phase 2 : Visit to Gansu, China (experimental soybean field,)

Phase 3 : school investigations

Workshop and seminar:

- Seminar on Agriculture and Food Security,
- Seminar on Water for Living,
- Teacher workshop on soybean cultivation
- Student workshop on DNA marker
- Student workshop on Smart Farming
- Student sharing at Biology SBA Annual Conference,
- Presentation of phase 1 outcomes by students,
- Visit to Farm
- Teacher visit to at Xinhua

(Photos have been deleted)

野生(根瘤)

培植(根瘤)

Students comparing soybean with and without root nodules at College

Students invented solution for irrigation with air con dripping and for pest control by net at College

(Photos have been deleted)

(Photo has been deleted)

Appendix 2 -Teaching and learning materials

Worksheet for Gansu visit

大豆的回家之路
甘肅蘭州實地考察之旅

學習工作紙

學習簡介

各位同學：歡迎大家參加「大豆的回家之路——甘肅蘭州實地考察之旅」，此次的學習方式當然與課堂學習大不相同。課堂學習一般都為同班同學設定基本上相同的學習目標，但考察學習則雖然為同學安排同樣的活動，惟同學所學到的則可大不一樣，取決於同學學習態度、考察前的準備、所用的學習方法和策略。

有關從考察活動中學習，如果只是被動的接收所聽、所見、所聞，學習的效果不會理想。但如果可以做到以下兩點，一定事半功倍，不枉此行。

(1)在考察活動前已有想過有甚麼想知道或學到的，就是「**帶着問題去考察**」;

(2)就**所見所聞的事物提出相關的問題**，就是「**抱着問題回家想**」，深化所學。

上次在　也曾簡單介紹**建構問題**的方法，在此再作簡述。同學們一般在兩種情況下可使用問題來促進及深化學習。第一種情況是對學習對象只有很少的認識，例如是專題研習的題目，或今次考察的地區或機構等。第二種情況是您已收到了一定的相關資料，但要了解資料中一些詞彙、概念、關係、道理等。當然，您所提出的問題未必即時得到答案，也值得把問題記下來待機會才解決(透過請教其他人或於網絡上尋找有關資料)。**建構問題**是*訓練同學*的***分析能力***(建構拆解資料組織的相關問題)、***批判思維能力***(建構判斷論據—論點之關連是否合理的問題)和***創意思維能力***(建構把內容放在不同領域的問題— 'Think Out of the Box')。

就如上次所提出，下面幾項皆有助同學建構問題，促進學習。

(1)**六何法 + 如果** (很有用問題詞彙：為何、如何、何人、何時、何地、何事/有何、如果);

(2)**相關合適的詞彙** (如「成效」、「經濟」、「因素」、「影響」、「關係」、「運作」……);

(3)**詞彙綱目** (如：中史的「治、亂、興、衰」；通識的「政、經、社、民、環」；科學的「*M.A.T* Exp.er.i.mental-model AS.AP」等)—這些都是從學習過程中累積得來的。

問題沒有好與不好，只要按自己的情況，有層次和有目的地建構問題，促進及深化學習。以參觀農科院為例子，嘗試說明建構問題的方法。

農民　　農科院　　組織/功能 ……………

- 農科院何時成立？何人成立農科院?..... (獲取相關資訊)
- 農科院有何「功能」？農科院如何運作? ……(增加了解)
- 農科院與「農民」有何關係? 農科院會處理「環境」問題嗎? (深化了解)
- 為何甘肅[會/要]有農科院?/ 農科院值得繼續存在? (這可能是一條核心問題)
- *如果*農科院變成私人擁有企業，會是一個商機嗎? (假設性問題—Think out of the box)

假設您於參觀過程中得到一項資訊，「半公升的水可種出 10 公斤農作物」，您的問題會是…：

- 該農作物是甚麼? (廓清資訊) 實驗是怎樣進行? 實驗誤差會是多少? (獲取相關資訊)
- 實驗結果與其他類近情況的比較合理嗎? 可有相關理論解釋實驗結果? 進行實驗是否需要特別條件? (合理性)
- 實驗結果有何應用? (拓展性)

活動：參觀甘肅農業科學院

A. 帶着問題去考察：

您希望這次參觀能解到甚麼問題

他們的種植方式有何不同

B. 抱着問題回家想

聽完有關農業科學院的介紹後，您有甚麼跟進問題以深化學習？

他們的地方都比較大，去除植物的污水，他們是如何做

C 學習反思

這次參觀，您學會/觀察到/發現/了些甚麼？

我學到，他們為土壤去毒的方法，係把原生土壤放進[illegible]試管養植，就可以有毒的土壤進行生產。而科學院有一個比較低價錢方法降溫。

調查表 － 黃羊試驗場 / 隴黃一號種植場

行距：大約50cm　株距：大約7cm　45cm

生長期：VE　VC　V1　V2
R1　R2　R3　R4
R5　R6　R7　R8

生長習性：直立　半直立　半蔓生　蔓生

株型：收斂　半開張　開張

大豆主莖：明顯　不明顯

主莖節數：6-7節

莖粗：大約0.5cm

莖形狀：正常莖　扁莖　曲莖

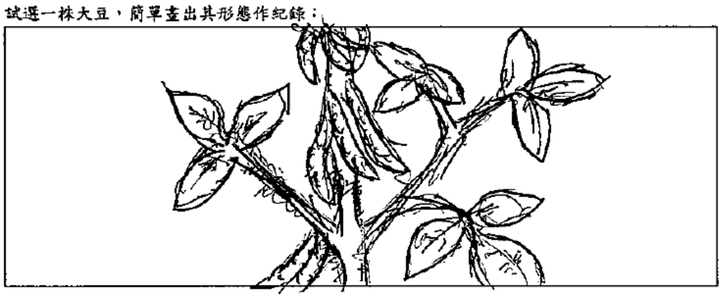
有效分枝數：3-4

葉柄長短：短　長

葉形：披針　卵圓　橢圓　圓

葉色：淡綠　綠　深綠

試選一株大豆，簡單畫出其形態作紀錄：

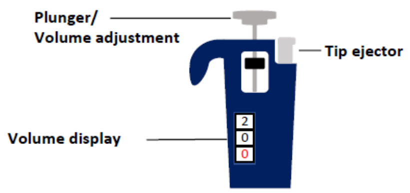


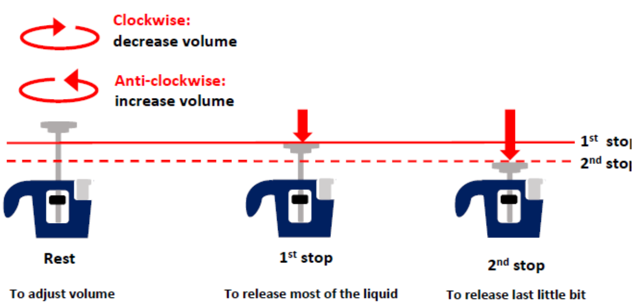
其他特別觀察：(如是否有蟲害？)　白色花

Instruction on lab skills- using micropipette and electrophoresis

Chapter 1　Learning Basic Laboratory Skills

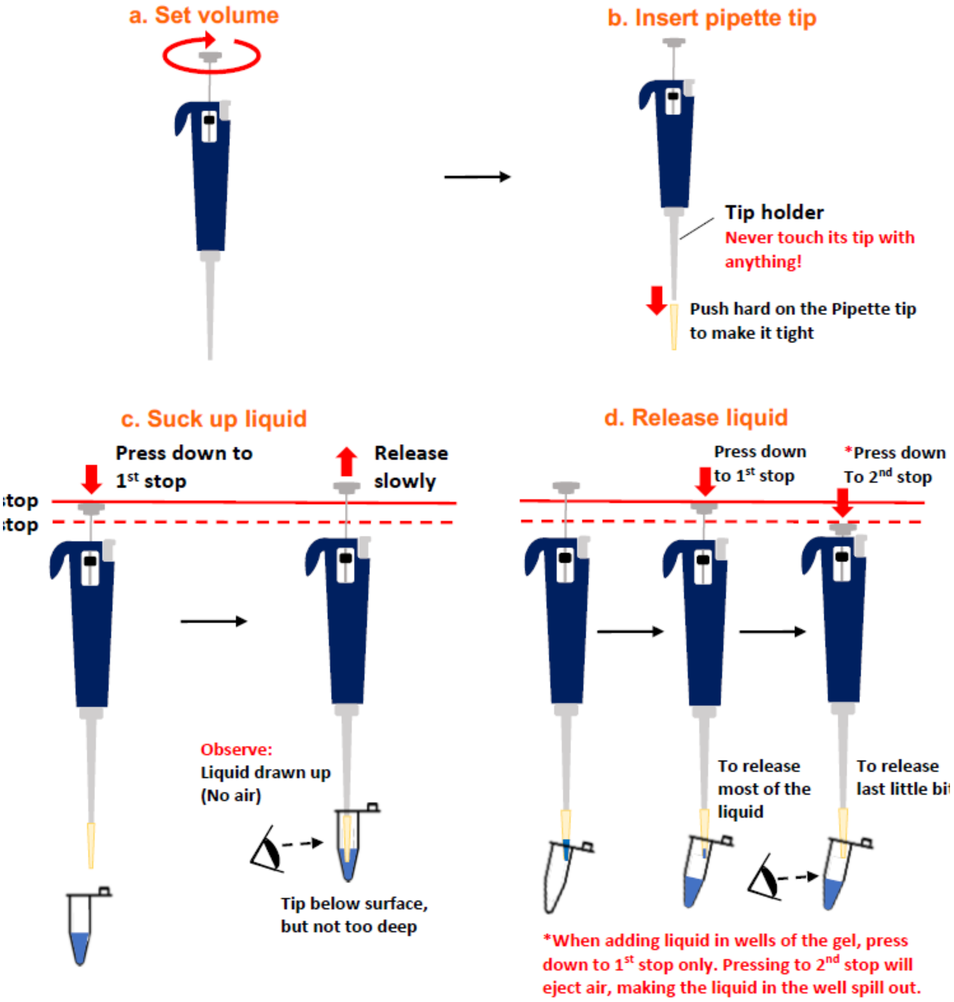
How to use a micropipette?





Do NOT over turn the plunger!

(2) Step of pipetting liquid



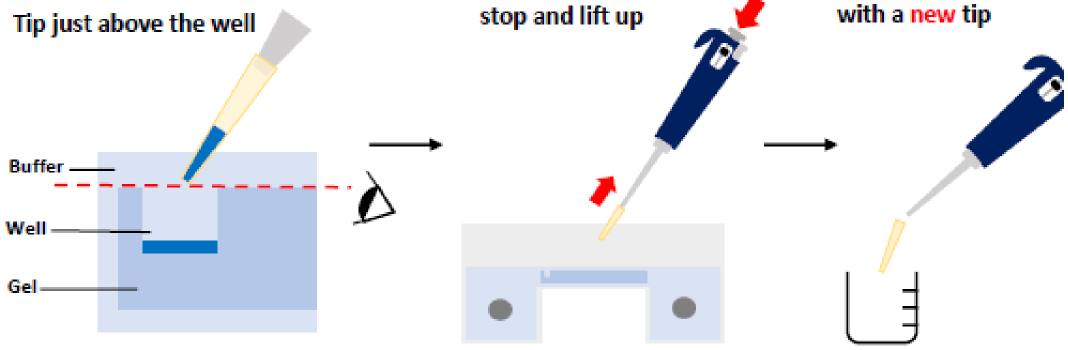
How to do a gel electrophoresis?

c. Add solution into the wells

Press to 1st Stop **only**
Tip just above the well

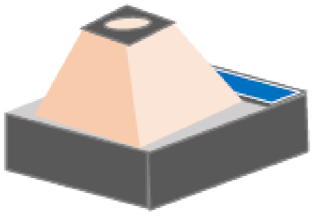
Keep pressing at 1st stop and lift up

Add another solution with a **new** tip



Press weak blue light to make the wells easier to see

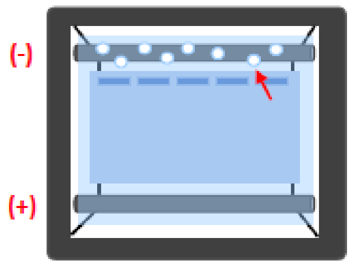
d. Turn on power



Place the photo hood on the gel system

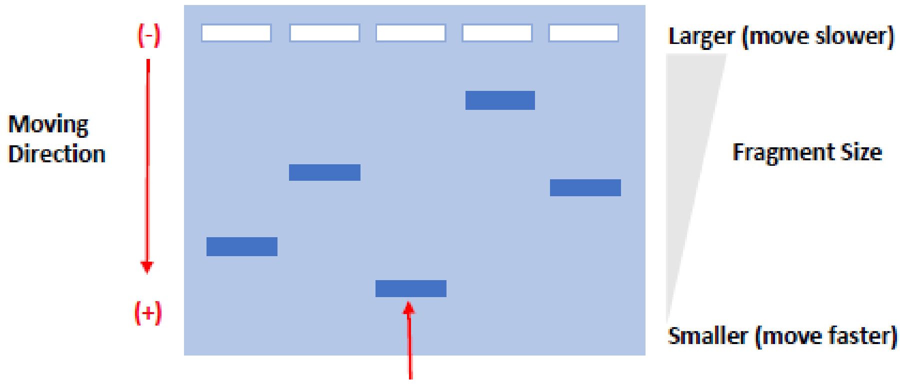
Press strong blue light to observe the bands

e. Start running the gel



Bubbles come out at **negative (-)** electrode

f. Observe bands appearing from (-) to (+) electrode



Bands show different sizes of DNA fragments