Quality Education Fund

The Dedicated Funding Programme for Publicly-funded Schools

Part B: Project Proposal

Project Title: Interdisciplinary STEM project-based learning in synthetic biology 跨學科 STEM 教育的項目性學習在合成生物學	**Project Number: 2019/0725** *(Revised)*

Name of School: G.T. (Ellen Yeung) College

Direct Beneficiaries

(a) Sector: ☐ Kindergarten ☐ Primary ☑ Secondary ☐ Special School *(Please put a tick in the appropriate box(es).)*

(b) Beneficiaries: (1) Students: 410 G7 – G11; (2) Teachers: 8

Project Period: 10/2021 to 09/2024

1. Project Needs

1.1	Project Aim(s)	The goal of this project is to enhance STEM education by developing a school-based STEM programme in the field of synthetic biology integrated with new technological advances for interdisciplinary project-based learning. Synthetic biology provides students an engineering context to learn molecular biology, genetic engineering, technology, computer science as well as bioinformatics. It encompasses the design and engineering of new biological parts or systems by assembly of interchangeable biological parts to address current and future challenges. Thus, synthetic biology serves as an ideal platform to engage in STEM and interdisciplinary education. The programme develops students' conceptual understanding and skills in the field of synthetic biology and engage students in interdisciplinary inquires to solve problems focusing on real world issues. The integration of STEM project-based learning in synthetic biology will enhance student interest, creativity and motivation which foster their perspectives and career aspirations in STEM.
1.2	Innovative element(s)	Our school has a school-based pull-out programme of biotechnology for G8 to G10 students since 2012 and the domain has been extended to synthetic biology since 2017. The program aims to arouse and sustain student interest in the field of genetic engineering and synthetic biology, strengthen STEM knowledges and skills by expose them to lectures with the advanced level of academic contents, various hands-on techniques in molecular biology and provide them with diverse learning experiences such as participating lab visits, workshops and science talks at universities to learn of the recent advances in science and technology. To transform the learning experiences into real life learning, 11 G8 to G10 students in the program joined as a team to participate in the International Genetically Engineered Machine (iGEM) competition, the largest synthetic biology competition in the world in 2019. Through two years of advanced level lectures in synthetic biology, various hands-on experiences and learning activities, scientific research experience at university lab and public engagement activities related to an authentic and complex challenge to solve plastic pollution problem, students not only be able to apply multiple disciplines to solve real-world problems which cultivates their curiosity, critical thinking and problem-solving skills but also being instilled with the core value

		of integrity, collaboration, respect, effort and excellence which are the generic skills that prepare students for a complex life and work environment in the 21st century. Therefore, such school-based curriculum integrated with project-based learning has been shown to be effective for building STEM literacy and bringing great benefits to students. With reference to the good learning outcome of this school-based pull-out programme through advanced learning and research experience, a STEM project-based learning programme in the field of synthetic biology will be developed. The ultimate goals of the proposed programme are (1) to inspire students and sustain their interests in STEM-related field for further study and career aspiration, (2) to enhance students' creativity, innovation, high-order thinking, problem solving and collaboration which are essential for life-long learning through the STEM project-based learning environment, (3) to promote STEM education in Hong Kong secondary schools, (4) to enhance professional capacity of teachers by exposure to cutting edge development in science and technology and to empower teachers' capacities in design and implement of a new programme. To fulfil the ultimate goals, the specific objectives of the program are (1) to design and implement an interdisciplinary STEM programme to prepare students to build knowledge and skills in the field of synthetic biology and to work in an interdisciplinary research environment. (2) to equip school laboratory with facilities and equipments necessary for students to have the capability to work on authentic research that is integrated within the curriculum and at the cutting edge of technology. (3) to evaluate the effectiveness of the programme for sustainable development of STEM education. (4) to disseminate the teaching resources and share experiences to other schools. **<u>Integration of Project-Based Learning in STEM Curriculum via Synthetic Biology</u>** Students in this generation are lived in technology and media embedded surrounding, they have access to Information and Communication Technology (ICT) which enable them to share, receive and collect information. To adapt to knowledge-based society, students need to have proficiency in 21st century skills, including problem solving, critical thinking, innovative thinking, collaboration and communication. In addition, they are required to have information literacy, media literacy and ICT literacy. A major objective of education is to keep pace and align with advancement in knowledge and skills to be successful. Traditional methods of teaching are teacher centered with less emphasis on connection between real world and subject matter. Project-based learning (PBL) is an instructional and curricular learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem[1]. This type of instructional approach emphasizes activities that are interdisciplinary, authenticity in real world and student-centered. PBL was found to be more effective teaching technique for teaching science at elementary level[2]. Our STEM programme is specialized in the field of synthetic biology because it interfaces biology with engineering, technology, and computer science which serves as a platform for interdisciplinary STEM education. It combines

different science know-hows with engineering techniques in order to design and create novel biological systems and bio-factories to address current and future challenges. For example, one of the applications of synthetic biology is the creation of bioengineered microbes. Bioengineered microbes may be used to degrade pollutants, produce pharmaceuticals and proteins, make biosensors for detection and improve biofuel production. Given a board application prospect in the field of agriculture, bioplastics, chemical synthesis, environment, energy and medicine, synthetic biology is the emerging field which will be one of the fastest growing industries for years to come. According to a report by Global Market Insight, titled "Synthetic Biology Market Size by Products", the global synthetic biology market is forecast to reach $11 billion by 2018 and is expected to reach US$ 55 billion by 2025. The compound annual growth rate is estimated to be 24% during the forecast period from 2018 to 2025[3]. In addition, the industry has attracted investments from various business leaders. For instance, Hong Kong University of Science and Technology has received HK$500 million donation in 2019, from Hong Kong real-estate tycoon Mr. Li Ka-Shing to launch a state-of-the-art institute for synthetic biology research. To ensure that Hong Kong have the needed world-class talent pool to catch the synthetic biology wave, creative educational methodologies shall be adopted to provide opportunities to train and to attract the interest of students – the potential next generation of synthetic biologists.

Interdisciplinary STEM Curriculum in Synthetic Biology

The first phase of the programme is to design and implement an interdisciplinary curriculum to prepare students to build and strengthen knowledge and skills in the field of synthetic biology and to work in an interdisciplinary research environment. Synthetic biology involves multiple disciplines including molecular biology, genetic engineering, bioinformatics and computational modeling which are highly interconnected. The new STEM curriculum encompasses four modules:

Module 1: Synthetic Biology

This module is a discovery module that provides an overview of fundamental knowledge of synthetic biology and hands-on experience of basic molecular biology techniques. Students will learn the synthetic biology theory and innovations and its underlying molecular biology principles including central dogma of molecular biology, principles and applications of common techniques in molecular biology such as molecular cloning, gel electrophoresis and polymerase chain reaction through interactive lectures and hands-on experiments.

Module 2: Genetic Engineering

This module is an investigative module that provides students with research experiences in genetic engineering that are less likely possible in the school laboratory settings. Students will learn how to apply their understanding of molecular biology to manipulate specific genes to engineer new biological parts or systems. They will also learn the applications of genetic engineering to see how scientists and engineers have used this practice to address real-world problems in a wide range of area such as environment, medicine and food.

In the practical class, students will design and engineer a recombinant DNA

construct from which a protein will be expressed and purified to learn the process of protein production from a gene. A recombinant DNA construct containing green florescent protein (GFP) gene will also be engineered and expressed for visualization of the gene product, GFP protein inside living cells under florescent microscope.

Module 3: Bioinformatics

Recent technological advance in high-throughput techniques in data generation and analysis such as entire genome sequence of different organisms provides rich sources of data for research. The store of data is largely held in freely available database softwares with public access. Students need a basic knowledge of bioinformatics to perform comparative analysis of genes and genome to identify candidate genes for genetic engineering applications. Bioinformatic tools are also important in data analysis.

This module is a design and development module which provides students an understanding of the use of bioinformatics softwares and web tools in data analysis and candidate gene identification. The acquired skills can be applied in design and development of research project. A series of exercise will be developed to led students through the basics of research paper retrieval using PubMed, sequence alignments using Basic Local Alignment Search Tool (BLAST) and translation using ExPASy. Students will then be able to perform computational analysis of a new candidate gene by drawing on information that can be retrieved from various bioinformatics databases.

Module 4: Computational Modeling

Synthetic biology focus on design and build artificial biological systems that do not naturally exist in the world through molecular biology and engineering approaches. Computational modeling has been used to provide quantitative data to analyse predicted behaviour of the new biological system and to identify desirable construct circuits design.

This module is a development module which allows students to build computational modeling concepts to predict behaviours of biological systems. Students will modeling the effect of different inducer isopropyl- β -D-1-thiogalactopyranoside (IPTG) concentrations on growth dynamics of *E.coli* BL21 carrying recombinant DNA construct in Module 2. In this study, growth experiment will be performed to obtain the growth curve for the effect of different IPTG concentration on the *E.coli* strain. The collected ($O.D._{600nm}$) data will be used as input data to generate growth predictions using computational modeling.

The integration of four modules transcends disciplinary boundaries and engage students with scientific inquiry, engineering design and new biological system development.

<u>Interdisciplinary STEM Project</u>

The second phase of the programme allows students to work on authentic research that is integrated within the curriculum and at the cutting edge of technology. It is aimed to encouraged students to design a synthetic biology system by building upon what they have learned in the curriculum. Project-based learning is a student-centered pedagogy that students have the opportunity to collaborate as a team and engage with vigorous problem that have not been contrived. The team will participate in the International

		Genetically Engineered Machine (iGEM) competition, which is the largest global synthetic biology event in the world to get involved in synthetic biology, showcase their innovations and share their ideas and experiences with global peers of synthetic biology community. To engage in an authentic research to address a real-world problem, students must attempt to build capacity to infuse creativity, innovation, collaboration and critical thinking and using interdisciplinary knowledges and advanced technology such as make use of three dimensional (3D) printing technology in an independently designed project. They also need to reach out to stakeholders from diverse communities to collect their points of view to reshape their project idea to make greater positive impacts to the community. Such learning experience not only motivate and sustain students' passion and engagement in synthetic biology and STEM-related field but also show true mastery of learned knowledge and skills in modules 1 to modules 4. In the end, students will be instilled with the core value of creativity, innovation, high-order thinking, communication, collaboration, effort and excellence, the transferrable skills that are essential in life-long learning to navigate a rapidly evolving society. **Learning Experiences Beyond Classroom to Nuture STEM Talents** The new STEM project-based learning programme aims to nurture global STEM leaders. In this regard, collaboration with other institutions or industry sectors will be developed to provide a platform to connect students with STEM professionals and cultivate them to be future STEM talents. Professors from institutions and entrepreneurs from STEM industries will be invited to visit our school to share about recent advance in their research innovations, their past life challenges and career prospects which could inspire our students to pursuit synthetic biology or STEM-related field for their further study and career aspiration.
1.3	Alignment with school-based / students' needs	The first major concerns in our School Development Plan (2019/20 – 2021/22) is to enhance teaching and learning to equip students with knowledge and competence in STEM education. The new programme enriches STEM curriculum in the field of synthetic biology with interdisciplinary modules and project-based learning to inspire and sustain students' interest, build and strengthen knowledge and competence in the field of synthetic biology and other STEM-related field which align with school-based and students' needs.

2. Project Feasibility

2.1	Key concept (s) / rationale(s) of the project	The rationale of the project comes from suggestions mentioned in the 'Report on Promotion of STEM Education – Unleashing Potential in Innovation'. The key concepts include: (i) renewing the curricula of the Science, Technology and Mathematics Education KLAs; (2) enriching learning activities for students; (3) providing learning and teaching resources. Our enriched interdisciplinary STEM curriculum in synthetic biology will be implemented in three cohorts of students. STEM-related subject teachers and 350 G7 to G9 students will be the first cohort to learn module 1 to module 3 of the STEM curriculum to build knowledge and skills in the field of synthetic biology, 60 G10 to G11 students studying at New Senior Secondary (NSS) curriculum in Biology will be the second cohort to consolidate and apply previous knowledges learned in module 1 to module 3 to engage in an interdisciplinary STEM project by constructing a new biological system. 20 G8 to G9 students in school-based pull-out programme of synthetic biology, who are selected by their good academic performance, STEM talents and skills will

		be the third cohort to learn and apply knowledge in module 1 to module 4 in an interdisciplinary STEM project by constructing a new biological system and participate in iGEM competition. All primary 6 students from our affiliated primary school will also be invited to experience molecular biology activities in the lab.
2.2	Applicant's readiness or ability/ experience/ conditions/ facilities for project implementation	School Department Head of Science and Mathematics and Biology Panel Heads has rich experience in teaching school-based pull-out programme of biotechnology and synthetic biology since 2012, mentoring STEM projects in various national and international science project competitions including Hong Kong Student Science Project Competition and being a primary investigator in iGEM 2019 competition and participate in a funded QEF project to build up STEM education unit: Mixed Reality (MR) courseware in Biology teaching in collaboration with tertiary institutions. Five STEM-related subject teachers including a Department Head of IBDP, a STEM coordinator, an Integrated Science Panel Head and two biology teachers have rich experiences in teaching molecular biology and its related techniques such as molecular cloning and gel electrophoresis. They also have experience in mentoring STEM projects. A Laboratory Technician has rich experiences in preparing laboratory apparatus and equipments for the lab. A Mathematic teacher specialized in computational modeling will be involved in curriculum design and implementation and involved in mentoring STEM project.
2.3	Principal's and teachers' involvement and their roles	A preparation committee will set up to coordinate, implement and monitor the progress of the scheme within the project period. The committee members include Principal, Department Head of Science and Mathematics, Biology Panel Head, Department Head of IBDP, Integrated Science Panel Head, STEM coordinator, Biology teachers and a Mathematics teacher. The Principal will monitor the progress of the scheme and provide support by allocating manpower resources and facilitating class period arrangements. All participated teachers will involve in the design and implementation of the curriculum, evaluation of the effectiveness of the project and dissemination of experiences and students learning outcomes.
2.5	Roles of collaborator(s) (if applicable)	Dr. Lo Sze Chung is an Associate Professor of School of Biological Science, The University of Hong Kong. His research expertise includes plant molecular biology, plant secondary metabolism and metabolic engineering. He is a collaborator of the project to give academic advices and technical supports to facilitate the development of STEM curriculum and experiment protocols. Dr. Fung King Tat is a Lecturer of Department of Linguistics and Modern Languages, The Chinese University of Hong Kong. He is specialized in Content and Language Integrated Learning (CLIL). He is a consultant of the project to give advices in the design and data analysis of surveys, assessments and progress evaluations which are useful tools to monitor the implementation of the project, evaluate learning outcomes of students and impact and effectiveness of the project.

2.6 Implementation timeline

Implementation period *(MM/YYYY)*	Project activities
10/2021 – 3/2022	- Purchasing relevant laboratory equipments and materials. - Recruitment of a project assistant. - Conduct meetings to review and enrich current STEM-related learning contents, design new curriculum, learning outcome indicators and student assessment tools to measure effectiveness of developed curriculum.
4/2022 – 9/2022	- Prepare learning materials of curriculum and implement different learning activities in S1 to S4.
10/2022 – 2/2023	- Conduct data analysis and evaluate the effectiveness of curriculum for refinement.
3/2023 – 8/2023	- Refine STEM curriculum and implement different learning activities in S1 to S5. - Evaluation of the effectiveness of developed programme. - iGEM team recruitment and project idea brainstorming.
3/2023 – 12/2023	- iGEM project planning and execution. - Project collaboration with other iGEM team. - Conduct iGEM outreach activities. - Project presentation in school and iGEM conference. - Attend iGEM 2023 competition that will be held in France in late October.
12/2023 – 9/2024	- Hold sharing session in school to showcase students' learning outcomes and reflections. - Organize teacher professional development workshops to share experience in planning and implementing the new program and showcase emerging science and technology field. - All curriculum contents including lecture notes and problem sets will be uploaded to the online platform for free public access.

2.7 Details of project activities

Student activity

Activity name	Content	Number of sessions and duration	Teachers' involvement and/or hired personnel	Expected learning outcomes
Synthetic Biology and Innovation	The following topics and contents will be integrated into learning curriculum of STEM-related subject in S1- S4: S1: Overview of synthetic biology – An introduction of synthetic biology including its innovation and application will be introduced. The structure and replication of DNA, chromosome organization and concept of central dogma of molecular biology will be integrated in STEM learning curriculum of Integrated Science topic 'Heredity and variation'. Students will be able to understand the background of synthetic biology and how the	S1: 2 sessions, 1 hour for each session. S2: 4 sessions, 1 hour for each session. S3: 4 sessions, 1 hour for each session. S4: 3 sessions,	To be taught by school teachers with relevant knowledge and experience.	The long-term goal of this project is to design, develop and implement interdisciplinary project-based STEM curriculum in the field of synthetic biology and evaluate its impact on student learning outcomes. The following are expected learning outcomes resulting from this module. Students will be able to: - appreciate synthetic biology is

	genetic coding system works. S2: Basic techniques of molecular biology - Fundamental principles and techniques of molecular biology will be introduced in school-based curriculum to stimulate students' learning interest and motivation and lay foundation for further study of related topics in S3. Students will perform the following hands-on experiments: bacterial DNA extraction, restriction enzyme digestion and DNA gel electrophoresis. S3: Basic techniques of molecular biology Fundamental principles and techniques of molecular biology will be introduced in learning curriculum of Cambridge IGCSE Biology topic 'Biotechnology and genetic engineering'. Students will perform the following hands-on experiments: polymerase chain reaction (PCR) and gel purification. S4: Advance techniques of molecular biology Fundamental principles of recombinant protein expression will be introduced and hands-on experiments: recombinant protein induction and protein gel electrophoresis will be performed. Such vertically integrated curriculum from S1 to S4 allows students to develop hands-on skills from basic molecular biology learned in S1 and S2 to a more advanced level learned in S3 and S4.	1 hour for each session.		advancing science and technology frontiers contributing to solving real-world problems in diverse fields. - explain the theory and practice of molecular biology field. - demonstrate their skills and ability to conduct different techniques of molecular biology. - direct related concept in molecular biology with latest laboratory techniques.
Genetic Engineering	The following contents will be integrated into learning curriculum of STEM-related subject in S2- S3 to consolidate the learned concepts in synthetic biology and innovation: S2: Plasmid analysis by basic molecular biology techniques S3: Visualization of protein with green fluorescent protein (GFP) tag in living cells under florescent microscopy will be used to	S2: 2 sessions, 1 hour for each session. S3: 2 session, 1 hour for each session.	To be taught by school teachers with relevant knowledge and experience.	The followings are the learning outcomes of this module. Students will be able to: - use systematic reasoning and critical approach to record and analyse data. - understand green florescent protein

	demonstrate the use of GFP as an important reporter for monitoring gene expression and protein localization. The following contents will be integrated into learning curriculum of Biology subject in S4 and S5 to link laboratory exercises in S2 and S3 that introduce students to important recombinant DNA and protein expression techniques to create new biological systems which could be visualized under florescence microscope and verified by successful recombinant protein expression. S4: Recombinant DNA construct making Engineering of a recombinant DNA construct with GFP reporter gene will be made and its visualization under florescent microscope will be performed for verification of gene expression. GFP signal will be observed if the recombinant DNA construct is successfully made. S5: Recombinant protein overexpression Recombinant protein overexpressing recombinant DNA construct made in S4 will be constructed to further verify recombinant DNA construction. S2 and S3 contents are vertically integrated into learning curriculum of S4 and S5. Important synthetic biology skills learned in S2 and S3, recombinant DNA and protein expression techniques allow S4 and S5 students to design and create new biological systems to solve real-world problems. New S4 and S5 learning contents will be integrated in New Senior Secondary Biology Curriculum compulsory part topics 'Basic genetics', 'Molecular genetics' and 'Biotechnology' and elective part topic 'Biotechnology'.	S4: 4 sessions, 1 hour for each session. Some of the tasks will be completed after lessons. S5: 3 sessions, 1 hour for each session. Some of the tasks will be completed after lessons.		(GFP) serves as an invaluable tool in monitoring gene expression. - integrate previous knowledge and laboratory skills to build a new DNA construct for subsequent protein expression. - gain experience of being part of an interdisciplinary STEM research project.
Bioinformatics	The following topics and contents will be integrated into learning	S1: 2 sessions, 1	To be taught by school teachers	The followings are expected learning

	curriculum of STEM-related subject in S1- S3: S1: To consolidate the concept of genetic coding system, students will work on analysis of functional genes that are available in organism genomes. The following database and software will be introduced: PubMed, sequence alignments using Basic Local Alignment Search Tool (BLAST) and translation using ExPASy. They should be able to identify a functional gene from a genomic DNA sequence, transcript sequence and translated product using bioinformatic tools. S2: Bioinformatic tools to identify restriction enzyme sites within DNA sequences and recombinant plasmid map will be introduced for plasmid analysis and subsequent experimental design. S3: Bioinformatic tools to design primers in PCR and study protein three-dimensional structure will be introduced. S4&S5: Use bioinformatic tools learned in S1 to S3 to perform computation analysis of a new candidate gene and give presentation about cloning strategies in the class.	hour for each session. S2: 2 sessions, 1 hour for each session. S3: 2 session, 1 hour for each session. S4 & S5: 2 sessions, 1 hour for each session.	with relevant knowledge and experience.	outcomes resulting from this module. Students will be able to: - access and analyse the data using bioinformatic tools. -perform computational analysis to identify a new candidate gene for future study.
Computational modeling	The following topics and contents will be integrated into the first year of learning curriculum of STEM pull-out program in synthetic biology for S2 and S3 students: 1. Introduction to growth dynamics The emphasis will be on the use of Hill Equation to model the grow curve of bacteria. 2. Introduction to mathematical modelling The least square method of parameter estimation will be introduced. 3. Introduction to computational modelling 4. Basic Matlab programming skills which allow students to fit	3 sessions, 1 hour for each session. Some of the tasks will be completed after lessons.	To be taught by school teacher with relevant knowledge and experience.	The followings are the expected outcomes of this modules: Students will be able to: - understand how mathematical and computer tools help in modelling and simulation of behaviors of new biological systems. - formulate modelling equations for new biological systems in interdisciplinary STEM project.

	experimental data in a given model.			
Interdisciplinary STEM project	The learning curriculum of S4 to S5 will be integrated into the first year of learning curriculum of STEM pull-out program in synthetic biology for S2 and S3 students to equip students with knowledge and skills required in authentic research project design and execution in the second year. Students will be able to use bioinformatic tools to design and synthetic biology skills to engineer a recombinant DNA construct with GFP reporter gene and subsequent recombinant protein expression. The integrated S4 to S5 learning curriculum build a strong foundation for learning so that students can learn at a faster pace and foster their learning interests and needs. In addition, coherent language of synthetic biology for expressing the structure and function of genetic design, Synthetic Biology Open Language (SBOL) Visual and Biobrick Standard Assembly will also be integrated into the first year of STEM curriculum of pull-out program. In the second year, the team will participate in iGEM 2023 competition held in France in late October to showcase their innovations and connect with global peers in synthetic biology community.	40 sessions in two years, 1 hour for each session. Some tasks will be completed after school.	To be taught by school teachers with relevant knowledge and experience.	The following are expected learning outcomes resulting from this activity. Students will be able to: - show their passion and interest, knowledge and skills in the field of synthetic biology. - design, analyse and evaluate a new biological system building upon what have been learned in the curriculum to real-world applications. - demonstrate ability to collect and analyse data for dissemination. - develop reasoning skills and high-order thinking skills to tackle problems. - demonstrate ability to translate several skills such as collaboration, public speaking, research skills and writing skills into other areas. - develop different generic skills which are essential for life-long learning.

a. Teacher training

Activity name	Content	Number of sessions and duration	Hired personnel	Expected learning outcomes
Professional development workshops	Professional development workshops will be arranged for STEM-related subject teachers. The contents include: 1. Curriculum planning of STEM project-based learning. 2. Implementation and evaluation	2 sessions, 3 hours for each session	STEM-related subject teachers will share experiences and provide teachers with necessary information and	Teachers should be able to - understand the designs of curriculum planning in STEM project-based

	of learning activities. 3. Lab equipments demonstration 4. Teacher experience sharing		training.	learning, the implementation and effectiveness of learning activities. - recognize synthetic biology as the emerging and cutting-edge development in STEM education - demonstrate basic knowledge and skills in relevant lab equipments.
Online learning resources development	Video lessons about different aspects of basic molecular biology techniques will be made.	4 sessions, 15 min for each session	A project assistant will assist in developing online learning materials and put them on the web.	Teachers should be able to understand knowledge and skills in basic molecular biology techniques.

b. Equipment (including installation of new fixtures or facilities)

	Details of equipment to be procured	Contribution to fulfilment of the project aim(s) and if applicable, the expected utilization rate
1	Low temperature freezer (-80^{o}C)	Long term storage of nucleic acids, proteins, bacterial cells, plant tissues and primers.
2	Florescence microscope with camera	For learning and teaching activities in the detection of GFP in bacterial cells and used in research projects.
3	Thermocycler	For learning and teaching activities in polymerase chain reaction (PCR) and used in research projects.
4	Trans-illuminator	For learning and teaching activities in DNA gel purification and used in research projects.
5	Benchtop autoclave	Sterilization of glasswares, Eppendorf tubes, culture medium for all experiments.
6	Water purification system	Provide purified water for all experiments.
7	Heat blocks	Provide stable temperatures for experiments involving restriction enzyme digestions and protein denaturation.
8	Refrigerated microcentrifuge	Centrifugation of DNA and proteins at low temperature.
9	Refrigerated 50 ml tube centrifuge	Centrifugation of recombinant proteins for purification.
10	Vortex mixer	Mix DNA samples in Eppendorf tube or falcon.
11	Nanodrop OneC Spectrophotometer	Optical density measurement of bacterial culture, nucleic acid and protein quantification.
12	Microplate reader	Enzyme assay and cell growth assay in 96-well plates.
13	Benchtop cooler	Maintain low temperature for temporary storage of enzymes, cells and reagents.
14	Bacteria growth incubator	Bacterial incubation
15	Ice- maker	Making ice for experiments.
16	Protein electrophoresis set	Protein electrophoresis experiment.
17	Ultrasonic homogenizer	Bacterial cell lysis for protein purification.

c. Construction works

	Details of the construction works proposed	Contribution to fulfilment of the project aim(s) and if applicable, the expected utilization rate

d. Features of the school-based curriculum to be developed

The goal of this project is to develop a school-based STEM programme in the field of synthetic biology integrated with new technological advances for interdisciplinary project-based learning in order to inspire students and sustain their interests in STEM-related field for further studies and career aspiration, consolidate STEM knowledge foundation and skills, enhance their generic skills essential for life-long learning, to promote STEM education in Hong Kong secondary schools, to enhance professional capacity of teachers in teaching science and technology and to disseminate experiences for the reference of other schools in the design and implementation of a new programme.
An interdisciplinary programme will be developed and integrated into STEM-related learning contents of S1 to S5 after holistic curriculum review. The programme includes an interdisciplinary curriculum with four modules to consolidate knowledge foundation in synthetic biology for S1 to S5 students and an interdisciplinary STEM project for pull-out programme students to work on authentic research by building upon what have been learned in the curriculum. The team will participate in the International Genetically Engineered Machine (iGEM) 2023 competition to showcase their innovations and share their ideas and experience with global peers of synthetic biology community.

e. Other activities

iGEM team students will engage in different outreach activities such as STEM expert interviews, school STEM activities, iGEM conferences and collaboration to solicit inputs from different stakeholders and share their idea and findings of authentic research. Such learning experience not only motivate and sustain students' passion and engagement in synthetic biology and STEM-related field but also show true mastery of learned knowledge and skills curriculum. In the end, students will be instilled with the core value of creativity, innovation, high-order thinking, communication, collaboration and effort, the transferrable skills that are essential in life-long learning to navigate a rapidly evolving society.

2.8 Budget

Total Grant Sought: HK$ 1,995,300

Budget Categories*	**Breakdown for the budget items**		**Justifications**
	Item	**Amount (HK$)**	
a. Staff	Project assistant (24 months including MPF) (HK$ 14,500 x 24 x 1.05)	365, 400	The candidate should have a university degree in biological science or related disciplines. He/she will be responsible for: - Assist in preparing teaching materials and surveys design; - Prepare, disseminate, collect and enter data of evaluation documents; - Assists in laboratory preparation works and mentor student projects; - Arrange and involve in learning activities and teaching sharing session; - Photo taking and video recording of learning activities; - Compilation and documentation of teaching materials, evaluation documents and student projects; - Build an online learning platform

			for resources development and dissemination.
b. Service	Travel expenses for iGEM competition (10 students) (HK$ 11,500 x 10)	115,000	iGEM competition is the world largest synthetic biology event for students to showcase their innovation and share their ideas and experience with global peers of synthetic biology community. It is one of the performance indicators to show students having a true mastery of learned knowledge and skills in the programme. Selected students should meet the following criteria: they must be 1) in G8 to G11; 2) in good academic and disciplinary standing; 3) fluent in the English language; 4) demonstrate passion and commitment to all learning activities in iGEM project.
	Online platform construction and hosting	5,000	All learning resources will be put online for sharing.
c. Equipment	Low temperature freezer	125,000	Long term storage of nucleic acids, proteins, bacterial cells, plant tissues and primers.
	Florescence microscope with camera	300,000	For learning and teaching activities in the detection of GFP in bacterial cells and used in research projects.
	Thermocycler	45,000	For learning and teaching activities in polymerase chain reaction (PCR) and used in research projects.
	Trans-illuminator	9,000	For learning and teaching activities in DNA gel purification and used in research projects.
	Benchtop Autoclave	110,000	Sterilization of glasswares, Eppendorf tubes, culture medium for all experiments.
	Water purification system	48,500	Provide purified water for all experiments.
	Heat block	14,000	Four heat blocks will be purchased to provide stable temperatures for experiments involving restriction enzyme digestions and protein denaturation.
	Refrigerated microcentrifuge	61,569	Centrifugation of DNA and proteins at low temperature.
	Refrigerated 50 ml tube centrifuge	7,433	Centrifugation of recombinant proteins for purification.
	Vortex mixer	10,070	Five vortex mixers will be purchased to mix DNA samples in Eppendorf tube or falcon.
	Nanodrop OneC spectrophotometer	143,997	Optical density measurement of bacterial culture, nucleic acid and protein quantification.

	Microplate reader	224,311	Enzyme assay and cell growth assay in 96-well plates.
	Benchtop cooler	4,600	Four benchtop coolers will be purchased to maintain low temperature for temporary storage of enzymes, cells and reagents.
	Bacterial growth incubator	24,000	Bacterial incubation
	Ice-maker	15,360	Making ice for experiments.
	Protein electrophoresis set	128,000	Eight Protein electrophoresis sets will be purchased for eight group experiments.
	Ultrasonic homogenizer	16,000	Bacterial cell lysis for protein purification.
d. General expenses	PCR reagents	40,025	Used in PCR reactions for learning and teaching activities and research projects.
	Lab consumables items	30,000	Consumable items such as pipette tips, eppendorfs, falcons, petri dish, 96-well plates etc. need to be used in experiments of module 1 and 2 and research projects.
	General chemicals	50,000	Chemicals such as agarose, bacterial culture medium, organic solvents etc. need to be used in experiments of module 1 and 2 and research projects.
	DNA extraction and purification kit	35,000	For DNA extraction and purification in experiments of module 1 and 2 and research projects.
	Computational analysis software	5,000	For modelling of bacterial growth dynamic and research projects.
	Auditing	15,000	Audit fee.
	Printing for dissemination and evaluation	1,000	Printing of learning materials for dissemination and surveys for evaluation of effectiveness of the programme.
f. Contingency	A contingency provision	47,035	(b+c+d) x 3%
	Total Grant Sought (HK$):	**1,995,300**	

Remark: Budget estimation of all items was prepared by requesting quotations from technology companies with item's function and size were taken into consideration. Product demonstrations were conducted for some of the items.

Procurement procedure set out by EDB would be strictly followed.

*

(i) Applicants should refer to the QEF Pricing Standards in completing the above table. All staff recruitment and procurement of goods and services should be carried out on an open, fair and competitive basis. Budget categories not applicable to this application can be deleted.

(ii) For applications involving school improvement works, a contingency provision of not more than 10% for carrying out works is considered acceptable.

(iii) For projects lasting for more than one year, a contingency provision of not more than 3% of the total budget exclusive of staff cost and works expenditure (including the related contingency provision), if any, is considered acceptable.

3. Expected Project Outcomes

3.1	Deliverables / outcomes	☑ Learning and teaching materials ☐ Resource package ☑ e-deliverables**(please specify)* Teaching materials and video lessons will be delivered via online platform. ☐ Others *(please specify)* _____ **For e-deliverables to be hosted on HKEdCity, please liaise with HKEdCity at 2624 1000.*
3.2	Positive impact on quality education/ the school's development	The aim of the project aligns with our school development plan. It aims to develop a school-based STEM programme in the field of synthetic biology integrated with new technological advances for interdisciplinary STEM project-based learning in order to inspire students and sustain their interests in STEM-related field for further studies and career aspiration, consolidate STEM knowledge foundation and skills, enhance their generic skills essential for life-long learning, to promote STEM education in Hong Kong secondary schools, to enhance professional capacity of teachers in teaching science and technology and to disseminate experiences for the reference of other schools in the design and implementation of a new programme.

3.3 Evaluation

Quantitative and qualitative measurements will be used to evaluate project effectiveness. For quantitative measurements, randomized pre-quiz and post-quiz research design will be employed to evaluate the effectiveness of integration of modules in enriched STEM curriculum. Students will be randomly divided into two groups. Students in both groups will do the pre-quiz. In the control group, students will receive conventional didactic teaching without integration of the related contents in STEM curriculum modules whereas students in intervention group will learn the same topic and related contents in STEM curriculum modules. Students in both groups will then do the post-quiz which is same as the pre-quiz to test their knowledge and understanding of the learned contents. Students in the control group will then learn the related contents in enriched STEM curriculum and do the post-quiz again. The difference between the mean academic scores of the pre-quiz and post-quiz after the intervention will be analyzed.

Questionnaires will also be given out to evaluate the effectiveness of integration of modules in terms of knowledge, skills, learning experience and integration of learning. Students will be asked to rate the following components using 5-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree): class overall; understanding of class content; lab experience; lab skill competence; support for the students as an individual learner and apply what have been learned in the class in other situations.

For qualitative measurements, interviews, class observation and student performance assessments will be conducted. Satisfaction of the curriculum contents, project-based learning experience and professional development activities will be the key performance indicators of the project. The following aspects of project effectiveness will be evaluated:

1. The effectiveness of the school-based STEM programme in promoting STEM education (success criteria: 80% of teachers and students agree that the project helps the school to promote STEM education).
2. Enhance student interest in learning STEM through synthetic biology learning activities (success criteria: 80% of teachers and students agree that the project helps to arouse student learning interest in synthetic biology activities.
3. Enhance student creativity, high order thinking skills and collaboration through learning activities and project-based learning (success criteria: 80% of teachers and students agree that the project enhance students the related generic skills).
4. Enhance teacher professional capacity (success criteria: 80% of teachers agree that the project enhance their professional capacity in teaching science and technology and serves as a useful reference for them in the development of new curriculum).

3.4 Sustainability of the project

By the end of the project, committee members and involved teachers will hold regular review meetings to discuss how to refine and further develop school-based STEM education in synthetic biology to promote learning of students and meet the future needs. With experiences in the development of a new STEM curriculum, our school will design teaching and learning activities for other themes.
The maintenance fee and the purchase of new equipments and items in the teaching of synthetic biology in the future will be borne by the school. The school will continue to make good use of the facilities and equipments to conduct teaching and learning activities in order to enrich students' learning experience in the field after the completion of the project.

3.5 Dissemination

The school will organize professional development workshops for teachers and sharing session for students by the end of the project to showcase students learning outcomes and share experience in design and implementation of STEM learning activities.
The deliverables will be uploaded to the school webpage and online platform for teachers' reference.
Good practices will be presented in national and international education seminar, workshop and conference.

Report submission schedule

Our school commits to submit reports in strict accordance with the following schedule:

Project Management (Should be submitted via the "Electronic Project Management System" (EPMS))		**Financial Management** (Hard copy together with supporting documents should be submitted to the QEF Secretariat by mail or in person)	
Type of report and reporting period	**Report due on**	**Type of report and reporting period**	**Report due on**
Progress Report 01/10/2021 - 31/03/2022	30/04/2022	Interim Financial Report 01/10/2021 - 31/03/2022	30/04/2022
Progress Report 01/04/2022 - 30/09/2022	31/10/2022	Interim Financial Report 01/04/2022 - 30/09/2022	31/10/2022
Progress Report 01/10/2022 - 31/03/2023	30/04/2023	Interim Financial Report 01/10/2022 - 31/03/2023	30/04/2023
Progress Report 01/04/2023 - 30/09/2023	31/10/2023	Interim Financial Report 01/04/2023 - 30/09/2023	31/10/2023
Progress Report 01/10/2023 - 31/03/2024	30/04/2024	Interim Financial Report 01/10/2023 - 31/03/2024	30/04/2024
Final Report 01/10/2021 - 30/09/2024	31/12/2024	Final Financial Report 01/04/2024 - 30/09/2024	31/12/2024

Reference

1. Savery, J. R. (2006). Overview of Problem-based Learning: Definitions and Distinctions. Interdisciplinary Journal of Problem-based Learning, 1(1).

2. Khaliq, S., Alam, M.T., Mushtaq, M (2014). An Experimental Study to Investigate the Effectiveness of Project-Based Learning (PBL) for Teaching Science at Elementary Level. International Journal of Academic Research in Progressive Education and Development, 4(1).

3. Kunal Ahuja and Amit Rawat (2019). Synthetic Biology Market Statistics| 2019-2025 Share Forecasts. https://www.gminsights.com/industry-analysis/synthetic-biology-market (retrieved on 5 March 2020)

Asset Usage Plan

Category	Item Description	No. of Units	Total Cost (HK$)	Proposed Plan for Deployment
Lab equipments	Low temperature freezer	1	125,000	Items will be used and maintained by the school for teaching and research purpose
	Florescence microscope with camera	1	300,000	
	Thermocycler		45,000	
	Trans-illuminator		9,000	
	Benchtop Autoclave		110,000	
	Water purification system		48,500	
	Heat block		14,000	
	Refrigerated microcentrifuge		61,569	
	Refrigerated 50 ml tube centrifuge		7,433	
	Vortex mixer		10,070	
	Nanodrop OneC spectrophotometer		143,997	
	Microplate reader		224,311	
	Benchtop cooler		4,600	
	Bacterial growth incubator		24,000	
	Ice-maker		15,360	
	Protein electrophoresis set		128,000	
	Ultrasonic homogenizer		16,000	
Computer software	Computational analysis software		5,000	

Annex I

Declaration

I agree and commit to participate actively in project promotion, publicity and dissemination activities in respect of the project.

Yours sincerely,
Dr. Yu Ka Yin
P.I.C. of the project
G.T. (Ellen Yeung) College