Part B Project Summary

Project Title:	**Project Number:**
Application of Innovative Mixed-Reality Technology in STEM Education Secondary Biology Teaching and Learning 應用創新混合虛擬現實技術在 STEM 教育:中學生物科教與學	**2017/1021** **(Revised)**

Name of Organization: School of Biomedical Sciences, The Chinese University of Hong Kong

(1) Goals: The goal of this proposed project is to enhance science education in secondary school curriculum by developing robust, innovative courseware using (Mixed-Reality) MR technology in the teaching and learning of biology

Objectives:
i. to support STEM education by applying MR technology in biology teaching;
ii. to enrich student's learning by enhancing the application of biology knowledge to the laboratory setting;
iii. to examine the effectiveness of the courseware as an educational intervention in the biology teaching and learning

(2) Targets: Secondary 4 to 6 from three participating schools.
Expected Number of Beneficiaries: 240 Students

(3) Implementation Plans:

i. Duration: April 2019 to March 2021

ii. Process

Time Schedule	**Milestone and Task**
Apr 2019 – Jan 2020	Courseware Development
Feb 2020– Aug 2020	Courseware Implementation and Evaluation
Sep 2020 – Mar 2021	Courseware Refinement, Dissemination and Publication

iii. Collaboration with other parties: [redacted]

(4) Products

i. Deliverables: Innovative MR courseware for topics of *Fluid Mosaic Model of Cell Membrane, Homeostasis and Blood Glucose,* as well as *Biotechnology and Genetically Modified Organisms*, composing of three features, including (1) MR-based learning, (2) gamified quizzes, and (3) narrative animations.

ii. Dissemination
- The school plans to organize sharing a seminar for the teachers of the district by the end of the project period so as to showcase students' learning outcomes, share the project experience and tips for implementing STEM learning activities.
- The deliverables and learning experience will be presented into local education conference and published in international conference

iii. Commercial-ization: This project services as a pilot study evaluating the effectiveness of applying MR in biology education. 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.

(5) Budget: The total estimated budget is HK $1,522,600 under the five budget items as listed:
(a) Services: $618,700
(b) Staff cost: $388,600
(c) Equipment: $243,000
(c) General expenses: $239,295
(d) Contingency: $33,005

(6) Evaluations: The project will be evaluated two approaches:

i. Performance indicators	**ii. Outcome measurements**
Pre- and post- quizzes	Scores assessing the effectiveness of the application of MR in biology teaching and learning
Student surveys and interviews regarding their learning experiences/user experiences	Identify areas for further improvement to increase the enjoyment and engagement in MR blended learning

Part C Project Details

Project Title: Application of Innovative Mixed-Reality Technology in STEM Education: Secondary Biology Teaching and Learning
應用創新混合虛擬現實技術在 STEM 教育:中學生物科教與學

Abstract

Science is one of the four disciplines in STEM education. The conventional teacher-centred approach although is widely adopted in secondary schools, its effectiveness in teaching and learning in science, especially Biology is limitedly reported. The application of Mixed Reality (MR) technology, the hybrid of virtual reality (VR) and augmented reality (AR) technologies providing an immersive interaction between the real world and the virtual world leads to a paradigm shift in the development of novel, innovative teaching courseware. To date, no MR courseware has been developed for secondary schools, in particular for integrating teaching and learning in science.

The goal of this proposed project is to enhance science education in secondary school curriculum by developing robust courseware using MR in the teaching and learning of biology. Three topics, fluid mosaic model of cell membrane, homeostasis of blood glucose level, biotechnology and genetically modified organisms are selected according to academic requirements and learning outcomes of the DSE curriculum from Secondary 4 to 6. The courseware comprises three features, including (1) MR-based learning, (2) gamified quizzes, and (3) narrative animations. Courseware effectiveness will be evaluated by user behaviour in MR courseware, and pre-and post-quiz to self-evaluate learning knowledge before and after the use of the courseware. Student surveys will also be used to evaluate the user's learning experience. The proposed outcome deliverables shall enhance teachers professional capacity to transit from conventional face-to-face instruction to a new teaching pedagogical method – blended learning, which encourages interactive than a one-way discussion.

Keywords: STEM education, Mixed reality technology, Biology, Blended learning

1. Background

The STEM, an acronym for **S**cience, **T**echnology, **E**ngineering, and **M**athematics education introduced by the National Science Foundation in the 1990s,[1] is the contemporary trend in educational pedagogy promoting students learning and development in the four specific discipline. In addition to core STEM knowledge, the Curriculum Development Council has devised Key Learning Area (KLA) in science education, supporting the learning of generic skills such as communication, critical thinking, collaboration and creativity.[2]

The conventional teacher-centred approach, in which teachers lecture students, although it is widely adopted in secondary schools, its effectiveness in teaching and learning in science, especially Biology are limitedly reported. In the authoritarian lecture-based pedagogy, students exposed to the materials passively with little time to digest information. Some studies suggested that this teacher-centred instruction promoted an overreliance on memorisation and discouraged subject-knowledge understanding.[3] An innovative pedagogical approach to teach biology is required to transform spoon-fed students into active learners. Education advocators shall proactively integrate information and communication technology, revolutionising and transforming teaching method and materials. The unprecedented growth of digital technology such as computer and mobile application has provided a complementary alternative to the teacher-centric teaching approach— blended learning.

Blended learning is a type of modern teaching that integrates didactic teaching pedagogy with media-rich technology. This approach is flexible in presenting content, where students can gain access to additional learning mediums in supplementary to the formal classroom teaching, tutorials or practicals. Blending e-learning materials with didactic lectures are now increasingly popular in the high school and tertiary education teaching practices, especially for STEM education,[4-6] majorly because of the observed learning benefits through verbal, visual, and auditory stimulations.[7,8] Most common advantages include enhanced motivation in self-regulatory learning, increased the level of engagement between students and teachers both inside and outside of the classroom,[9-11] improved long-term retention of information for better cognitive learning outcome.[12]

Mixed reality (MR) technology refers to the hybrid of virtual reality (VR) and augmented reality (AR)[13] that benefit learners from immersive hands-on experiences. AR technology allows users to view the real world overlaid with computer-generated imagery and information that help clarify concepts simultaneously. VR technology provides an immersive experience in a three-dimensional (3D) assigned physical environment. The MR combines immersion and holography enabling interaction between the real world and the virtual world. The interest in MR proliferates and has been applied for vocational and cooperates training. For example, the military has used VR for combat simulations, medic training, flight simulators, and vehicle simulators.[14] The medical field used MR to train new surgeons by simulating the operation room.[15] MR is anticipated to be an optimal teaching method to supplement the static face-to-face pedagogy, make instructions more straightforward to understand by displaying them directly over the real-world objects that require manipulation.[16] Recent research estimated that the application of VR would lead to a paradigm shift in the development of novel, innovative teaching courseware.[17] To date, no MR courseware has been developed for secondary schools, especially for integrating teaching and learning in science.

The goal of this proposed project is to enhance science education in secondary school curriculum by developing robust, innovative courseware using MR in the teaching and learning of biology. The courseware will address three scopes of experiential learning, including (1) basic biological knowledge, (2) biotechnology skills, and (3) problem-solving skills. More importantly, the proposed outcome deliverables enhance teachers professional capacity to transit from conventional face-to-face instruction to a new teaching pedagogical method – blended learning, which encourage interactive discussion.

1.1 Proposed Study Objectives

In line with the overall goal above, the specific objectives of the proposed project are:

1) to support and sharpen STEM education by applying MR technology in the biology teaching
2) to enrich student's learning by enhancing the application of biology knowledge to the laboratory setting
3) to examine the effectiveness of the courseware as an educational intervention in the biology teaching and learning

1.2 Project significance

To the best of our knowledge, this is the first MR courseware to be developed in the STEM education, especially for science. The significance of this project is three-fold as listed below:

- <u>To create virtual interaction in the science curriculum</u>
  Using MR technology, this pilot study set up a mixed of VR and AR environment to acquire modern molecular genetic skills including the restriction enzyme digestion of gene fragment and

the analysis steps. Students can also gain knowledge concerning the design and setting of animal experiments through the innovative MR teaching method.

- To develop a mobile application for blended learning
  Our courseware serves as an additional content that will be readily accessible to the students with a mobile device on both [redacted] platforms. By using either of these platforms, which are supported by our developed software, they enable access to the learning materials anytime and anywhere. As a result, students will increase their learning opportunities without any restrictions or limitations. The use of communication technology, e.g., AR technology, can motivate students in the learning process by enhancing their self-efficacy and self-worth.

- To encourage self-directed learning among students
  The interactive and gamified elements of the courseware will increase learning concentration and the retention time of memorised facts. The incorporation of the enjoyable searching atmosphere into knowledge development, which also enhances students' learning motivation, is a core component of STEM education.

1.3 The Benefits in Supporting of the Development

This proposed project is the first pilot development of MR-learning courseware for improving, enriching and strengthening students' technical knowledge in Science KLAs, to overcome their frustration in performing hands-on experiments.

1.3.1 Pro for Students

Students will benefit in the following ways:

- Students receive an opportunity to have hands-on experience in applying textbook knowledge in laboratory settings.
- The courseware as a form of personalised learning enables students to learn autonomously, revisiting learning materials for formative assessment.
- The courseware will allow senior students to review their laboratory techniques. It is which is vital because of senior students most likely to forget what they have learned, especially regarding instructions for instrument usage.

1.3.2 Pros for Teachers

- The innovative elements in the courseware not only assist teachers' delivery in class but also enhance science teaching quality and teacher's professional capacity that in line with the long-term goal of the schools' development in STEM education.
- The courseware allows facilitating the engagement in-class and after-class discussion between students and teachers, as opposed to one-way teacher-centred instructional models.
- The project enables the teaching staff to acquire knowledge about the incorporation of MR in the teaching and gain valuable practical experience from the implementation of the project.

2. Courseware Development

2.1 Method

A mobile application, using MR, will be developed on both [redacted] platforms for the pedagogy of blended learning.

2.2 Topic of Interest

Three topics are selected according to academic requirements and learning outcomes of the DSE curriculum among the domains in cells and molecules of life, organisms and environment and biotechnology from Secondary 4 to 6 (S4 to S6).

Topic 1: *Molecular Cellular Organization: Fluid Mosaic Model of cell membrane (Suitable for S4)*

Rationale:

The cell is the primary and single unit of the life in the human body. Using the fluid mosaic model, students can understand how the unifying structure of the cell membrane can protect, separate and interact the intracellular physiological conditions of the cytoplasm and nucleus with the extracellular matrix of interstitial fluid.

How MR contributes to the topic essentially?

The integration of the immersive in the microscopic virtual situation in MR makes students to learn the concept of the cell membrane effectively as it is an excellent resource to help students master the visual-spatial learning process.

Topic 2: *Homeostasis of Blood Glucose Level (Suitable for S5)*

Rationale:

The context of blood glucose level regulation is included in the DSE curriculum, that teaching resources in this topic are albeit limited. Students are merely told what happens in the experiment without an actual encounter with a real animal.

How MR contributes to the topic essentially?

Animal use in the science is indispensable but rarely addressed in the education due to limited resources. For example, the transgenic mice are chosen to investigate physiological changes between different organs systems in understanding the homeostasis, mice and mealworms are used as model animals to study the release of carbon dioxide in respiration experiments or pig hearts and kidneys are dissected in the examination of the anatomical structures in the circulatory and excretory systems. In particular, the concept of the homeostasis is much easier caught up by the students as they can have the multiple links from the learning resources to facilitate their thinks and connection of the new information to what they have already taught.

As a secondary goal to KLA, the proposed courseware allows students to explore the significance in the science spectrum but also the human side of the experiment – animal rights and animal welfare. As a result, an early exposure in raising ethics awareness among high school students is crucially essential to equip them the humanity side of the science.

Topic 3: *Biotechnology and genetically modified organisms (Suitable for S6)*

Rationale:

Biotechnology is a new topic, offering students an opportunity to understand how technologies apply modern techniques to improve ecosystems, revert the genetic disorders, prevent the infectious diseases, and contribute to regenerative medicine at the cellular and molecular biological processes.

How MR contributes to the topic essentially?

MR provides virtual hands-on experience in performing a basic experiment that high schools' students rarely exposed to, for example, bacterial cloning procedures. Due to the limited laboratory facilities, there is a restriction for the secondary students to have the hands-on experiences in doing the biotechnology-related experiment. The learning assisted by information technology enhances, enriches and strengthens their knowledge in biotechnology techniques from the realistic virtual world.

2.3 Features of the proposed courseware

Table 1 summarises the features of the courseware in respective to the topics. The proposed designs the contents based on the DSE biology curriculum, which will involve the blended learning approach pedagogic method for the interaction of MR simulation in classroom with online self-reflection. In total, the courseware composed of three features, including (1) MR based learning, (2) gamified quizzes, and (3) narrative animations. The following section provides a detailed description of each feature.

2.3.1 MR based learning

2.3.1.1 MR Based learning in VR environment

VR environment provides different virtual simulated situation from which student can have the realistic sensory learning process to promote problem-solving and critical thinking. The VR environment with computer device, head-mounted display and the motion controller setup, students can interact with 3D immersive learning objects for hands-on experience. More importantly, students do not rely upon memorisation for the knowledge cognitions. In our project, our team will be set up three coursewares as discussed:

2.3.1.1.1 The Fluid Mosaic Model

In the MR environment as shown in Figure 1, students can understand the components and the receptor types of the cell membrane (Figure 1a). They can also "see" the molecular interaction of the cell membrane realistically of how the non-polar molecules (oxygen or carbon dioxide) can pass through the cell membrane by the simple diffusion (Figure 1b); why the water, some ions and water-soluble polar molecules (e.g. glucose and amino acids) via the facilitate diffusion to the cytoplasm (Figure 1c). Moreover, they understand well in the mechanism cognitively with joyful engagement for STEM education. Also, it can facilitate those spatial or slow learners to abstract the concept more easily from the verbal explanation during the face to face teaching.

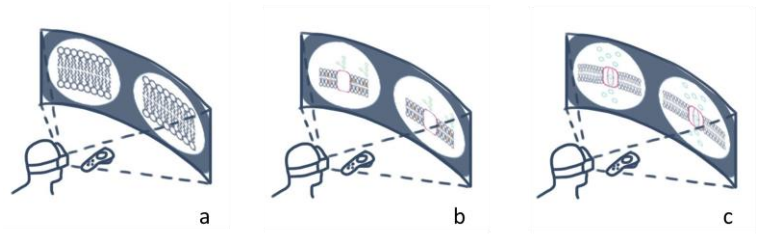

Figure 1 shows the MR based learning courseware facilitates the quality of STEM education in the teaching the concept of the fluid mosaic model.

2.3.1.1.2 The Blood Glucose Test in Animal Model

It will be applied in the animal use in a regulation of blood glucose level experiment in the homeostasis topics. Figure 2a to c show how 3D immersive environment simulates a biology laboratory.

After the students put on the headsets and controllers, students will be immersed in an animal facility house, and they can do the virtual experiment that involved animals. For example, in the exercise, students will be stimulated in an animal laboratory where they will be instructed to grab the mice and perform tail vein injections.

The learning experience of students anticipated are enriched by this exposure as they are doing a new technique that they cannot do these procedures at secondary schools, i.e., they can pick up the mice and administer the injections. This experience allows students to visualise and experience the laboratory skills and steps involved in handling animals. It also stimulates students' awareness of essentials to be considered in the design of an experiment.

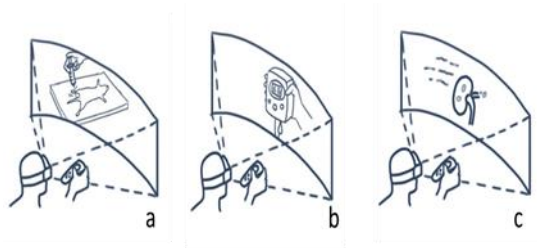

Figure 2 Using virtual animals in the regulation of blood glucose level experiment as an example: a) interact with the virtual object in the mobile device ([redacted]); b) study the simulated results and record the experimental data and c) watch the 3D animation how glucose affects internal organs.

2.3.1.2 MR based learning in AR environment

The AR environment will just be applied to the topic of bacterial isolation in DNA cloning and restriction enzyme digestion. It is designed for in-class use and will be adopted at the didactic tutorial laboratory.

Figure 3 shows the virtual agar plate in the bacterial DNA cloning experiment. Firstly, the AR code is put on the physical agar plate (Figure 3a). When students scan the code, DNA cloning experiment will be shown on the mobile device. The mobile device (e.g., Samsung Note 9) acts as the guidebook, showing relevant information on cloning selection (Figure 3b). Then, the mobile device acts as a simulator, for example, allowing students to pick up the clone into the broth for culturing (Figure 3c). Finally, the mobile device provides additional information on 3D animation concerning how restriction enzyme digestion works for cutting the DNA insert out from the plasmid (Figure 3d).

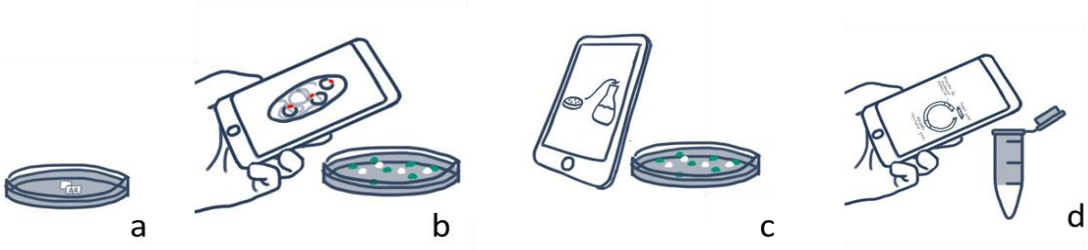

Figure 3 Using virtual agar plate in the DNA cloning experiment for training students' critical thinking process.

2.3.2 Gamified Quizzes

Competitive interventions are incorporated into the design of quizzes to increase students' engagement in the revision facilitating students' cognitive learning (Figure 4a). Our team will design quiz questions in line with the course objectives. Three difficulty levels will be set up to address varying students' need: Basic Level requires memorisation of fundamental knowledge; Advanced Level requires an understanding of the correlation with functions; Challenging Level requires a comprehensive understanding and application of relevant conceptual understanding. Students would be notified whether they answer the questions correctly or incorrectly.

2.3.3 Narrative Animation

Animation based video using cartoons will be produced using Vyond software® to illustrate the importance of the recombinant DNA technology, the technique of the polymerase chain reactions, the fundamental concepts of homeostasis, and the disease of diabetes. Figure 4b shows the sample video that each duration last about three to five minutes long.

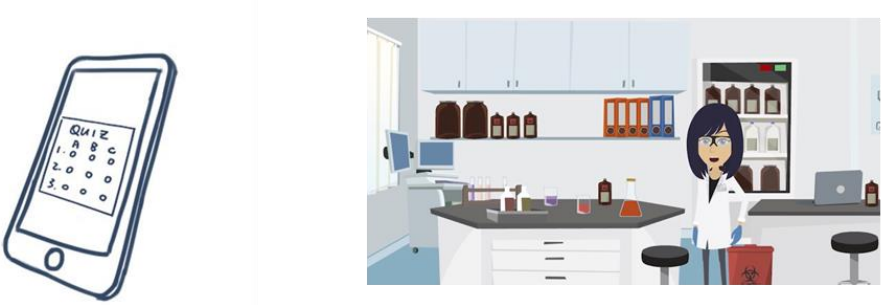

Figure 4 Features of the gamified quiz (a) and narrative animation (b).

Table 1 Features of the courseware in respective to selected topics.

Topics	Narrative Animation	Mixed AR /VR Bio Lab	Gamified quizzes
Secondary 4: The Fluid Mosaic Model of cell membrane			
The concept of the fluid mosaic model of the cell membrane including its property and function		✓	
The components of the cell membrane	✓		✓
Movement of substances across the cell membrane	✓		✓
Secondary 5: Homeostasis of Blood Glucose Levels			
Handling experimental animals & Setting the experimental and the control group		✓	
Concept of homeostasis	✓		✓
What is Diabetes?	✓		✓
Regulation of Blood Glucose level			✓
Experimental design to investigate the changes in blood glucose and insulin levels after the tail injection of glucose solution		✓	
Secondary 6: Biotechnology and genetically modified organisms			
What is recombinant DNA technology?	✓		✓
The Polymerase Chain Reaction (PCR) and its application	✓		✓

The Gene Cloning Steps: Transformation→ Selection of recombinant clones → Grow the clone in the broth → Restriction Enzyme Digestion	✓	✓

3. Courseware Evaluation: Plan of investigation

3.1 Subjects

The proposed study will consist of S4 to S6, which is approximately to 240 students from three participating secondary schools.

3.2 Methods

Two evaluation methods to be held in two consecutive phases will be adopted to evaluate the proposed courseware. Figure 5 shows the evaluation framework by the flowchart.

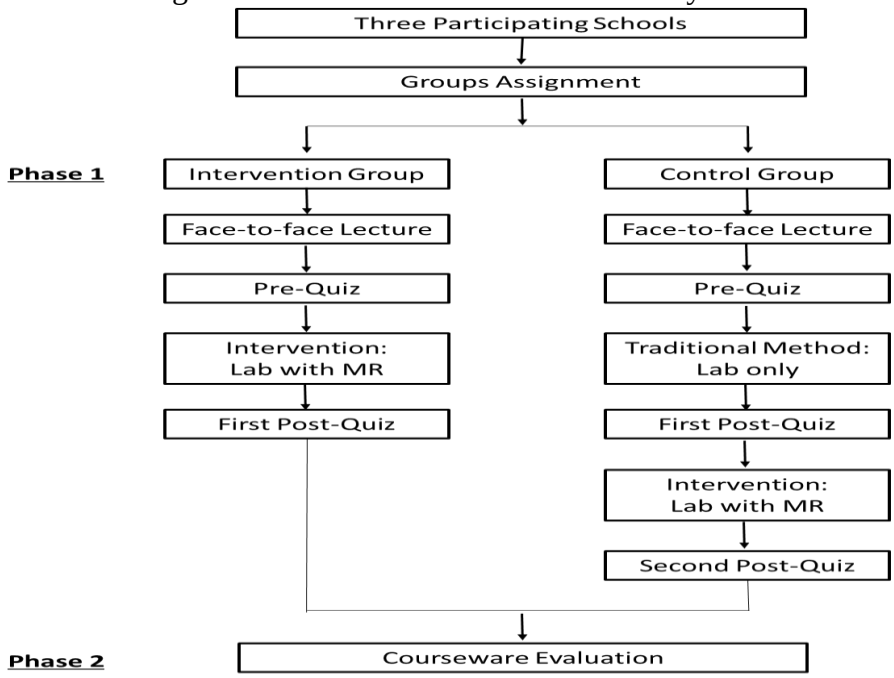

Figure 5 Courseware Evaluation Framework

3.2.1 Phase I: Pre-quiz and post-quiz

In the first phase, a randomised pre-quiz/post-quiz research design is employed to evaluate the effectiveness of the proposed educational intervention.[18] Three participating schools will be randomly assigned into two arms. In the control arm, students will receive conventional didactic teaching, a "face-to-face" lecture, followed by a laboratory tutorial without the use of MR. In the intervention arm; participants will learn the same topic with the use of MR in addition to the didactic lecture. A post-intervention quiz, the same as pre-intervention one, will then be conducted assessing their knowledge of the topic. Students in the control arm will receive additional laboratory tutorials using the MR this time, and post-quiz will be conducted.

3.2.2 Phase II: Course Evaluation by Questionnaire

In the second phase, a cross-sectional quantitative questionnaire with seven statements assesses attitudes towards courseware design, content presentation, features as well as the perception of a learning environment where technology is used. Students will be asked to rate the statement using a 5-point Likert scales ranging from 1 (strongly disagree) to 5 (strongly agree). The project team will develop questions according to the domain listed in Table 2 below:

Table 2 Domain of Investigators for Courseware Evaluation

Domain of Investigation	Research Questions
Perceived utility of teaching courseware (a) Essential function (b) Usability	○ How often do you use the interactive MR? ○ Is the MR interesting and motivating your self-learning? ○ Is MR user-friendly and that you can find the structures easily?
Perceived effectiveness of teaching courseware (c) Attractiveness (d) Organisation	○ Is the interactive MR helpful in understanding the knowledge related to the application? ○ Do the contents of interactive MR facilitate your enrichment in critical thinking? ○ Do the formative assessment stimulate your self-reflection for the problem solving during the examination? ○ Is the information given on the topics in MR also applicable to your science curriculum?

3.3 Data Analysis

Descriptive analyses will be used to describe the participants' perceived attitude of the courseware from the evaluation. The outcome results from the control and intervention groups in pre- and post-intervention time points to generate four sets of outcome data will be pooled. First, we will compare the two sets of outcome results across the two groups at the pre-intervention time point. After that, we will compare the outcome results of the post-intervention time point. We expect comparable outcome result and no statistically significant differences between the correlation coefficients of the control and intervention groups. If the correlation coefficients are significantly different between the control and intervention groups in the post-intervention results, we could assume the difference is from the effect of the intervention. Two-Factor mixed design analysis of variance [redacted] will be conducted to examine the overall effect of the intervention on the outcome across two-time points and between two groups. Among the control group, another comparison will be conducted between the first and second post-quiz results. The [redacted] will be used to analyse all data.

4. Project Timeline

According to the strategic timeline of our proposed project, we target the courseware implementation within 24 months, beginning in April 2019 and ending in March 2021. Our team will assure that the planned tasks on the timeline are carried out on schedule.

Table 3 Milestone Timeline

Time Schedule	Milestone and Task
Apr 2019 – Jan 2020	**Stage 1: Courseware Development** - Prepare and design the MR courseware - Set up the App on the [redacted] system - Fine-tune the courseware - Conduct the trial run for evaluation

Feb 2020 – Aug 2020	**Stage 2: Courseware implementation** - Adopt the courseware at participating schools
	Stage 3: Courseware Evaluation - Distribute the quizzes as designed - Conduct data analysis - Evaluate the quality of the courseware for its sustainability and scalability.
Sep 2020 – Mar 2021	**Stage 4: Courseware Refinement** - Refine the courseware based on the comment **Stage 5: Courseware Dissemination and Publication** - Introduce the courseware to other Hong Kong or International institutes through seminars, workshops, group interviews and conferences - Prepare a paper for publication on the overall evaluation of active learning, including the effects on student learning

5. Collaboration with other partners

This is a collaborative project involving teammates from various disciplines, including [redacted] and the consultant of the entrepreneur, each of which will contribute at different phases of the proposed project, for example, during the content design for the MR coursewares, the technical and logistic resources management and execution and the project's outcome evaluation. Table 4 lists the specific role of the project leader and collaborators who have confirmed to participate in the project.

The Principal of [redacted] provides our team with full support, by allocating workforce resources and facilitating class period arrangements. The Biology Panel head, [redacted] will be the leader of the principal school, [redacted] and will take part in the curriculum integration and its promotion to other schools. There is a total of three Biology teachers from [redacted] and two partner schools, [redacted] and [redacted], participating in the implementation and reflection meetings. Each has substantial experience in the teaching of biology that they will actively be reviewing existing curriculum and develop context according to students' need.

Table 4 The role of projector leader and collaborators in the project.

Name of Collaborators	Name of University	Area of Expertise	Role in the project
[redacted] (Principal Investigator)	[redacted]	A well-trained biomedical researcher in teaching human body systems and techniques in biomedical research	– Build up the STEM education content in the Biology curriculum of KLAs – Advise on the courseware development of MR
[redacted]	[redacted]	An experienced teacher of Biology Panel Head,	– Participate actively in the design of education content according to the curriculum

	Department Head of Science and Mathematics	– Disseminate the courseware throughout the academic year
[redacted]	An experienced teacher of Biology Panel Head	– Implement and incorporate the MR – Collect and deliver the surveys to the [redacted]
[redacted]	An experienced teacher of subject-in-charge of Biology	– Implement and incorporate the MR – Collect and deliver the surveys to the [redacted]
[redacted]	An expert in MR development	– Create the courseware platform – Develop the MR's hands-on study
[redacted]	A research fellow with expertise in research method design	– Design the evaluation framework – Design questionnaire – Conduct data analysis evaluating users' experiences
[redacted]	An applied linguistics researcher with expertise in Content and Language Integrated Learning and English as the Medium of Instruction assessment.	– Provide support and advice on developing the linguistic and communication skills of students in writing up experimental results – Provide help and advice in creating assessment questions
[redacted]	Entrepreneur - the veteran in knowledge transfer and Biotech/Life Science project management	– Explore potential outcomes for successful technology & knowledge transfer and to facilitate commercialisation

6. Project Sustainability and Dissemination

The sustainability and dissemination of the proposed project are discussed as follows:

Project Sustainability	− At present, due to the limit of this grant funding, we aim to develop the courseware for high impact topics only. Our team regards this project as a pilot study. 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. − The purchased items, such as mobile device, Google cardboard or Samsung VR Gear, could be reused in the next project. The maintenance fee in future will be borne by the Grantee. The Grantee will continue to make good use of the facilities and equipment to conduct learning and teaching activities to enrich students' learning experience after the completion of the project.

Project Dissemination	– Our team will disseminate information regarding the benefits of the new STEM pedagogies on student blended learning by organising workshops, seminars for other schools and publishing in an educational newsletter dedicated to MR technology in STEM education. – Our team will also visit other schools to showcase these teaching methods and organise series dissemination activities organised to showcase students' learning outcomes, and to support other biology teachers via teacher development workshop training. – Our team have expertise in academic publications. We will publish our experience of developing and applying MR to STEM education in Hong Kong, and students learning experience in international peer-reviewed journals.

As our project is aligned with the mission of KLA for the promotion of students' development and application in generic skills (such as communication and critical thinking), it offers significant challenges regarding embracing the idea of transforming spoon-fed students into active learners. Moreover, we should step forward and find new ways of a paradigm shift to make breakthroughs in STEM education.

7. Budget

The proposed budget is estimated as below.

Item	Amount (HK$)		Amount (HK$)
	2019 Mar to 2020 Feb (12 months)	2020 Mar to 2021 Feb (12 months)	
(a) Services – Courseware development			
• Mobile App for [redacted] Platform – Basic Navigation – Loading the slide image (30 digital slides) onto the App – Zoom-in and out of the slides – Quizzes	60,000		60,000
• Setting up the MR courseware involving – Graphic Design and UI Design for the Mobile App – Basic icon and graphic design for the App – User interface design – Illustrations – 3D model creation – Setup the animations – Game-room development – Interaction with VR controller – Motion tracking with AR marker – Choice selection by eye tracking	500,00		500,000

– Motion recording for analysis – Three MR in VR or AR environment – Three Animation Clip development – Publish to iOS and Android – Support [redacted] and [redacted] VR			
• Fine tune and update the App		50,000	50,000
• [redacted] (yearly plan)	1,800	1,800	3,600
• [redacted] (yearly plan)	5,100		5,100
Subtotal			618,700
(b) Staff Cost			
• Student helpers for the App development and content preparation: @$55/hr x1.05 (MPF) = $58 x 200 hr/ year	11,600	11,600	23,200
• Supporting Staff*: One Project Assistant (University graduate) Monthly payment: $14,500 x 1.05 (MPF) =15,225/mon x 12	182,700	182,700	365,400
Subtotal			388,600
(c) Equipment			
• Mobile devices with Gear VR***** for 40 sets: $5,000 x 40	240,000		240,000
• [redacted] Software		3,000	3,000
Subtotal			243,000
(d) General expense			
• Conferences, poster design, publications, proof-reading, editing		10,000	10,000
• Dissemination* (Organisation of workshops, seminars, showcases & booth)		20,000	20,000
• Account Audit		15,000	15,000
• University handling grant charge (activities take place off campus): 15%			194,295
Subtotal			239,295
(e) Contingency			33,005
		Total	1,522,600

Justifications for a request for workforce/equipment and travelling expenses *

Item	Justification
Staff Cost: Supporting Staff: Project Assistant	Assist the courseware implementation in teaching, including setting the devices, activities design, surveys preparation and collection, data input and analysis, evaluation and promotion to other schools.
Equipment: mobile device with Gear VR or equivalent	High-performance VR device is needed which can be used to support our project development. However, there are no standardised mobile devices owned by all Schools that can be used for the entire class.
General Expense: Dissemination expenditure	Regarding the application of innovative MR learning leadership, our team members will disseminate the findings at local via booth, showcases, conferences and workshops to promote our MR learning courseware.

8. Equipment Usage Plan

Our team will keep the record of the equipment after the purchase and submit details as follows to which the equipment should be deployed and the planned usage of the asset in activities upon project completion.

Category (in alphabetical order)	**Item / Description**	**No. of Units**	**Total Cost (HK$)**	**Proposed Plan for Deployment***(Note)*
Equipment (mobile device and VR gear)	*Mobile device with VR gear,*	40 sets	240,000	They will be kept by our School or our partner schools for the teaching purpose.
Equipment (computer software)	*SPSS software*		3,000	It will be kept by our School in the future project for the analysis purpose.

9. Report Submission Schedule

Our team will commit to submit progress 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 1/4/2019-30/9/2019	31/10/2019	Interim Financial Report 1/4/2019-30/9/2019	31/10/2019
Progress Report 1/10/2019-31/3/2020	30/4/2020	Interim Financial Report 1/10/2019-31/3/2020	30/4/2020

Progress Report 1/4/2020-30/9/2020	31/10/2020	Interim Financial Report 1/4/2020-30/9/2020	31/10/2020
Final Report 1/4/2019-31/3/2021	30/6/2021	Final Financial Report 1/10/2020-31/3/2021	30/6/2021

10. References

1 Katzenmeyer C, Lawrenz F. National Science Foundation perspectives on the nature of STEM program evaluation. *New directions for evaluation*. 2006; 109:7-18.
2 The Curriculum Development Council. Science Education: key learning area curriculum guide (Primary 1 – Secondary 6). *Hong Kong SAR: Education Bureau*, 2017.
3 Hammer D. Epistemological beliefs in introductory physics. *Cognition and Instruction*. 1994; 12: 151-83.
4 Hua L, Goodwin D, Weiss A. Traditional vs blended learning of pharmacology. *Optometric Education*. 2013; 39:28–34.
5 Funke K, Bonrath E, Mardin, WA, et al. Blended learning in surgery using the Inmedea Simulator. *Langenbeck's archives of surgery* 2013; 398:335–340.
6 Lewis KO, Cidon MJ, Seto TL, Chen H, Mahan JD. Leveraging e-learning in medical education. *Current problems in pediatric and adolescent health care* 2014; 44:150–163.
7 Jelonek D. The Development of Software Agents in e-Learning. In: ICIT 2015 The *7th International Conference on Information Technology*; 2015:332–337.
8 Selim HM. Critical success factors for e-learning acceptance: confirmatory factor models. *Computers & education* 2007; 49:396–413.
9 Dantas AM, Kemm RE. A blended approach to active learning in a physiology laboratory-based subject facilitated by an e-learning component. *Advances in Physiology Education* 2008; 32: 65–75.
10 López-Pérez MV, Pérez-López MC, Rodríguez-Ariza L. Blended learning in higher education: students' perceptions and their relation to outcomes. *Computers & education* 2011; 56:818–826.
11 McLaughlin JE, Griffin LTM, Esserman, DA, et al. Pharmacy student engagement, performance, and perception in a flipped satellite classroom. *American journal of pharmaceutical education* 2013; 77:196.
12 Paas F, Sweller J. An evolutionary upgrade of cognitive load theory: using the human motor system and collaboration to support the learning of complex cognitive tasks. *Educational Psychology Review* 2012; 24: 27–45.
13 Tamura H, Yamamoto H and Katayama A. Mixed reality: Future dreams are seen at the border between real and virtual worlds. *IEEE Computer Graphics and Applications* 2001; 21: 64-70.
14 Van Krevelen D and Poelman R. A survey of augmented reality technologies, applications, and limitations. *International journal of virtual reality* 2010; 9: 1.
15 Aggarwal R, Black S, Hance J, Darzi A and Cheshire N. Virtual reality simulation training can improve inexperienced surgeons' endovascular skills. *European journal of vascular and endovascular surgery* 2006; 31: 588-593.
16 Milgram P, Kishino F. A taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems*. 1994; 77(12): 1321-9.
17 Izard SG, Juanes JA, Peñalvo FJG, et al. Virtual reality as an educational and training tool for medicine. *Journal of Medical Systems* 2018; 42: 50.
18 Tikkanen, Stephanie. Two-Group Random Assignment Pretest-Posttest Design. 2017. In Mike Allen (eds), The SAGE Encyclopedia of Communication Research Methods. SAGE Publications.