Quality Education Fund
Application with Grant Sought Not Exceeding $200,000
Part B: Project Proposal

Project Title	Project Number
Augmented Reality Models for Enhanced Learning Experience of Physics Concepts	**2017/1036** (Revised)

Basic Information

Name of School / Organisation / Individual
Hong Kong Polytechnic University, Department of Applied Physics

Beneficiaries

(a) Sector: ☐ Kindergarten ☐ Primary **X** Secondary ☐ Special
(Please tick the appropriate box(es))

(b) Students: __100_____ (in number) and __S4-S6_____ (class level)

(c) Teachers: _____6_____ (in number)

(d) Parents: _____ (in number)

(e) Participating Schools (excluding applicant school): __2___(in number and types)*

(f) Others (please specify): _____

** Please specify where appropriate*

Proposal

(I) Project Needs

(a) Please state the aims of the project in clear and concise terms and elaborate on how the proposed project could impact on school development.
(*Example: To enhance students' interests in reading through story-telling, singing, and drama...)*

Objectives:

1) Promoting active learning in large classes through effective use of technology, namely, Augmented Reality (AR) models.
2) Adopting blended and/or flipped mode of teaching and learning.

The main goal of the project is to build AR simulations for four physics and materials science phenomena: *projectile motions, electromagnetic principles, collision and linear*

momentum, and *waves & optics (interference)*. Priorities will be given to topics that are difficult for textual or verbal explanations, or those problems which involve multiple physical dimensions in the same scenario. Furthermore, these topics might be adjusted after finishing the survey on students' need and perception of AR mobile apps. With the developed tools we would like to gauge the effect of AR in improving students' knowledge of related physics topics, and the impact of the AR in the studying patterns of students.

(b) (i) What are the areas of the needs and priorities of the school?
(*Please tick the appropriate box(es)*)

☒ Enhance learning and teaching to facilitate students' knowledge on subjects / learning areas / generic skills development
☐ Promote students' social and emotional development
☐ Enhance school management / leadership and teachers' professional development / wellness
☐ Others (please specify) _____

(ii) Please give background information to justify the demonstrated needs as mentioned in (b)(i).

☒ Literature review summary: To many students, physics is a difficult subject because of the abstract concepts involved, and the frequent use of mathematical/geometric techniques. Various teaching aids exist in the market in order to assist the learning and teaching of the physical concepts, such as videos, figures and models [1-5]. Although the provision of such illustrations are conductive to students' understanding, sometimes these illustrations (even those that have been used in classic textbooks for decades) contain pitfalls for students who are new to the topic. Literature abound to discuss such problems, but there are no simple solutions, given the complexity of the physics concepts. Very often problems arisen from the lack of *multiple* perspective to view the very same problem: often they are three dimension (in space) problems, compounded with the considerations of other abstract physical concepts (energy, field) [5, 6]. Detailed guidance from instructors, together with extra attention from students, are needed to have a complete understanding of the issue; unfortunately both attributes are often missed from classes due to the lack of lecture time and size of lectures.

In this regard, augmented reality (AR) simulations allows the demonstration of complicated physics concepts from a multitude of dimensions [7, 8]. There are many existing AR applications available for mobile devices, however most of these applications were designed for a broad audience, such as primary school or younger students [9]. Seldom of these apps are tailored for senior secondary school level physics course. Therefore, much modification would be required if not a complete makeover of the apps. Another practical issue to consider is the sustainability of a purchased or subscribed app from a third party. Since the operation system (OS) of mobile devices are updated relatively frequently, OS compatibility of the AR app used needs to be tested and updated accordingly. The update of a purchased or subscribed app is not a guarantee, which can affect the course progress.

We therefore propose to develop a number of AR mobile apps for use in secondary physics courses. By developing our own app, we can tailor the app to students' needs and even modify its content as we receive feedbacks from the students. Moreover, we are in control of the stability and availability of the app, so better course planning can be done in advance. Overall, a better learning experience for students can be provided if we are to develop a new mobile app specifically for the DSE Physics courses. With mobile phones, students will be exploring the multi-dimensional graphics from various perspective, allowing clearer understanding of the physical scenario. Such explorations will be paced by the students instead of the school teachers, allowing students to take charge of their learning and becoming self-motivated in learning physics. The blending of new technology into the learning process is also advocated by Hong Kong Government in enhancing the learning experience of students.

References:
1. 'Even honors students have conceptual difficulties with physics', P. C. Peters, *Am. J. Phys.* **50**, 501 (1982).
2. 'Observations on student difficulties with mathematics in upper-division electricity and magnetism', R.E. Pepper et al., *Phys. Rev. ST Phys. Educ. Res.* **8**, 010111 (2012).
3. 'Investigating physics teaching and learning in a university setting', J. Guisasola, M. de Cock, S. Kanim, L. Ivanjek, K. Zuza, et al., *II Nuovo Cimento C* **38**, 96 (2015).
4. 'Students' difficulties with vector calculus in electrodynamics', L. Bollen, P. van Kampen and M. de Cock, *Phys. Rev. ST Phys. Educ. Res.* **11**, 020129 (2015).
5. 'Student understanding of light as an electromagnetic wave: Relating the formalism to physical phenomena', B.S. Ambrose, P.R.L. Heron, et al., *Am. J. Phys.* **67**, 891 (1999).
6. 'Real-Time Data Display, Spatial Visualization Ability, and Learning Force and Motion Concepts', *J. Sci. Educ. Technol.* **15**, 1 (2006).
7. 'Augmented reality in education', M. Billinghurst, *New horizons for learning*, 12 (2002).
8. 'Mobile Augmented Reality: The Potential for Education', D. Nincarean, M.B. Alia, N.D.A. Halim and M. H. A. Rahman, *Procedia Soc. Behav. Sci.* **103**, 657 (2013).
9.http://www.teachthought.com/the-future-of-learning/technology/32-augmented-reality-apps-for-the-classroom-from-edshelf/

☐ Assessments on students' performance: _____
☒ Relevant experiences:

1. The Department of Applied Physics (AP) in PolyU provides physics teaching for 1st year undergraduate students in science and engineering-discipline, and has gathered experiences in the shortcoming of students in terms of experimental technique and critical thinking for solving physics problems.
2. Five QEF teaching projects (ref. Nos. 2013/0127, 2014/0600 and 2014/0761, 2016/0255 and 2016/1098) have been launched by the team members starting Sep 2014. In these projects, collaboration between local high schools and our team members were in good conditions. The team members have the necessary technical knowledge and scientific instrumentation experiences in developing teaching aids proposed here. The local high school teachers will help us to deliver the teaching aids for trial run in their schools. They will give us feedback on the performance of the teaching aids.

☐ Others (please specify) _____

(c) Please elaborate on the innovative ideas or new practices to enhance, adapt, complement and/or supplement the existing practices that will facilitate the development of the school to address the needs specific to its own context.
(Example: Drama and music are effective means to stimulate students' interest in reading and help develop their multiple-intelligences...)

There are a number of benefits on the use of AR in physics teaching:

- As discussed in previous session, parts of the difficulty in studying physics lie in understanding phenomena that occur in three-dimensional spaces, which are often linked to other abstract parameters. For many students, 'visualizing' such concepts using two-dimensional figures is a daunting task. The use of AR allows easy understanding of the concepts, and letting students to view the phenomenon under multiple perspective, greatly enhancing their understanding of the phenomena.
- Reaching out students in large classes is a challenge, and it is impossible to devise a single methodology that can ensure the understanding of the topic by

all students. The additional use of AR allows student to explore the concepts by themselves which, together with the lecture materials, should boost the understanding of students on the topics concerned.

The following deliverables will be generated at the end of the project:

i. Android and iOS-based mobile apps which hosts four AR physics models
ii. A website that contains the apps and relevant materials (image markers) for public download

At the end of the project, we expect the following outcomes to be achieved:

i. Enhance students' understanding of the physics topics as illustrated by the AR physics simulations.
ii. Arouse students' interests in self-motivated learning.

(II) Project Feasibility

(a) Please describe the design of the project, including:

(i) Approach/Design/Activity (Applicants are advised to provide details on project activities as well as learning and teaching arrangements.)
(Example: The project adopts the drama-in-education strategy and uses popular children songs to arouse students' interest in reading in a fun and interactive way...)

- The AR models, being built for explaining general physics and materials science concepts, is anticipated to be of use for senior secondary school students. The resulting apps (and related image anchors) will be prepared for free download from AP websites.
- The experiences of using AR as teaching aides will be presented in community of practice sessions, in order to raise the awareness of secondary school teachers in the latest development of technology and their roles in enhancing students' learning experience.
- Results of the tests will be analysed, with the aim of publication in referred journals

Work Plan

1. Survey on user needs (2 month)

Before the design and implementation of the AR mobile apps, survey will be conducted to gauge students' needs of such learning aids. Through such survey, we will gather information on their learning difficulties in specific physics topics, and how specific features of AR could possibly improve their understanding of the related physics concepts. The proposed survey will be conducted during the summer, in form of focused group interview with small student groups. Simple questionnaire will also be issued to target user groups for collecting their opinions.

2. Construction and Optimization of AR mobile apps (6 months)

Based on the information gathered during the survey and interviews, four AR mobile apps will be constructed. Relevant physics models will first be constructed by professional 3D-drawing softwares (3D-Max or AutoCAD), and constructed models will be rendered by physical modelling software (such as Unity) for building the AR apps. AP has recently acquired the modelling software for use of final year project students in constructing AR and virtual reality (VR) simulations. The Apps will be completed in two phases: two will be ready by the end of Dec 2019 and the other two will be finished by the end of March 2020.

3. Using AR in teaching and evaluation of learning impact (5 months)

The pilot of the AR apps will be performed once they are ready, and should start from April 2020. Students will be instructed to download the apps into their mobile devices before the lessons. During the teaching of related topics, instructors will guide students through the process of using the AR and explain the topic based

on the apps. Students will then perform tutorial worksheets about the topics in class. With the installed app student can also use it for their revision of examination. To gauge the impact of the apps on student learning motivation, attitude tests will be issued to students before the apps are prescribed to them, and at the end of the semesters. The impact of the apps on student performance will be checked by reviewing student exam performances across different cohorts.
After the pilot test of the apps in the April 2020, user survey will be conducted, and students' feedback on the features and functionalities of the AR apps will be incorporated into the revision of the apps. This process will chiefly be conducted during May 2020, with the targeted re-launch taking place in Aug 2020.

Elaboration on the design and methods

There are two aspects which we would like to investigate on the impact of AR on the L&T of students: (1) how the users perceive the AR and (2) has the AR actually improved the learning.

For (1), cross-cohort investigations on the test and exam performance will be analysed. By comparing the scripts of different batches of students, an understanding can be obtained on the understanding of students in the physics topics covered by the AR.

For addressing (2), surveys will be issued to students, consulting them on the opinions about the AR. Topics covered in the questionnaire will include the ease of operation, level of satisfaction upon usage, plus comments concerning the AR. Besides, focus-group interviews with students, helpers and subject lecturers will be organized, in order to collect opinions from different stakeholders.

Evaluation plan:

To assess the functioning of the AR apps and gather user feedback for potential improvement. Methodologies including a) Meetings with users (teachers and students) to gather opinions on the qualities of deliverables; b) Survey forms to students and teachers for feedback on the usability and potential implications on intended learning outcomes; c) Gather information on usage patterns based on site visit; d) Pre-tests and post-quizzes for students to assess their understanding of the related topics. Pre-tests are necessary to benchmark their abilities before the start of the L&T activities.

(ii) Key Implementation Details

Project period: Aug/2019 to Aug/2020

Month / Year	**Content / Activity / Event**	**Target Beneficiary/ Participants**
Aug/2019 to Sept/2019	Survey on students' needs and perception of AR mobile apps	Students & Teachers
Oct/2019 to March/2020	Design and implementation of AR Apps in Android	Students & Teachers
April/2020 to Jun/2020	Application of AR for teaching of topics in partner schools Evaluation of student performance	Students & Teachers
July/2020 to Aug/2020	Revamp of AR Apps for iOS Implementation of AR in teaching of other subjects	Students & Teachers
Aug/2020	Analysis of results and concluding of project	Students & Teachers

(b) Please explain the extent of teachers' and/or principal's involvement and their roles in the project.

(i) Number of teachers involved and degree of input (time, types, etc.): 2

(ii) Roles of teachers in the project:
(*Please tick the appropriate box(es)*)

☐ Leader ☐ Co-ordinator

☐ Developer x Service recipient

☐ Others (please specify) _____

Involvement of the teachers:

a) Help the team to perform the survey on students' needs
b) Give suggestions on the details of AR stimulation model
c) Deliever the AR apps for trial run in their schools
d) Collect feedback on the performance of the AR apps

(c) Please provide the budget of the project and justify the major items involved.
Grant Sought: HK$ 198,200

Budget Item*	**Expenditure Detail (Including the breakdown for the budget items)**		**Justifications**
	Item	**Amount ($)**	
i) Staff	Project Assistant	$16,000 x 1.05 x 11 months = $184,800	See **J1** below
ii) Equipment	Equipment required for the development of VR, such as two tablet PCs, relevant software or other AR/VR-related devices, etc.	$8,000	To facilitate the development of the VR app
iii) General expenses	Printouts of teaching materials, Audit fee	$5,010	
iv) Contingency		$390	
Total Grant Sought ($):		$198,200	

J1*: The personnel involved will assist the project team members to develop the AR models, and teaching materials, run for the activities, and collect feedback form the participants. After the contract of the hired staff has ended, team members will continue the analysis of results and concluding the project.*
** Please cross out as appropriate*

(III) Expected Project Outcomes

(i) Please describe how to evaluate the effectiveness of the project.
(*Please tick the appropriate box(es)*)

☐ Observation: _____

☒ Focused group interviews:
Interviews on randomly selected participating teachers and students will be conducted to gather their opinions on the project and impact on students' learning.

☒ Pre-and post-activity surveys:

Questionnaires will be used to collect both students and teachers' opinions on the project.

☒ Performance change of students in assessment: Assessments on students' scientific development, such as motivation and creativity will be administered.

☐ Others (please specify) _____

Success criteria:

1. The developed mobile apps which hosts four AR physics models will be used by not less than 80 secondary students from at least two secondary schools.
2. The website that contains the apps and relevant materials (image markers) for public download will be visited by at least 200 visitors within one year after the website has been accessed in public.
3. The developed mobile apps will be promoted to public through our university activities such as information day.

(ii) Please state the project deliverables or outcomes.
(*Please tick the appropriate box(es)*)

☐ Learning and teaching materials
☒ Resource package
☐ DVD
☐ Others (please specify) _____

Assets Usage Plan (N/A)

Report Submission Schedule

I/My organisation commit(s) to submit proper reports in strict accordance with the following schedule:

Project Management		**Financial Management**	
Type of Report and covering period	**Report due date**	**Type of Report and covering period**	**Report due date**
Progress Report 1/8/2019 – 31/7/2020	31/8/2020	Interim Financial Report 1/8/2019 – 31/7/2020	31/8/2020
Final Report 1/8/2019 - 31/8/2020	30/11/2020	Final Financial Report 1/8/2020 - 31/8/2021	30/11/2020