Needs and Applicant's Capability

Needs Assessment: An evaluation of the current situation and the needs for the present project

Information technology reform in Hong Kong's education system

In 2020, the COVID-19 epidemic taught the world about the importance of Information technology (IT) in every aspect of human life. As most of the education institutions were closed during this pandemic, Hong Kong Education Bureau (EDB) have also given top priority towards the IT sector for refining the education system. According to the EDB, different levels of mixed learning modes, i.e., face-to-face classes, e-learning at home or other modes of learning, may become the new normal in teaching and learning (T&L) due to this unpredictable outbreak. Hence, it is the high time to implement different educational methods based on IT in the Hong Kong's education system, which will be very essential for the students in upcoming future [1].

IT is the study, development, design, implementation, support, or management of computer-based information systems in particular software applications and computer hardware. Nowadays, with the introduction of IT in every field, the world is getting a lot of new and rapid innovations. IT moves forward towards something new every second and people have been welcoming them as these innovations are making human lives easier and productive. IT has become one of the inevitable parts in the education system also. The use of technology makes the process of education more impactful and interactive. This is the era of generation who are living every second of their life using some aspect of IT. Therefore, the education sector also needs to adapt continuously with these changes.

Science education is one of the core aspects for students in schools. However, there are some limitations which affects the learning process of the students because all the concepts cannot be understood by reading books only. Moreover, not all local secondary schools have all the necessary materials as well as supports to teach everything practically. In particular, based on the current COVID-19 situation, students may require to learn most of the things themselves at home or through online classes without getting the proper practical knowledge. Therefore, it is required to find some alternative ways that can support the students especially with science subjects which required a lot of abstract concepts. Physics is one of the compulsory part of science education. All the Physics related topics are consisted of a lot of abstract concepts and 3-D geometrical objects which are taught by viewing illustrated images from the book or by describing the structures of the objects in words. Hence, a lot of attention and time is mandatory to understand these theories thoroughly. Without doubt, visionary and practical learnings are very effective rather than traditional theoretical approach of learning. Moreover, as it is very expensive to provide every school with all required science equipment, many schools do not own enough laboratory equipment and facilities to demonstrate all the experiments. In addition to this limitation, another issue that physics students are facing while practicing problems related to their syllabus is the quality of the question bank. As we know physics topics are mainly based on mathematical problems, due to the limited number of problems in the textbook, students do not get to test themselves with a lot of options to check their preparation. If a student practises the same questions for the second time, it does not help them much as they already know the answer or the procedure. Therefore, addressing these problems such as need of visionary learning, lack of expensive equipment and limited exercise problem, IT can be introduced as a solution to improve the T&L process in the Physics education in Hong Kong.

Augmented Reality (AR) is an interesting innovation of IT, which is an overlay of virtual objects in real life objects and helps to demonstrate the complicated topics of different educational subjects especially physics topics in such a manner that these tough topics becomes comprehensible faster. AR is one of the most popular areas in modern science and technology, in particular, it can boost interactive and self-learning process. Visionary learning is efficient and effective in many ways in comparison with traditional system. The most significant and effective benefit of AR is that it does not require any external hardware or any device, otherwise it would have been very costly and difficult to provide everyone with the required materials. Students can experience all the benefits of AR only with their mobile phones. And the concept of AR is very interesting, because it places one virtual object on top of a real life object. So, this is a very unique and interesting blending of reality and virtuality. The interactive learning system makes the learning process easy and fuels the learning curve in terms of adaptation. It will make the observation process of the students easier, which will eventually have effect on their interpretation of the theories. Moreover, by utilizing AR for performing laboratory experiments, the proposed AR app can help the students to observe all the possible outcomes of an experiment by themselves without using expensive equipment. Therefore, AR can be an excellent solution for the visionary learning and performing cost effective laboratory experiments.

Artificial Intelligence (AI) is another major part of IT sector nowadays. Through the use of algorithms and computer-based training, AI and Machine Learning (ML) can effectively be used to create expert systems, that can be further utilized in the T&L process of physics education in Hong Kong. By developing a system with the help of AI and ML, it is possible to provide students a vast number of mathematical problems and scenarios by which they can develop their understanding about physics topics. This AI based system will be accessible to students through mobile phone and

laptop. Therefore, they can easily access the system as they desire i.e. they learn at their own pace (student-centred learning). As we know, after learning some topics it is necessary to practice related problems to sharpen the understanding level. However, with the assistance of teachers and textbooks, it is only possible to solve a handful number of exercise problems. Therefore, AI/ML technology can be introduced to develop a system that can provide numerous problems with different difficulties, which will be a useful tool for the student physics learning.
This programme will have different questions related to their studies and the questions will be arranged in three different stages, basic, medium and advanced. The question will start popping to the students from the medium level. Based on the accuracy of the students' answers, the system will either lead them to basic or advanced level. This system will be the students' guide to explore their own studies and level of their understanding. At the same time, this system will provide different questions with different values each time and it'll make transition in between the different question level to test the students thoroughly. It will give the guidance to the students showing them their exam preparation and will be a great tool for self-evaluation.

On the basis of these proposed tasks, an AR application and AI/ML based system named as **"A comprehensive Augmented Reality Apps with AI Tools for Enhancing Learning Experience of Physics''** will be designed and developed for providing an ideal learning experience to the senior secondary school students. The well-designed interface of the apps and the system with various topics, assignments, laboratory manuals as well as learning materials will be developed which will be allocated to the secondary students through a website. The capability of such learning apps in enhancing the students' learning experience will be investigated thoroughly so that the apps can be modified as required.

In summary, the objectives of the current project are:

i. To develop an AR based application containing **ten physics topics** and **five laboratory experiments** from the senior secondary school physics syllabus of Hong Kong, for both android and iOS devices. This app will assist the student to visualize the abstract topics in 3-D and do the laboratory experiments with all possible outcomes.
ii. To assist the students for evaluating their learning experience through an AI/ML based system, which will be accessible through mobiles and laptops. By generating different set of scenarios based on physics topics each time, this AI/ML system will let the students to solve different theoretical and mathematical problems. The problems' difficulty level will be modulated based on the answers provided by the student. The questions will be based on the secondary school textbook, but the system will change the conception each time to make it more effective in the study of the students.
iii. To prepare specific guidelines for the application and the system, according to the features that will be provided, so that students can utilize them to do in depth analysis of the topics.
iv. The applications, system information, instruction guides, and target images will be uploaded into a website so that students can find all the resources in one place.

(a) Readiness of the applicant organization for undertaking the project

Applicant Organization's Strength and Experiences

The proposed project will be conducted principally by a group of academic staffs in the Department of Applied Physics (AP), the Hong Kong Polytechnic University (PolyU) led by and . Besides, a number of experienced physics teachers from the ten partner secondary schools will join this project.

<u>i. Technical Competence of Project Team</u>
The project is managed by a team of academic staffs in AP, PolyU. They have the experiences and essential technical knowledge in implementing the platform proposed here. The team has capability in App programmes development, scientific instrumentation and arduino design, which are essential for the construction of the software as well as the design of the AR experiments. In fact, instrumentation teaching is a major component of the Engineering Physics degree program offered by AP at PolyU. The team members have extensive experiences in the development of arduino-based experiments, either for research and/or teaching-related purposes. Several PolyU-supported pilot projects and four large-scale QEF projects have been launched by our team since July 2013 to design and implement a remote experimental platform, Physics experiments utilizing smartphones as detectors for conducting selected undergraduate/high school laboratory sessions, and Arduino-based experiments. Furthermore, a small-scale QEF project has been funded to develop an AR based app to allow high school students to learn some basic concepts in Physics. The AR based project is made to view and observe the abstract physics structures, which makes the concepts clearer to students as visual learning is very effective. The project is designed to make the best use of the visual learning process and also provides interactive learning experience. This combination makes the application unique and effective. In the project, due to the

limited funding and time, only four topics from the senior secondary physics syllabus have been covered, which comprise very tiny portion of the whole syllabus. We would like to extend this project, covering more topics to make it a full experience for the students in learning physics.

ii. Experiences in Science Education

The team members in PolyU have extensive experiences in science teaching at post-secondary levels. They have previously taught degree level as well as sub-degree level physics to students of various disciplines (science, engineering and health studies), and are in a good position to correlate various physical phenomena in different professional contexts and daily applications. Such insights are beneficial for secondary students to grasp the significance of the topics covered by the experiments, so that they can apply these physics concepts in daily-life. Indeed, one of our team member, served as member in the Hong Kong Examinations and Assessment Authority HKDSE Physics Subject Committees. In that capacity, he oversees the running of the DSE physics examination and its future development. He, therefore, has a deep understanding on how the learning and teaching of DSE physics could be further enriched and enhanced based on our proposed platform. This proposed project will be benefited from his expertise in DSE committees and teaching at the university level.

Ten secondary schools will involve in the current proposal as co-investigators. Based on their first-hand experiences on physics teaching, the teachers can provide relevant suggestions on the supporting teaching materials to be developed, so as to maximize the benefits achieved through the use of the platform. Participating school members will also assist in the testing and evaluation of the app programme at various stages of the project development. Teachers will make assessment of the platform and provide timely feedbacks for the project team. By incorporating the app programme platform in their teaching, they will assist in evaluating the platform's impact on students' learning experiences and collecting feedbacks/comments from students. Such information will be useful in gauging the effectiveness of the current project.

iii. Previous Experiences in Education-based Projects

Our team has previously obtained various grants related to science education at secondary education level. Between 2014 and 2020, four large grants (amount > $1.5 M) were funded by QEF projects to our team.

Title	Objective	Period & Funding amount
Laboratory with no limits: AnyTime, Anywhere (Real-time Access Remote Laboratory Platform for S4-6 students)	To develop an educational platform allowing students to perform some remote physics experiments at their own convenience. In this platform, students will perform some pre-designed experiments developed in the platform through internet control	2013/0127 HK$1.9 M
Secondary School Science Laboratory utilizing smart phones as detectors: Physics Experimental Apps for Flipped Classroom Learning	To develop mobile Apps for secondary students to perform experiments using their own mobile phones	2014/0761 HK$1.6 M
Laboratory in your pocket – real-time hand-on experiments on Arduino-Smartphone system	To develop Arduino-based experiments for secondary students to perform experiments	2016/1098 HK$2.0 M
Borderless Lab365: A student-centered learning science experiment platform to enhance STEM education for secondary schools	To develop an educational platform allowing students to perform some remote physics, chemistry and biology experiments at their own convenience.	2018/0030 HK$5.6 M

Furthermore, another QEF project related to AR app programme has been funded to develop four physics and materials science phenomena: projectile motions, waves & optics, electromagnetic principles, and collision & linear momentum. This AR project was a small-scale project, which only covered 4 topics of the whole syllabus of HKDSE. The concept of this application-based project is unique and is not available for HKDSE syllabus till this project was funded. This project holds a strong scope of a new form of self-learning which is very beneficial for the students, especially for this time when home-schooling is the only option. This project is due for a successful finish and it is highly expected that there will be a satisfactory outcome. All the projects are closely related to secondary school teaching and learning. Through these projects, our team has fostered a strong network with numerous local physics teachers, who are at the

forefront of the secondary school education and can provide us with a holistic view on the physics education in Hong Kong.

Goals and Objective:

Our focus is to choose physics topics from senior secondary school syllabus, which are difficult to illustrate by traditional teaching methods. 3-D animated physics models will be used to help the students visualize the concepts and the abstract parameters in equations. The user interface (UI) will be designed in such a way that the students find the experience motivating and interactive. The features of the app can be divided into two parts, firstly it will view different objects in 3-D animated structures. Secondly, the students will be able to interact with the different aspects of that theory with several relevant parameters. This will help students to investigate the correlation of the various parameters. Our intention is to create an easy self-learning platform so that students possess greater insight of the physics topics. Secondly, the app for laboratory experiments will help the student to do the lab work by using only their mobile phone anytime/anywhere. Considering the present condition of the world, now more than ever, the education system needs to bend towards creating a platform which helps students to learn by their own. Since it is difficult to go into the physical class or labs to learn, technology can bring new magnitude to solve this problem. AR is a great platform for a self-learning and interactive education system which can provide experience like real life events. For the laboratories, it is sometimes inefficient to do the lab experiments as every student might not be able to hold the equipment and sometimes it is impossible to provide separate equipment for each student in the laboratory. As every student can have the AR in their own phone without any extra cost, this project will be safe and effective in every aspect of learning. In addition, the AI based system will be designed as a problem solving tool for the student. As mentioned earlier, it is difficult to provide a vast number of different sets of question based on a physics topic in a textbook. Therefore, to enhance the learning experience of a student, this AI/ML based system will generate a **comprehensive question bank** for the students, so that they can solve questions of various levels and learn the topics more clearly. As we know practice makes perfect, therefore, by creating different conceptual situation every time this expert system will let the student to practice the problem from different point of views. Moreover, this will also develop the critical thinking capabilities of the students by modulating the questions difficulties.

Short Term Goals:

The short-term goal of this project is to provide an AR application for both iOS and android platform for selected physics topics which are interesting to view. **Ten theoretical topics** and **five laboratory experiments** topics from the syllabus are included in this project. Moreover, **one AI/ML based problem solving tool** will be developed for mobile phones and laptops. Students are expected to experience a more interactive way of learning in their own space by using the apps and tool. For the theory portion of the application, eight topics from compulsory part and two topics from the elective part of the DSE curriculum syllabus is selected. For laboratory, in total five experiments will be developed. In Phase I, six theory topics and three laboratory topic are planned to be completed. In Phase II, remaining four theory topics along with two remaining lab topic and the AI/ML based tool will be designed and implemented. These topics were selected to give the students an overall package from every part of their syllabus. Indeed, some of the topics (for example, electric field) are difficult to be explained easily based on 2-d graphics inside textbook. These topics are interesting to be seen in 3-D animated view and should be very interactive when it is combined with the excellence of AR. Supplementary materials will be prepared to facilitate the students to entirely learn the usage of the apps by using their mobile phones. Through the use of such platform, students are expected to grasp more thorough understanding of the corresponding topics in physics. The degree of achieved goals will be assessed during the project duration. To make the adaptation of the application easier, video demonstration of the app programme will be prepared and those videos will be available to the website. All the applications, instruction guides, and target images will be added in a single website so that students can find all the resources in one location. Thus, a unique platform for senior secondary school students will be established by the end of the project. The evaluation of the project will be done by the end of this project through survey among the students and teacher.

Long Term Goals

The project could become an inspiration of making IT based education resources for different stages of education. Based on experience gained in this project, it is expected that AR based apps and AI/ML based tools could be designed for students in different stages of education, and thus maximizing the functionalities of the platform. As all the applications, the related theories, video demonstration and instructions along with target images will be uploaded in a single website, therefore all the students/teachers from different levels can access the materials from anywhere/anytime. Through the website, valuable suggestions from users will be collected so that the apps and concepts of the problem solving tools can be improved as required. The website will be freely accessible for the public AR and AI based apps are not confined for physics topics. Based on the requirement of the Hong Kong education sector, topics from different subjects can be

covered with AR and AI apps. Therefore, home schooling and T&L process for all level of students can be improved. As during the situation like COVID-19 where remote learning is the top necessity, AR and AI apps can be able to provide assists to both teachers and students for the T&L process. Moreover, by arranging several workshops and surveys, Applied Physics Dept. at PolyU can play a supporting role for finding out more activities that can be taken to improve the Hong Kong Education by implementing IT in the T&L process.

In summary, the goals of the current project are:

1. To develop AR based mobile applications which will cover the ten theory topics and five laboratory experiment topics from the DSE syllabus, for both android and iOS devices. In this app-
   a. All the theory topics will be illustrated using the 3-D animated models. And there will be options of changing various parameters related to the theories. This will allow students to do in-depth analyzation beyond the theories mentioned in textbook. Therefore, students can relate them with the real events.
   b. The experimental topics will be designed in such a way that students can utilize all the necessary equipment required. This will allow the students to illustrate all the possible outcomes that can be found from the experiment. Due to the expensive devices used in the laboratory experiments, most school only show one version of the lab and students learn the theory of other scenarios by their imagination. However, this app will assist the student to evaluate all the possible scenarios by themselves via their own mobile phones.
2. To create an engaging and effective system for the students to practice the theoretical and mathematical related problems from different topics of secondary school physics syllabus by using AI/ML technology. This proposed system will generate different scenarios of specific physics problems and regulate the difficulty level of the questions according to the performance of the student, so that the learning experience become more interactive.
3. To create assignments with guidelines on report writing for DSE physics courses, utilizing the developed Apps.
4. To prepare specific guidelines for the application, according to the features that will be provided in the app so that students can utilize them to do in depth analysis of the topics.
5. Adding the applications, instruction guides and target images in a website so that students and teachers can access all the resources in one place.

Targets and expected number of beneficiaries

DSE physics students in senior secondary school will be the primary group benefitted and affected from this project. The total numbers of students participating and secondary school teachers in this project will be around 450 and 20 respectively. They will experience a new technique which boosts up their self-motivated learning on the abstract science topics. To make the applications benefit maximum, promotions will be conducted, development workshops will be organized subsequent to the completion of the learning activities of each of the two phases, so that the user count does not get limited within the participating school students. Based on the survey questionnaires, educational papers will be published in international journals. This will also boost up the research field and will benefit local and oversea students. This will maximize the user to other educational levels than senior secondary school.

Innovation

This proposed project proposal is an extended part of our previous project **"Augmented Reality Models for Enhanced Learning Experience of Physics Concepts" (Project No: EDB/QEF/2017/1036)**. That project involved only four topics of senior secondary school physics syllabus, which comprise a very small portion of the whole syllabus. Furthermore, the AR app developed in this project had limited functions. The AR model only showed the 3-D animation without ML question bank. The overall concept of the project is to motivate the students for self-learning.

There are multiple number of AR applications in the market, but none of which is based on HKDSE physics. This project is the first AR project which is built according to the HKDSE physics syllabus. And during the situation like COVID19 where self-learning and home schooling are becoming more and more necessary, this kind of apps will be very effective for the new T&L process. By using AR technology, it is possible to provide an option to the students, where they not only can observe the whole scenario in 3-D animation, but also practically determine the formula by changing different parameters. Hence, this will help the students to grasp the theory quickly and visualize the topics easily. In fig 1, the view of the application for wave is shown. Here, we kept two waves for comparison purpose. For example, students can view two transverse wave and can change the amplitude, period, wavelength of both the wave in real time. This gives them a clear and fresh understanding of how the parameters of the wave affects the overall appearance of the wave. Besides, students can compare one transverse wave with one longitudinal wave to understand the difference between them clearly. In fig 2, the view of electromagnetism showing the magnetic field around a long straight wire. Here, students can change the value of current and radius and can see the changes of the value of magnetic field in real time. Also, they can change the direction of current and can see the changed direction of the magnetic force field due to the

change in the direction of current. This application makes it easy to understand the relation between the parameters and can shows how they affect each other in real time.

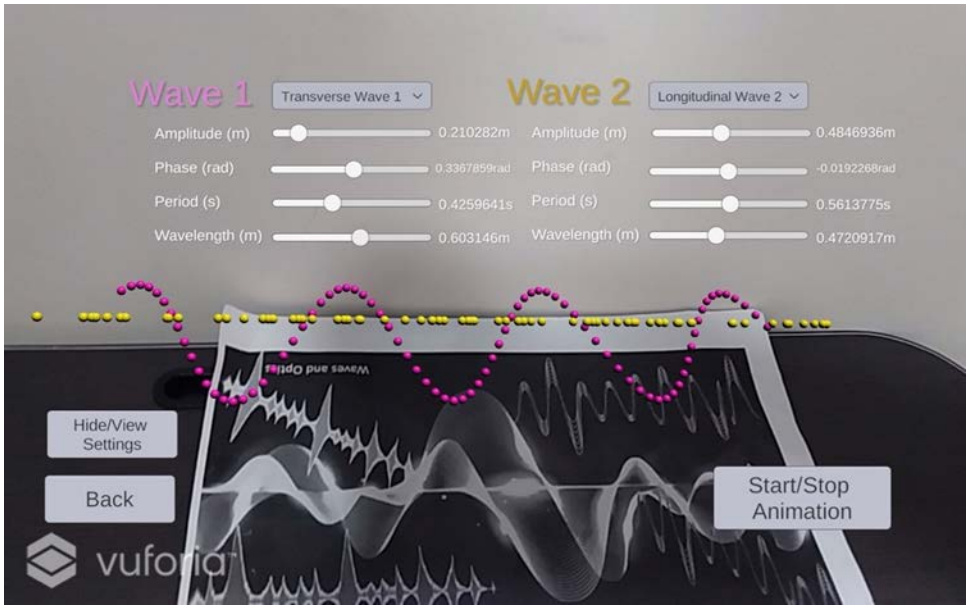

Fig 1: AR application viewing the characteristics of different waves

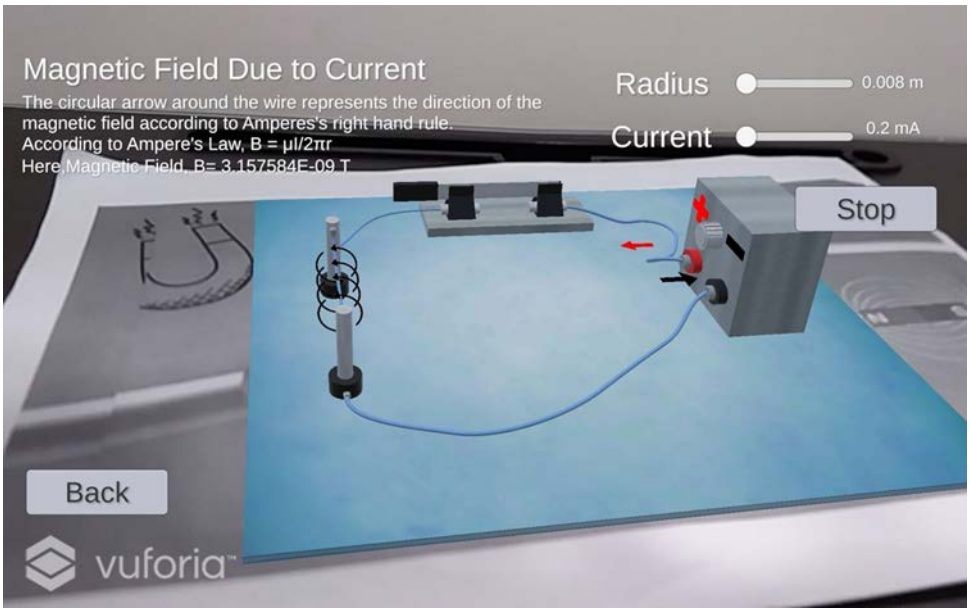

Fig 2: AR application viewing magnetic field around a straight wire

In this current proposal we want to propose a mobile app that can define ten specific physics topics from senior secondary school level physics syllabus with AR. Moreover, five laboratory experiments will also be designed with the AR app, so that students can perform the labs whenever they want wherever they choose, by only using a mobile phone or tablet device. In addition, an AI/ML based tool will be developed, so that students can perform different problem-solving exercise through this tool. This tool will assist the student to practice numerous numbers of physics problems based on their understanding. The difficulty level of the problems will be regulated for developing the critical thinking capabilities of the students. As human minds can only provide a specific number of problems, hence, with this expert system it will be attempted to develop more practicing problems related to the physics topic for the students to solve. Therefore, in order to assist the students, we propose an **AR based mobile app and AI based tool** that can be used as interactive learning platforms.

Conceptual Framework

Although it is not a new technology, the development of the hardware and software made the application of AR and AI easier now. Mobile companies are making their phones compatible with AR applications. All the big companies are moving their footsteps towards the world of AR. The application of this technology is now being used in various sectors, like, gaming, architecture, interior design, medical and education. By using the AR in educational sector, it is possible

to provide the students necessary assistance to examine the areas of confusion by viewing the real phenomena with the help of virtual objects. AR can help the students to learn topics from small chemical bonding to complicated medical surgery. For example, all the science students learn about DC motor in their physics course. In fig.3 (a), a conventional picture of DC motor is provided with the description. But if that picture is defined in 3-D animation with the help of AR as shown in Fig. 3 (b), it will be very useful for the students [2]. Among all the sections of science, physics is one of the complex areas, where a lot of geometrical concepts as well as abstract concepts are taught. Most science classrooms do not have the tools that will assist to introduce the different topics with new methods of teaching which will make them interesting and creative. In general, science textbook illustrates different topics with the help of 2-D images. However, most of the concepts demands the students to imagine the structures of different objects in 3-D spaces. Because of this, the understanding of these kind of topics depends on the imagination accuracy of the students, which stands in the way of proper conceptualization. These 3-D structured topics as well as the abstract topics then becomes one kind of mythical thing. And the key behind the successful grasping of these phenomena becomes reliable on the students' visualization.

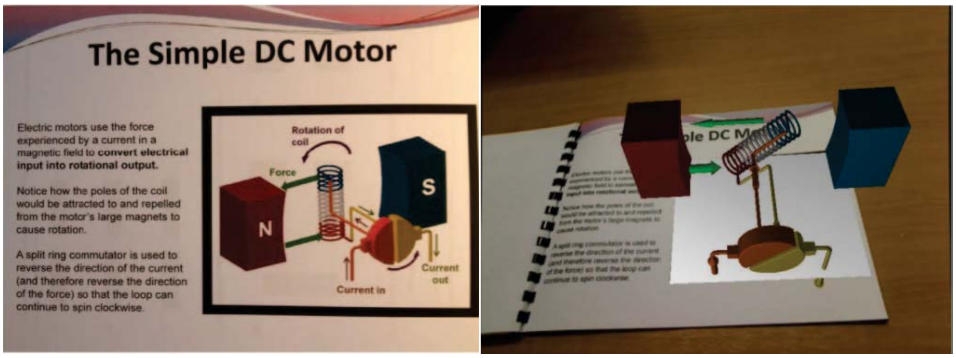

Fig.3 (a) Text and diagram of a simple DC motor; (b) Animated 3D model of the DC motor.

There are lot of AR apps available for different kinds of educational topics but none of those apps are directly focus on the HKDSE Physics syllabus. Moreover, most of the existing apps are only used to represent the topics in 3-D animation. There are none or only a few options that can be used to vary different parameters for determining the actual theory behind the concepts.

For T&L of physics subjects, AR and AI can be a revolutionary assistant. AR combines the real and virtual worlds which gives the users a unique visual experience. In classrooms, AR can play a very effective role to grab the attention of students and act as a useful tool to achieve a more interactive education environment. Studies have been performed to determine the effectiveness of AR in classrooms [3]. Results show that AR enhances the interaction in the classroom between the teachers and the students, and plays a role in student's appreciation of the topics and shows students how to relate the learned theories to real life. AR provides ease in task related study by engaging students to explore the content. It offers advantages over the traditional method of teaching because students get to interact with the animated model of the content. In addition, a smart AI system can help the students in their practice session. After learning the topics by using AR based apps, student can apply them in different problems/questions introduced by our AI system. The difficulty level of the problems will be changed based on the performance of the student.
Therefore, this project will develop the student's learning process in a larger scale. In addition, this app will save time because it minimizes the time needed to learn a new tool, as well as it reduces cost because it does not require additional tools. Users can easily download the app into their mobile phone and this application will give them a useful interactive learning method. This one reason differentiates Virtual Reality (VR) applications with AR applications. VR takes away the users from their environment with the help of external tools which are expensive and harder for practical applications.

Implementation Plan and timeline

For the optimization of the applications scope, everything of this application will be available on a single website, so that the users can visit one place and find all the materials needed to experience the benefits of this application. The users will be able to download the application, target images, user guide, teaching materials etc. from the same website. Video demonstration showing how to use the application will help the users understand the functionality of the application. The users will need to download the application into their mobile devices and print the target images. Then they will be able to view the 3-D animated structures of specific experiments by opening the application, and holding their mobile phone on top of the target images. They will have an interactive experience with the application because the functionality of the application will allow them to change values of different parameters within the scope of the topic. The application will be available for both Android and iOS platform. Based on the described functionalities above, the platform should contain a website which contains all the necessary materials required to use this application. The website

will contain the applications for both Android & iOS, target images, user guide, videos, teaching guide etc. All the STEM project websites completed by Applied Physics Department is hosted under one domain and is maintained from a central system (https://stem-ap.polyu.edu.hk/home_en.html). All the projects completed before are still available for the mass to access. The website of this project will also be hosted under the same domain to elongate the sustainability and this website will be freely accessible to public. Since the website is hosted and maintained by our department, we believe it will be maintained in good conditions even many years after the completion of the project.

Selected topics for this project:

The topics we selected are based on the vision to be able make these concepts visualize with the help of 3D objects and animation. The topics are chosen from both the compulsory part and elective part with the goal to make these representable through animated objects in a mobile device. Ten topics from the theoretical part and 5 topics from laboratory section is selected for this project, our aim is to design the selected theoretical parts enriched in a manner that it also gives the practical experience and to design the laboratory section in a way that it helps in gaining the knowledge & understanding its theory.

Theoretical Sections:

Force and Motion

1. **Uniform Circular Motion:** This will give the students an idea about how object moves around another object in different conditions governed by various parameters. This will be an interactive experience which will be giving them the knowledge of the impact of different factors in the same concept.
2. **Newton's Law of Motion:** This will view objects' behaviors according to the three laws of motion.
    i. First law
    ii. Second Law
    iii. Third law
3. **Gravitation:** This example will show the universal law of gravitation by applying $F=GMm/r^2$ to a virtual object.

Electricity and Magnetism

4. **Electric field**: This example will show the electric field strength around a point charge and different conditions responsible for it.
5. **Series and Parallel circuits**: This will show them the comparison of series and parallel circuit in terms of potential difference across the components of each circuit and the current through them.

Heat and Gases

6. **Boyle's Law:** This will show the inverse relationship in between pressure and volume of gases.

Radioactivity and Nuclear Energy

7. **Atomic Structure:** Atomic structure is one of the key topics where students are shown the images and are required to imagine how the electron stays in their orbits and moves around the nucleus. Most schools do not have microscopes with such ability to show the atoms as these are very expensive. This module of the application will show the students how the atomic structure looks like and what are the positions of electron, proton and neutron in the atom.

Atomic World

8. **Bohr's Atomic model of hydrogen atom:** This will show the structure of the hydrogen atom described by Neil Bohr. This will give the students idea about the structure organization and surroundings of the atom.

Light

9. **Difference between Reflection and Refraction:** It will show how light rays travel and how reflection and refraction take place with the difference in characteristics.

10. **Refractive index:** This will show the direction of light rays through different medium according to their refractive index.

Experimental/Laboratory Sections:

11. Measurement of the specific heat capacity of a liquid using a low voltage immersion heater and a foam cup.

In this experiment the specific heat of a liquid can be measured. Specific heat is the amount of energy required to heat 1kg of substance by 1ºC. Usually, different kinds of liquid can be used to measure the Specific heat based on the formula-

$E = c.m.\Delta\theta$

Where, E is the applied energy (Power × time), c is the specific heat, m is the mass of the substance and $\Delta\theta$ is the temperature difference.

12. Resistance measurement

(a) Measurement of the resistance of a conductor with a voltmeter and an ammeter (Ohm's law).
(b) Change of the resistance of a conductor with its length and cross-sectional area.
(c) Change of the resistance of filament of a lamp with temperature.

13. Circular Motion

Experimental test of $F = \frac{mv^2}{r}$ by whirling a rubber bung

14. Electricity and Magnetism

Study of the factors affecting the strength of an electromagnet.

15. Newton's Law of Motion

Measure the relationship between applied force and acceleration.

Artificial Intelligence (AI)/ Machine Learning (ML) based problem solving tools:

An AI/ML based problem solving tool with a large question bank will be developed for assisting the students in their problem solving practice session. Based on several physics topics such as Newton's Law of Motion, Reflection of light, the problems will be designed. By using this expert system different questions with different difficulty level will be provided to the student for solving. We selected the topics for this question bank from the compulsory section from the HKDSE physics syllabus. Our aim is to cover most of the compulsory part in this question bank. The questions will be of multiple choice question (MCQ), fill in the blanks (FB) or answer in a word. Different type of questions will be given to test the students more thoroughly. We expect to have minimum 30 questions of various levels for each topic in the question bank. The selected topics are:

1. Heat and Gases

a. Temperature, heat and internal energy
b. Transfer Process
c. Change of State
d. Gases

2. Force and Motion

a. Position and Movement
b. Force and Motion
c. Projectile Motion
d. Work, Energy and Power
e. Momentum
f. Uniform Circular Motion
g. Gravitation

3. Wave Motion

a. Nature and Properties of wave
b. Light
c. Sound

4. Electricity and Magnetism

a. Electro statistics

b. Circuits and domestic electricity
c. Electromagnetism

5. Radioactivity and Nuclear Energy

a. Radiation and radioactivity
b. Atomic model
c. Nuclear Energy

Schedule of the project

Phase 1: Develop and assessment of 6 topics and 3 laboratory of the application

Phase 1(a): Designing the graphics and software of the experiments

In the beginning of the project, the prototype of the AR app will be developed. In this phase, graphical part of 6 theory topics and three laboratory manuals will be designed using AutoCAD/ blender. For making the graphical objects interactive to the users, Unity game engine will be used. Meanwhile, the teaching materials will also be prepared. Image targets will be designed to hold the mobile camera for viewing the objects. The application, image targets, user guide and teaching materials of the chosen topics will be uploaded to a website so that all the materials are available in the same place easily.

Phase 1(b): Pilot-run and assessment of prototype setup in partner secondary schools

After the development of the software, supplemented with the corresponding L&T aids, the AR application will be evaluated by the 10 partner schools. During the trial run period, the functionality of the application, the graphical accuracy and the experimental data accuracy will be evaluated. The teaching materials will also be assessed by the students and the teachers. After the test run of this application, students of the partner schools will be invited to take part in survey to give their opinions and comments on the application. Comments concerning (but not limited to) the following technical aspects of the platform will be collected:

- Website access: Ease of access to the system, stability of system, User-friendliness of interface, Ease to download the application to their mobile phones etc.
- Graphics: User-Interface of the application, graphical quality of the objects, functionality of various components, ease of control etc.
- Software: Data accuracy, interaction with the components, performance of the system etc.
- Supplementary L&T materials: Accuracy, clarity of instruction and effectiveness of the teaching materials and user guide.

The collected information and feedback will be used to make modifications and update to the performance and functionalities of the application.

Phase 1(c): Promotion of the AR application and Organizing 1st workshop:

Promotion of the AR application will be conducted through various mediums, with the target audiences being the secondary school students.

- Demonstration sessions will be conducted during the annual Information Days of PolyU in summer, during which the actual setups will be displayed to the visitors.
- Participating secondary schools will provide demonstration sessions of the platform during their school Open Days, with posters featuring the functionalities of the system displayed to enhance the publicity effect.
- Publicity will also be made via the publicity channels of PolyU, Video footages showing the operation of the experiments will be displayed on the department website, as well as the YouTube channel of PolyU.

Phase 2: Implementation of remaining theory and laboratory topics, development of the AI/ML based system and Promotion of the Fully-Developed Platform

Phase 2(a): Implementation of remaining topics and AI/ML based tool and gather feedback from the secondary schools

In this phase, the tool for examining the students will be built. This tool will be designed using AI/ML which will provide unique questions each time for the students to test their conceptual knowledge. The survey's result and students'

feedback will be evaluated as the scope of improvement of the application to make it more desirable to the students. Four remaining theory topics and two experiment will also be developed in this phase. The application made in the first phase will be adjusted according to the requirement and suggestions of the students. Video lessons of the application will also be made for better demonstration. The application for the practise questionnaires will be built in this phase.

Phase 2(b): Organizing the 2nd Workshop :
In this workshop, we will invite more secondary teachers and introduce the application. We will share the impact of the platform on students learning physics. Students will be introduced with the AI tool and surveys will be done for measuring its impact.

Implementation Timeline:

	2021-2022	2022-2023				2023		
Phase 1	Dec-Mar	Mar-June	June-Sept	Sept - Dec	Dec - Mar	Mar - June	June - Sept	Sept - Nov
Design the graphical objects of the 6 topics and 3 experiment & develop the software								
Prepare teaching materials and videos to demonstrate								
Pilot-run of prototype setup in the ten partner secondary school								
Survey of the pilot-run application								
Modification of the application based on the surveys								
Promotion of the application at different occasions								
1st Workshop: Training Workshops on Platform								
Phase 2								
Develop the AI tool with questions								
Design the graphical objects of the other 4 topics and 2 experiment & develop the software								
Prepare teaching materials and videos to demonstrate								
Launching of fully-developed Experiments and AI tools in both partner and participating secondary schools								
Evaluation on the fully developed application								
2nd workshop								
Final Evaluation on the Project & Concluding Report								

Table 1 Project Timeline

Teachers' and Principals' Involvement in the Project

Structure of project team:

Project Leader	
Deputy Project Leader	
Team Members	
Partner Schools	

Budgets

Items breakdown:

Annual Expenses			
	Year 1	**Year 2**	**Cost**
Staff			
Research Associate (x1, 24 months) -design & plan the functionalities of the app with the 3D objects and animation according to the need of a particular physics topic (12 months) -coding and developing the structure of the mobile application, -designing the functionalities of the AI/ML based quiz platform (12 months)	$28,500 x 1 x 12 x 1.05 = $359,100	$28,500 x 12 x 1 x 1.05 = $359,100	$718,200
Research Assistant (Technical) (x 1, 24 months) - making graphical animation, coding for the mobile application, maintenance of system - designing and making the website of the project. (12 months) - Generate questions for the AI/ML question bank according to the DSE syllabus - development of supporting teaching materials (user guide, video etc.) , project evaluation, promotion & co-ordination (12 months)	$17,500 x 12 x 1 x 1.05 = $220,500	$17,500 x 12 x 1 x 1.05 = $220,500	$441,000
		Sub-total	**$1,159,200**

Equipment - Hardware and Computer Software			
Desktop Computer for development	2 x $15,000 =$30,000		$30,000
Mobile Phone	$6,000x10 = $60,000		$60,000
license for development (per year)	$15,000/year	$15,000/year	$30,000
store account fee to upload android application	One-time fee = $200		$200
store fee to upload iOS application	Membership for 1 year =$800	Membership for 1 year =$800	$1,600
for image target recognition	$25,000/year	$25,000/year	$50,000
for graphical designs	$17,000/year	$17,000/year	$34,000
Tools required for AI/ML		$50,000	$50,000
Video editing software	$2400		$2,400
		Sub-total	**$258,200**
Service			
- Recruitment of student helpers for the events (6 workers per workshop, 12 hours per worker)	$60/hr x 3 hr x 6 students x 1 events= $1,080	$60/hr x 3 hr x 6 students x 1 events = $1,080	$2,160
		Sub-total	**$2,160**
General Expenses			
Training workshops (1 per year) and seminar (1 per year)(2 events per year) - Lecture materials reproduction costs (50 sets per activity)	$2,000	$2,000	$4,000
Supplementary teaching materials - purchasing of copyrighted items (images etc.) - editing costs -Server Costs for publishing	$20,000	$20,000	$40,000
Publication and publicity - Posters, pamphlets, banners	$2,500	$6000	$8,500
		Sub-total	**$52,500**
Audit Fee		$15,000	$15,000
		Sub-total	**$15,000**
		Project Total	**$1,487,060**

Asset Usage Plan:

Category	**Item/Description**	**No. of units**	**Total Cost**	**Proposed Plan for Deployment**
Equipment	Desktop Computer for development	2	$30,000	PolyU : the platform will be maintained at PolyU so that secondary schools can continuously assess the platform for teaching purpose
Equipment	Mobile Phone	10	$60,000	PolyU
Software	for development	1	$30,000	PolyU
Software	store account fee to upload android application	1	$200	PolyU
Software	store fee to upload iOS application	1	$1,600	PolyU
Software	for image target recognition	1	$50,000	PolyU
Software	for graphical designs	1	$34,000	PolyU
Software	Tools required for AI/ML	1	$50,000	PolyU
Software	Video editing software	1	$2,400	PolyU

Expected Project Outcomes

At the end of the project duration, the following deliverables are expected:

1. AR application for both iOS and Android platform.
2. Teaching materials for the various experiments which will explain the functionality of the experiment.
3. An AI/ML system which can be used for physics problem solving. This system will provide different questions with new values and scenarios each time so that student can practice the problems and gather more in-depth understanding.
4. A website where the iOS and Android application, target images, user guide and teaching materials will be available.
5. According to the results of the surveys, the effectiveness of this platform on the new DSE Physics syllabus, we might publish educational papers in international journals so that both the local and oversea education community will be benefitted and thus the application will have more recognition as an established work.

These deliverables will be aligned with the intended learning outcome of the experiment platform:

1. To increase the understanding of the abstract concepts of physics with the help of the 3-D animated models of the AR application.
2. To understand the dependency of the parameter related to the topic, with each other and how they interact with each other in different conditions.
3. To increase the critical thinking capability of the students by providing them a numerous number of problems to solve with different difficulty level through an AI/ML based system.
4. To develop an interactive and interesting learning platform to increase self-motivated learning.

Project Evaluation

Methods and Parameters

Several approaches will be applied to examine the level of this project's effectiveness mentioned in this proposal are achieved, also being useful to meet the learning goals of the students.

User-feedback questionnaires

Survey questions will be issued to students and teachers, which will have queries regarding all general and technical aspects of the project for e.g. user interface, user experience, accuracy of the experiments in comparison with real life

theories, design of the experiment, interaction features, experiment result etc. Results of this survey will be analysed and will be used to update the application for better user acceptance and effectiveness.

User Registration and Visit Logs to the Platform
The webpage statistics of the user visit will be monitored regularly to understand the usage of the application, which will eventually describe its effectiveness and impact on students learning method.
Frequency of Visits: the count of the visitor of the webpage and the download count of the application will indicate the popularity of the project. As AR is gaining its popularity worldwide, it is expected to be a useful means of self-learning.

Interviews
Interviews will be arranged for students and teachers using different experiments to cover same topic, which will help to evaluate the upside and downside of certain features.

Expert Reviews
After the development of all the materials of the project, all of the aspects of the project will be checked and evaluated by an independent panel, consisting of colleagues from EMB and physics/engineering/education departments of local tertiary institutions and secondary schools. All the aspects will be checked including user interface, user experience, teaching materials. Based on the expert review, the project can be updated and can be made more useful for the students in their learning process.

Evaluation Plan

Pilot Run Stage	
Aim of Evaluation	To test the interaction of the platform with the users and get the users choice of functionality of the application to maximize its effectiveness.
Methodologies	-Demonstrating the application to the students to collect their opinion on the functional features of the platform -Do surveys of the feedbacks of the students to make the applications quality better -Collect the user traffic on the website to understand the projects usage
Full Development Stage	
Aim of Evaluation	To assure the potential quality of the application in the learning outcomes of the students physics learning
Methodologies	-Survey of the users on the platforms role in their intended outcome of studies -Expert reviews will be collected to determine the applications impact on the learning curve of the students

<u>Dissemination/Promotion of Project Outcomes</u>

The sustainability of the outcome of the project depends on the interactive user functionality of the project.
This platform can be used as a base to develop more applications for other science subjects in secondary school level which will establish the applications usage at the maximum. New experiments design applicable for this platform can be made according to the specific needs of the students. This platform can be an inspiration for other science subjects to develop application based on their requirement. This allows the continual use of the system for educating science students in various sectors.
Some outcome of this project can be used further to commercialize it as teaching materials for secondary school students. This project can help learning specific topics in HKDSE Physics syllabus as supplementary medium.

*The copyright of the deliverables / materials developed should be vested with the QEF.

*The recruitment of staff and the procurement of goods and services is conducted on an open, fair and competitive basis with measures taken to avoid conflict of interests in the procurement process. It will follow the PolyU regulation.

Report Submission Schedule

My organization commits to submit proper 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 01/12/2021 - 31/05/2022	30/06/2022	Interim Financial Report 01/12/2021 - 31/05/2022	30/06/2022
Progress Report 01/06/2022 - 30/11/2022	31/12/2022	Interim Financial Report 01/06/2022 - 30/11/2022	31/12/2022
Progress Report 01/12/2022 - 31/05/2023	30/06/2023	Interim Financial Report 01/12/2022 - 31/05/2023	30/06/2023
Final Report 01/12/2021 - 30/11/2023	29/02/2024	Final Financial Report 01/06/2023 - 30/11/2023	29/02/2024

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