

Part B Project Summary

Project Title: <i>(Please fill in the blank)</i> Laboratory in your pocket - Real-time hand-on experiments on Microcontroller-Smartphone Platform	Project Number 2016/1098 (Revised)
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Name of Organization: Department of Applied Physics, The Hong Kong Polytechnic University

- (1) Goals: Enhance the L&T experience through flipped classroom learning mode in DSE physics by providing access to well-designed Microcontroller –Smartphone based experiment.
 Objectives:
 - (i) To implement a platform that utilizes the microcontroller-smartphone system for extracting data collected by various physical sensors
 - (ii) To devise assignments with guidelines on report writing for DSE physics experiments, utilizing the developed microcontroller-based smartphone as the measurement tool
 - (iii) To assess the impact of introducing project-based learning on students' motivation in physics studies and their understanding in specific physics topics
- (2) Targets: Secondary School, Physics teachers and DSE physics students
 Expected number of beneficiaries: Teachers: 40; Students: 450
- (3) Implementation Plan:
 - (i) Duration: Mar 2018 – Feb 2020
 - (ii) Process / Schedule: Phase 1 Establishment and Pilot Run of Prototype Experiment (Mar 2018 - May 2019); Phase 2 Implementation of Two new Experiments and Promotion of the Fully-Developed Platform (Jun 2019 - Feb 2020)
 - (iii) Collaboration with other parties / partners: 5 target partner schools
- (4) Products:
 - (i) Deliverables/outcomes:
 A central platform for performing microcontroller-smartphone based experiments, with a collection (40 sets) of equipment and the corresponding sensors.
 - (ii) Dissemination of deliverables / outcomes: Short Video
 - (iii) Commercialization potential of deliverables / outcomes:
- (5) Budget:

(a) staff cost: \$149,100; (b) equipment: \$401,980; (c) services: \$51,280; (d) works; (e) general expenses: \$30,042; and (f) contingency: 14,498.
- (6) Evaluation:
 - (i) Performance indicators:
 User-feedback questionnaires; User Registration and Visit Logs to the Platform: Frequency of Visits ; Utilization feedbacks for various experiments; Interviews
 - (ii) Outcome measurements:
 User-feedback questionnaires; User Registration and Visit Logs to the Platform: Frequency of Visits ; Utilization feedbacks for various experiments; Interviews

Project Details

Laboratory in your pocket - Real-time hand-on experiments on Microcontroller-Smartphone Platform

Needs and Applicant's Capability

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

STEM Education Reforms in Hong Kong

In the Policy Address of 2017, Chief Executive stressed the importance of reforming the Education System in Hong Kong. EDB will strive to promote Science, Technology, Engineering and Mathematics (STEM) education. Of course, students must be the focal point of the STEM Education Reform [1]. Among the various priorities in the STEM education reform, fundamental science training is no doubt being the key issue in the reform. Students with high-level science capability, if properly nurtured, will become crucial contributors to the more advanced, knowledge-based and technological society. On this premise, good science education helps achieve betterment of Hong Kong Society.

Without doubt, laboratory teaching is an indispensable part of science education [2]. The processes of making observations, performing systematic and quantitative investigations with meticulous control of the experimental parameters, data collection and analysis, subsequent logical interpretation of results and drawing relevant conclusions, are the skills fundamental to the training of *all* science as well as technology and engineering subjects. Performing experiment also serves to reinforce students' classroom learning experiences. Well-controlled laboratory settings provide students with first-hand experiences to the relevant scientific phenomena and verify their knowledge acquired from textbooks.

Ironically, many of the scientific ideas covered at secondary school levels are taught with only very limited support of the corresponding experiments, for a number of reasons: 1) experiments require many sets of equipment in order for the students to perform the experiments by themselves during the class period, high schools require lots of budget as well as space to maintain the large number of experimental set up; 2) some experiments may pose risks associated with the handling of the apparatus and materials to untrained personnel (students in particular); 3) some involves experimental setups that are highly specialized. Teachers may also lack knowledge and experiences in handling and maintaining such equipment, and they may not even have used such facilities during their undergraduate studies; 4) time is another important issue that obstructs the teachers to arrange enough experiments in their teaching schedule. General speaking, the syllabus of science subjects in high schools is very tight and packed, thus it is very difficult for high school teachers to arrange enough laboratory time for the students to perform experiments during class time.

Faced with these limitations, typical solutions, either to perform slide/video shows of the related experiments or to run computer simulations based on textbook equations and models, are suggested. While such alternative learning and teaching (L&T) approaches provide supplementary information to students about the scientific principles involved, there are pitfalls associated with these techniques: 1) Video/slide demonstration as a learning mean is highly passive in nature. Students are forced to receive information from the videos/slides as they are, without the opportunity to verify and challenge the concepts by performing the laboratory work themselves; 2) For computer simulations, in many cases subtle details are neglected simply because of their irrelevance to the main scientific phenomena under consideration. For example, increasing the separation between the sound source and the receiver naturally leads to a reduction in the detected sound intensity (inverse-square law), irrespective to the presence of interference or diffraction effects. The absence of such features convey a naive message that real-life experiments have simple correspondences between the experimental parameters and the observables discussed, and are free from other potential influences. Including such complexities in simulation, while possible, is cumbersome and it involves a tricky balance between highlighting the specific phenomena and the complexity of the real-world situations. Additionally, as simulations always yield 'perfect results', students are deprived of the opportunities to understand how randomness, imperfections and errors can arise in real experiments. For example, randomness in radioactive decay processes is inevitable and can be systematically analyzed, while systematic errors or instrument noises can be suppressed with proper experimental techniques. The discussion of such 'imperfections' are also of significance for scientific studies. Therefore, **real-time hand-on experiments** are indispensable part of STEM education.

In order to tackle the problem of limited real-time hand-on experiments in high schools, we propose to adopt a centralized depository of selected experiments based on **Microcontroller-smartphone Platform** for improving the physics learning experience of senior secondary students (Microcontroller such as _____). This platform will use the students' smartphones connected onto an _____ system as the measuring tool. Smartphones are different from computers or

notebooks in computer lab because the smartphone is personal technology. Most students have invested a great deal of time learning about the features as well as the limitations of the smartphones. They know how to navigate smartphones well. The other reason to really rethink the smartphone debate is because learning on the smartphone can extend beyond the walls of the school or the confines of a class period. Some people may want to ban smartphones from classrooms, however, we didn't ban pens in our schools because students can pass notes during class. The pencils have also survived even though you could poke someone in the eye. This is a new time in education and with dwindling budgets, so we need to rethink possibilities, stretching every dollar. These mini computers are walking through the school doors each day, let's put them to work.

Most of smartphones embedded several sensors such as light sensor, proximity sensor, magnetometer and accelerometer. These sensors can be used to perform simple physics experiments in education purpose. There are several advantages of using sensors in smartphone comparing to those experiment kits used in school. For example, all those sensors can be controlled by the phone and record data simultaneously. It greatly reduces the complicated connection. It is portable which can perform the experiments without location restriction. Although these experiments based on the built-in sensors have several advantages; however, number and type of sensors in smartphone are limited. Thus, it limits the kinds of experiments that can be performed. For some specific or complicated experiments such as voltage and current sensor in physics experiments, gas sensor and pH meter in biology or chemistry experiments are not presented in most of the smartphones. Fortunately, these specific sensor modules are mostly available in market. Figure 1 shows several common-used sensor modules such as force sensor, motion sensor and humidity sensor. These sensor modules are cheap and easily obtained from market but they are not compactable with most of the smartphones and need an interface in order to be used with the smartphones. Even with those sensors that are compactable with the smartphone, the number of sensors that can simultaneously connect to the smartphone is limited i.e. smartphones usually can connect with one to two external sensors. Thus, in order to perform experiments using more than two sensors, an additional interface system will be required between the smartphones and sensors. Another reason for not connecting the sensors directly to the smartphones is that when the sensors are connected to the smartphone during experiments, the smartphone will be at risk as the signal from the sensors is directly connected to the smartphone without protection. Therefore, it will be better if we can have a interface/data-logger that communicate between the smartphones and sensors, and at the same time allows many sensors to be connected.

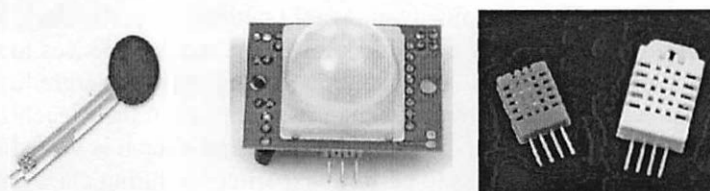


Figure 1) Force sensor, motion sensor and humidity sensor

Among various types of connectors used to communicate between smartphone and sensors, USB is preferred because of its low cost and small size. In our proposal, USB will be used as a universal interface as well as data-logger between sensors and smartphones. Figure 2 shows an Arduino Uno (without and with Bluetooth embedded) which can be used to configure the sensors and received the digital or analog signal from the sensors. General speaking, the sensors will be connected to the Arduino board through USB connectors. Figure 3 shows an alcohol sensor and temperature sensor which have been connected to a USB connector and can be coupled onto an Arduino board easily. With the help of a 3D printer, our team has developed a hosting case which is used as a data logger as well as interface box to collect data from sensors and successfully transmitted the data to smartphone through Bluetooth or Wifi.

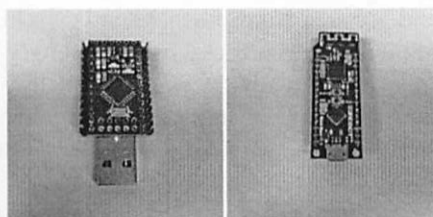


Figure 2) , Arduino board without (left) and with (right) Bluetooth embedded

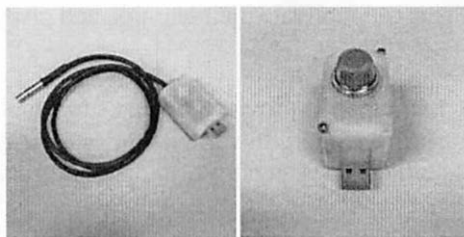


Figure 3) Alcohol sensor and temperature sensor

Figure 4 shows the data logger with six sensor ports. Different sensors can be connected to the hosting case system through USB plug. The system will be powered by portable battery pack. Figure 5 shows the whole setup including the smartphone, a temperature sensor, data logger case and a portable battery pack. The screen on the smartphone shows that signal is collected via the data logger using the Bluetooth technique.

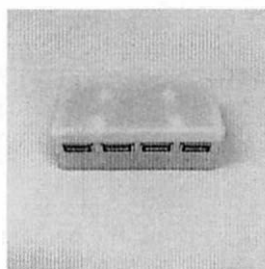


Figure 4) Data logger with six sensor ports

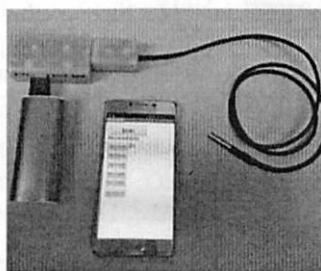


Figure 5) Whole setup include smartphone, temperature sensor, data logger case and portable battery pack

These sensors provide an interesting possibility of performing experiments inside/outside school laboratories, dramatically increasing the potential experiments and even permit project-type experiments in many science subjects, in particular, Physics and Chemistry. By using this **flipped classroom learning** mode based on our proposed platform, we intentionally shift teaching and learning to a learner-centered model in which class time is dedicated to exploring topics in greater depth and creating meaningful learning opportunities for students.

In this proposal, the proposed Eight experiments are either not normally installed in secondary schools or those experiments which are strongly correlated to daily life. The smartphone platform allows students to perform the experiments during lunch time or after school. Indeed, the flexibility of this platform can provide various L&T modes to be adopted as deemed suitable by teachers. For example, teachers can use a particular setup for in-class demonstrations i.e. the teachers select suggested experiments within the curriculum. The platform also provides a channel for conducting group-based investigative studies as well as science projects. We should stress that the latter type of investigations is particularly suited for the Investigative Studies as proposed in the DSE Physics curriculum. Furthermore, this platform allows students to perform experiments and submit their own experimental reports to their teachers. In this case, teachers can use this platform as one of the school-based assignment (SBA) tasks. Currently schools are faced with difficulties in providing sufficient equipment and projects to encourage students to take part in investigative study, and many of them opt for long laboratory reports as an alternative. Furthermore, this platform also encourages inquiry based learning (IBL) among secondary school students. The present platform thus offers a possible solution for schools to handle such a task and to provide students with an exciting learning opportunity. Accompanying the platform are supporting materials that can be used to facilitate various L&T as well as IBL approaches. This platform also provides a scaffold for students to take and analyze a large number of good quality data. In traditional experiment lessons, students can only take a very limited number of data during class experiments (due to limited time and/or limited set of equipment) and try to get the results by analyzing only a few data points. This platform gives students a chance to learn how to analyze many data points and draw a reasonable conclusion based on such analysis. Besides, this platform allows students to repeat the

experiments based on their own requests. This can motivate their learning and give them chance to perform an experiment that up to their own standard.

On the basis of these proposed tasks, this platform will provide an ideal flipped classroom learning experience to senior secondary school students. The well-designed interface with various sensors, assignments, laboratory manuals as well as learning materials will be developed which will be allocated to secondary students. The capability of such learning tools in enhancing the students' learning experience will be investigated.

In summary, the objectives of the current project are:

1. To implement a platform that utilizes the microcontroller-smartphone system for extracting data collected by various physical sensors
2. To devise assignments with guidelines on report writing for DSE physics experiments, utilizing the developed microcontroller-based smartphone as the measurement tool
3. To assess the impact of introducing project-based learning on students' motivation in physics studies and their understanding in specific physics topics

As the ultimate users are DSE students and their science teachers, secondary schools play a crucial role in the sustainable development of the platform. Secondary school partners will be involved in the design and implementation of experiment setups as well as associated teaching materials. They also help us to incorporate such setups in the teaching of related topics.

b) Readiness of the applicant organization for undertaking the project

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Goals and Objectives

The main purpose of this project is to enhance the L&T experience through flipped classroom learning mode in DSE physics by providing access to well-designed microcontroller-smartphone based experiments. It should be stressed that authentic, hands-on laboratory experience cannot, and should not, be replaced by virtual experiments and/or demonstrations; the positive intellectual impact of hands-on experiments, as successfully performed by students, is undeniable. In reality, as mentioned in the first section, many constraints prohibit students from getting access to such hands-on experiments. The microcontroller-smartphone based experiment platform, we believe, is a good solution to the situation. The capability of such learning tool in enhancing the students' learning via this proposed microcontroller-based laboratory platform will be investigated.

Short Term Goals

The immediate goal of the project is to provide selected physics experiments on topics at senior secondary levels through the microcontroller-smartphone based experiments which are intellectually stimulating but generally easily to be performed in daily life environment. Four microcontroller-based experiments are planned in Phase I of the project, covering mechanics in the core DSE curriculum as well as environment and energy in the elective part. Supplementary materials will be prepared to facilitate classroom teaching by teachers and guided experiment sessions performed individually by students. Through the use of such platform, students are expected to grasp a more thorough understanding of the corresponding topics in physics. The degree of how such goals are achieved will be assessed during the project duration. Furthermore, four more microcontroller-smartphone based experiments will be designed and implemented in Phase II of the project. A unique platform for students/teachers to download the experiments or upload the students' reports as well as their own designed microcontroller-smartphone based experiments will be established. The performance of this platform will be tested during the project period. The project effectiveness will be evaluated by the end of the project.

Long Term Goals

The project could evolve into a self-sustained mode and as an exemplary model of efficient utilization of education resources among secondary schools. Based on experience gained in this project, it is expected that microcontroller-smartphone based experiments at various levels could be designed for students in different stages of education, and thus maximizing the functionalities of the platform. Know-hows of developing these microcontroller-smartphone based experiments and attaching them to the platform will be passed on to teachers of participating secondary schools. The platform allows the teachers/students to develop their own interesting microcontroller-smartphone based experiments and upload into our platform to share their whole experiences. The workshops in this project also served to disseminate these skills and ideas to more secondary school teachers. At this stage, AP at PolyU will be playing a supporting role, providing technical consultancy to school teachers when the need arises. With the platform established, individual schools can therefore implement experiments and activities that are deemed suitable for their students, and share their experiences/outputs through the platform. Besides, students' active participation in the construction of the experiment would boost their interests in high-level science learning and engineering design practices.

In summary, the objectives of the current project are:

1. To develop a microcontroller-smartphone based platform with eight experiments covering various topics in DSE Physics that allows extracting the data collected by physical sensors within the smart phones. This platform should include:
 - a. A web-based remote-login system that allows the users to log-in the system and download the information of the microcontroller-smartphone based experiments or uploads their own developed experiments.
 - b. Auxiliary materials or assignments with guidelines accompanying specific experiments, for the perusal of school teachers to use the platform for various teaching activities. These include demonstration videos showing the procedures of the microcontroller-smartphone based experiments, self-contained laboratory manuals for performing experiments at various levels (individual work, group-based learning assignments, investigative-studies type projects or inquiry based learning), teaching notes/instructions concerning the specific microcontroller-smartphone based experiments and potential investigative project suggestions based on the capabilities of the setups.
2. To devise assignments with guidelines on report writing for DSE physics courses, utilizing the developed microcontroller-smartphone based setup as the measurement tool.
3. To assess the impact of introducing project-based learning on students' motivation in physics studies and their understanding in specific physics topics. To evaluate the effectiveness of the platform, as in contrast with other teaching means (virtual reality simulations, displaying of video shows, etc.) generally used for teaching scientific concepts when the access to authentic laboratory setups are hindered.
4. To create engaging and effective inquiry based learning activities in secondary schools based on the uniqueness of this platform. A series of activities will be developed in order to guide students through the platform to scaffold their investigations. Through this platform, students can create their own personally relevant questions and try to answer them.

Targets and expected number of beneficiaries

- Students enrolled in the DSE physics curriculum in participating schools will be the primary group benefited from the project. The total number of students involved is estimated to be **450**, based on the number of participating students (around 45 for each school) in each participating schools (10 schools in total).
- Physics teachers in the participating schools (~20 teachers with 2 teachers per participating school) will be benefited from the provision of teaching materials and the experiment setups for conducting their teaching. They will also acquire the knowledge on the design principles and techniques of building new setups in the platform. Among these 20 teachers, half of them are project team members who will also involve in the design of teaching materials as well as supporting materials. A series of teacher development workshops will be organized subsequent to the completion of the learning activities of each of the two phases. It is expected that a total of two workshops will benefit around 200 school teachers. Therefore, we estimate about 220 teachers will be benefited.
- At the final stage of the project, a booklet and a website will be produced to compile the results of the project. Based on the study of the effectiveness of this platform on the L&T of the DSE students, educational papers will be published in international journals. These tangible deliverables are of benefit to a large number of stakeholders in both the local and oversea education community.

Implementation Plan and Timeline

-smartphone based experiments Platform

In this platform, registered users (students/teachers from the participating schools) can securely login to a server hosted in PolyU, which grants access to the proposed platform which is responsible for the users to download the information of the experiments, teaching materials including the laboratory sheets, background reading as well as supporting materials etc. Demo video is also available for the users to visualize the experiment 'in action'. Through the booking system available in the platform, school teachers can borrow the hardware of the experiments, such as the _____ system and corresponding sensors. In this proposal, we suggest to develop 40 sets of hardware (including the _____ and different types of sensors). In additional, the design as well as the fabrication information can be obtained in the platform for those teachers will want to build their own system in their high schools.

The platform will not be just designed as one-way platform, but also acts as an interactive platform among the users. A forum will be available for the users to share their comments/feedbacks among themselves. In the forum, users can upload any suggested _____-smartphone based experiments for further development/discussion or even their own developed _____-smartphone based experiments into the platform.

Based on the above mentioned concept, the platform should contain the following components:

1. A log-in system which allows registered users to gain access from smart phones and/or computers to the platform hosted at PolyU. The log-in system should possess the following functions:
 - providing necessary security features to ensure access to the system only by registered members;
 - permitting users to download the teaching materials of the experiments for conducting specific experiments;
 - allowing the users to upload their experimental reports to the platform so that their corresponding school teachers can access their reports.
 - providing a booking system for teachers to borrow the developed hardware (_____ and sensors) from the platform.

After logging into the system, background materials as well as a demo video will be provided to make sure that the users/students have enough information on carrying out the experiments. In this system, the users can share their opinions among other users, and this definitely facilitates self-learning among secondary students.

2. 40 sets of experimental setup including the _____-based data logger boxes and various types of sensors are necessary for performing the experiments. For example, one of the main components for mechanics experiment is the accelerometer which is almost a standard component in the smart phone. In this project, we propose to build 40 sets of _____-based data logger boxes which allow school teachers to borrow. In additional, apart from the data logger boxes, 40 set of various sensors including those sensors not commonly available such as PM2.5, UV and pH sensors, will be also available for the high school teachers to borrow for performing experiments.

3. A webpage based platform interfacing the users will be established. To facilitate peer learning among students, a forum will be setup in the platform so that the feedbacks/comments from the users will be shared among themselves.

4. Supplementary L&T materials related to the experiments will be developed. We will design our supporting materials (in English as well as Chinese) based on three approaches that we expect students/teachers would utilize the setups:

- as a class demonstration of relevant phenomena in DSE curriculum;
- as a take-home individual or group assignment; and
- as a setup for conducting Investigative Studies to enhance inquiry based learning (IBL).

5. The following materials will be prepared accordingly to facilitate the teachers when performing the above mentioned tasks:

- Short videos on the procedures of logging into the system and operating the setups. Sample videos showing the user how to perform the experiments will also be prepared, illustrating the physical phenomena expected to be observed from the experiments.
- Background information on the physical phenomena will be provided in dedicated webpage, accessible directly from the experiment site.
- Laboratory worksheets to guide the students through the experiments. Structured questions will be prepared, through which students will practice their skills in making observations, doing analysis and drawing conclusion by performing the tasks sequentially. Separated worksheets will be prepared to cater for group-based experiments, in which students will solve problems of greater complexity through discussions. Instruction sheets for proposed Investigative Studies projects based on the _____-smartphone based setups. Currently, students use long experimental report to fulfill the requirement of the SBA requirement of the DSE Physics curriculum; with the platform, students can design their own investigations or make refinement based on our designed experiments so that teachers can use these investigation studies as their SBA assignments. Brief guidelines and experimental techniques will be provided, as the purpose of providing such instruction sheets is to kick-start the brainstorming process among students in deciding their project objectives and experimental methods.

Choice of Experiments

Experiment 1: Monitoring the Environmental

Environmental issue has been an interesting topic for the new STEM education. Selection of this experiment into the platform will provide students with their own hands-on experience to measure several important parameters in learning environmental protection. Using PM2.5 sensor, UV sensor and pH sensor, students can grasp a general idea of how to measure air quality, UV radiation and rain acidity at location near their school. By integrating a _____ card into the _____ system, students can use the whole setup to monitoring the pollution factor for a long period. This remote-access arduino-smartphone based setup eliminates the potential hazards (such as long exposure time under the sun) to students, and yet allows them to acquire the related experimental techniques and concepts. Furthermore, in this study, more than hundred data points will be collected. This gives students a chance to learn how to analyze a large number of data points and draw a reasonable conclusion based on such analysis.

Experiment 2: Monitoring the growth of a plant.

During the growth of a plant, a lot of factors will affect the growth of the plant. This experiment allows the students understand the effects of various parameters, such as temperature, humidity, amount of O₂ and CO₂ on the growing process of a plant. The remote-access arduino-smartphone based setup eliminates the potential hazards to students as well as long experimental time, and yet allows them to acquire the related experimental techniques and concepts. By integrating a _____ card into the arduino system, we can allow the students to monitoring all the growth parameters of the plants in a long period of time and yet can eliminate the time consuming procedure.[7]

Experiment 3: Magnetism

Magnetism is one of the important topics in HKDSE Physics curriculum. A current carrying wire generates magnetic field which is the basic working principle for electromagnet. The magnetic field strength depends on the various factors, including applied current, structure of the wire-formed (circular loops or solenoid, Number of turns of the coils) and permeability of the medium. The _____-smartphone based experiments platform which integrated both the current source and magnetometer. Students can control the applied current through the platform and investigate the relationship of magnetic field strength of circular coils / solenoid and record the data simultaneously. Different structure of coils / solenoids will be provided and allow students to investigate the magnetic field strength.

Experiment 4: Gas Law

The Gas Law describes the relationship between pressure, volume, the number of atoms or molecules in a gas, and the temperature of a gas. Student can investigate the relationship between pressure, temperature, volume, and the amount of gas occupying an enclosed chamber by the _____-smartphone based experiments platform. Mostly, the measurement required an equilibrium/ steady-state in temperature which is a time consuming procedure. This is a challenging task for teachers/students to finish the experiment in the class with limited time. By integrating a _____ card into the Arduino system,

teachers/students can use the whole setup to monitoring the process of the experiment and have a hundred of data in pressure and temperature.

Schedule of Project

Phase 1: Establishment and Pilot Run of Prototype Experiment

Phase 1a: Adoption of the hardware for prototype experiment

At the start of the project, the server system of the existing PolyU-based experiment platform (developed in the QEF project (2013/0127)) will be adopted and strengthened. Our preliminary version of the microcontroller-smartphone setup will be modified to perform the proposed experiments. Meanwhile, four microcontroller-smartphone based experiments including the hardware and the teaching materials will be developed. The setups are chosen due to their board impact and the lack of such experiments being conducted in secondary schools. At the same time, corresponding L&T materials will be drafted for students' laboratory work and teachers' classroom teaching purposes. As there are two types of school in Hong Kong, namely, Chinese as Medium of Instruction (CMI) and English as Medium of Instruction (EMI), we propose to develop the experiments in bilingual mode, so that both CMI and EMI schools will be facilitated. In addition, help desk service and "Frequent Q&A" section will be provided.

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

Once the experiment setup is established and is supplemented with the corresponding L&T aids, the microcontroller-smartphone based experiment platform will be pilot-run in the five partner secondary schools for evaluation. During the test period, the functionalities of the hardware as well as the teaching materials will be thoroughly tested by students and teachers of the participating schools. At the end of the test period, students and teachers of the five partner schools will be invited to take part in a survey on their opinions about the experiments. Comments concerning (but not limited to) the following technical aspects of the platform will be collected:

- Reservation and login system: Ease of access to the system, stability of system, functionality of multiple user-login features, User-friendliness of interface, etc.
- Hardware: User-friendliness of the microcontroller-smartphone systems; Functioning of various components (stability of microcontroller-smartphone systems, sensor performances, quality of experimental data, Bluetooth communication); ease of control.
- Supplementary L&T materials: Accuracy, clarity and attractiveness of background information and laboratory manual; effectiveness of L&T aids in stimulating self-motivated learning among students; clarity of video of experimental setup.

Phase 1c: Promotion of microcontroller-smartphone based experiments at various occasions and Organizing the 1st Workshop: Knowledge transfer to school principals/teachers

Promotion of the microcontroller-smartphone-based experiments will be conducted via various channels, with the target audiences being secondary school teachers and 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 WeChat channel of PolyU [3].

A teacher development workshop will be organized to introduce our new developed microcontroller-smartphone based experiments to secondary schools in Hong Kong. This workshop also provides a forum for secondary school teachers, principals and educators to interact and share their experience in laboratory teaching. To enhance the long-term sustainability of the project, school principals and teachers will be invited to take part in the design and construction of four new sets of microcontroller-smartphone based experiment not specified in this proposal. Workshop will be organized for teachers and students during summer holidays, detailing the concepts and technical issues in building setups that are compatible with the platform. Interflow sessions will also be held, providing an arena for the schools to share their ideas and challenges faced.

Phase 1d: Launching of Modified Platform (with four experiments) to more secondary schools

After collecting information and feedback from the partner secondary schools for the pilot-run, modifications will be made to improve the experiments' performances and functionalities. From this point onwards, modified setups will be launched sequentially to more secondary schools (with a target of not less than 5 more secondary schools other than the five partner schools).

Although the teaching schedules among schools may vary in details, it is anticipated that there are some similarities in the sequence of coverage in the topics among different schools. The demand for a particular setup may, therefore, be peaked within a short period of a few months but is otherwise seldom used for the rest of the year. To make the best use

of the setups throughout the year, participating schools will be encouraged to design investigative projects based on the experimental setups. Students will be given access to a particular setup and allowed to make simple adaptations to fulfill the needs of their investigations if necessary. This is not expected to be a major problem for other teachers and students, who use the platform mainly for L&T purposes: the investigative studies are generally done once or twice every month for each group. Supporting materials will be provided to schools for brainstorming of project ideas based on the available setups, as discussed previously.

Phase 2: Implementation of Four new Experiments and Promotion of the Fully-Developed Platform

Phase 2a: Implementation of four smartphone experiments with the feedback from secondary schools

It is desirable to have different sets of experiments rolled out one after another. This would allow the accumulation of valuable experiences in constructing and improving the experimental setups. The modular design concept serves to simplify the process of constructing different experiment setups, as they can be built by schools through assembling of various modules with necessary sensors. Complicated electronics for data sensing, encoding and communications are hidden away from the students in black boxes. This would have the effect of encouraging students to take part in the experiment construction process. Afterwards, the newly developed experiments will be launched to all the participating schools for evaluation. Besides school principals and teachers' views in the design and construction of the four new sets of experiment in Phase 1, views from Science Education Section of Curriculum Development Institute, EDB will also be sought to meet the curriculum objectives.

Phase 2b: Evaluating the impact of the platform on L&T experience

Focus group of teachers from the participating schools will be formed. Information on how the experiments affect their teaching and how the experiments perform will be collected. Furthermore, another focus group of students from all the participating schools will also be formed. The evaluation will be shifted and concentrated on how the experiments enhance and enrich the students' learning of DSE science related subjects.

The smartphone based experiments are built on the belief that it is a preferred solution when there are difficulties for students to perform experiments in their school laboratories. The main focus of the evaluation is therefore to compare the smartphone based experiments with other alternative, when the schools are faced with identical constraints. These alternative solutions include the use of multimedia clips featuring specific experiments, as well as computer simulations. Teaching without the use of any additional L&T aids will be considered as control cases.

To assess the effectiveness of the aforementioned L&T methods [4], pretests will be issued to all students to ensure the even distribution of their intellectual capabilities. After the performance of smartphone based experiments, short quizzes will be conducted on students who have been taught on the same topics with different L&T means, and their performances will be (anonymously) assessed. Interview sessions will also be conducted with teachers and students using different modes of teaching to cover the same topic, evaluating the merits and shortfalls of different types of techniques. Such assessments will be done about three months after the experiment setups are launched. The feedbacks obtained will be used for refinement of the setups and the supporting materials.

At the end of the project duration, a panel of independent experts will be formed for conducting a comprehensive evaluation on all the aspects of the project, performing a SWOT analysis on the prospects of the platform. Further elaborations of these evaluation methods will be discussed in the later parts of this proposal.

Phase 2c: Organizing the 2nd Workshop

In this workshop, we will invite more secondary teachers and introduce the platform as well as the smartphone based experiments. We will also share the experiences as well as the impact of the platform on L&T experience in the participating schools.

Implementation Timeline

	Mar 2018 - May 2018	Jun 2018 - Aug 2018	Sep 2018 - Nov 2018	Dec 2018 - Feb 2019	Mar 2019 - May 2019	Jun 2019 - Aug 2019	Sep 2019 - Nov 2019	Dec 2019 - Feb 2020
Phase 1								
Establishing hardware for the four prototype experiments								
Pilot-run of prototype setup in the five partner secondary school								
Assessment of pilot-run setup								

Modification of the four microcontroller-smartphone based experiments								
Promotion of platform at various occasions								
1 st Workshop: Training Workshops on Platform								
Launching of modified experiments to other participating secondary schools								
Full Evaluation on the four Experiments								
Phase 2								
Design and Construction of the four more microcontroller-smartphone based experiments								
Launching of fully-developed Experiments in both partner and participating secondary schools								
Second Full Evaluation on the microcontroller-smartphone based experiments								
2 nd Workshop								
Final Evaluation on the Project & Concluding Report								

Table 1 Project timeline

Expected Deliverables and Outcomes

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

1. A central platform for performing microcontroller-smartphone based experiments, with a collection (40 sets) of equipment and the corresponding sensors. Such setups will be made accessible to registered secondary school teachers and students.
2. Supplementary L&T materials for various experiments. These include background and supporting teaching materials, laboratory manuals, and websites with information relevant to particular experiments for both teachers and students.
3. Skills on the know-hows of constructing similar microcontroller-smartphone based experiments and incorporating them into the platform. Skills and experiences will be accumulated and passed onto teachers and students of participating schools.
4. On the basis of the investigation of the effectiveness of this platform on the new DSE Physics teaching, we might publish educational papers in international journals so that both the local and oversea education community will be benefitted.

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

1. To enhance the understanding of the scientific phenomena through operations of the microcontroller-based experiments.
2. To understand the functions, strengths and limitations of various instruments and experimental setups based on the microcontroller-smartphone system.
3. To develop an interest in self-motivated and independent physical science learning through online project-based investigations.

The copyrights of the deliverables/materials developed shall vest in the QEF. Any reproduction, adaption, distribution, dissemination or making available of the deliverables to the public for commercial purposes is strictly prohibited.

Safety Measurement for Secondary School

As some of experiments may be conducted in laboratory in secondary school, laboratory safety measures will be taken and the "Safety in Science Laboratories", Education Bureau, 2013 will be observed.

http://cd1.edb.hkedcity.net/cd/science/laboratory/safety/SafetyHandbook2013_English.pdf

Evaluation Methods, Parameters and Plans

Methods and Parameters

Several approaches will be employed to examine the extent to which the project objectives prescribed in this proposal are achieved, bearing in mind the experiment platform should also attain the intended student learning outcomes.

User-feedback questionnaires

Questionnaires will be issued to teachers and student users. Survey form for students will cover aspects on the general impression of the platform (visual appeal, user friendliness, content of supporting information). More technical questions will be posed to the teachers, focusing on issues such as the design of experiments, accuracy of information, responses of students towards the -smartphone based experiments. Results extracted from these surveys will be analyzed and their implications on the platforms' effectiveness as L&T means will be determined.

User Registration and Visit Logs to the Platform

The impact and effectiveness of the experiment platform will also be inferred by the webpage statistics extracted regularly (for example once a month) from the server, which are indicators of the performance and popularity of the system:

- *Frequency of Visits*: The **hit-count** for the server of the platform is a 'popularity' indicator of the platform amongst students. As the platform also hosts useful L&T materials related to the experiments, it is expected to be a popular means for enhancing students' learning experience.

- *Utilization feedbacks for various experiments*: For example, the **number of registered users** indicates whether students and/or teachers are interested in the idea of -smartphone based experiments. On the other hand, subsequent **login counts** by users after registration can reveal the appeal of the platform to students (assuming the experiment is of appropriate level and does not require multiple accesses by students to finish one single experiment).

Interviews

Interview sessions will also be conducted with teachers and students using different modes of teaching to cover the same topic, evaluating the merits and shortfalls of different types of techniques.

Expert Reviews

The fully-developed platform, experimental setups and supporting materials will be comprehensively reviewed by an independent panel, consisting of colleagues from EMB and physics/engineering/education departments of local tertiary institutions and secondary schools. Aspects such as the design of the experiment, user experience, supporting L&T material qualities will be thoroughly examined. Special emphasis will be made on the effectiveness of the platform in helping students achieve the intended learning outcomes. During the review process, all the data and information obtained by the aforementioned methods will be evaluated by the panel, based on which a holistic picture about the effectiveness of the platform can be drawn.

Evaluation Plan

<i>Pilot Run Stage</i>	
- Aim of Evaluation	To assess the functioning of the platform and gather user feedback for potential improvement
- Methodologies	<ul style="list-style-type: none">- Meetings with users (teachers and students) to gather opinions on the qualities of deliverables.- Survey forms to students and teachers for feedbacks on the usability and potential implications on intended learning outcomes- Gather information on usage patterns based on site visit and user registration/login records.
<i>Full Development Stage</i>	
- Aim of Evaluation	To fully assess the suitability of the -smartphone based experiments platform in achieving the intended learning outcomes and its impact on students' science learning.

- Methodology	<ul style="list-style-type: none"> - Comprehensive user (teacher/student) survey on the effectiveness of the platform for science teaching/learning, and the extent in which the intended learning outcomes are achieved. - 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.[4] - Gather information on usage patterns based on site visit and user registration/login records. - Expert review panel to adjudicate the performance of the platform.
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Sustainability of the outcomes of the project

The sustainability of the outcomes in this project relies on the continual functioning of the platform as alternative L&T means. Part of the project plan is to disseminate the responsibilities of constructing and hosting new setups to the participating schools. As mentioned previously, the platform allows the establishment of-based experiments for different topics using the system and various sensors. Knowledge transfer through workshops within the project duration allows the know-how of constructing the experiments to be spread among secondary school teachers, who can develop other setups and hence achieves the self-sustained operation of different experiments in individual schools. In a broader sense, the establishment of the prototype platform in this project will also serve as the standard for other interested parties (such as teachers of other science subjects) to follow. New experiment designs suitable for these subjects can be made according to their specific needs, based on the methodology of constructing the platform as laid out in this proposal. This allows the continual use of the system for educating science students in various disciplines.

Budgets

Items breakdown:

	<u>Annual Expenses</u>			
	Year 1	Year 2		Cost
<u>Staffing</u>				
Research Assistant II (Technical) (x3, 24 months) - implementation of hardware part of the platform and new experiment setups - software coding and maintenance of system - development of supporting teaching materials	\$17,500 x 12 x 3 x 1.05 (MPF) = \$661,500	\$661,500		\$1,323,000
Student helpers (x 2, 24 months, max. 20 hours/wk for undergraduates) - assisting the technical staffs of the project	\$60/hr x 20 hr/wk x 35 wks x 2 = \$84,000	\$84,000		\$168,000
			Sub-total	\$1,491,000
<u>Experiment sets (only major components are listed)</u>				
<i>Microcontroller-Smartphone based Experiment kits:</i>	\$5040 (for 8 experiments) x 40 (set) = \$201,600			201,600
<i>Equipment to perform sensors calibration</i>	\$140,000			\$140,000

<u>Hardware and Computer Software</u>				
Server-grade computer	\$10,980			\$10,980
Standalone desktops	\$5,500 x 2 =\$11,000			\$11,000
	\$110 x 40 =\$4,400			\$4,400
Mobile Phone	\$5,000 x 4 =\$20,000			\$20,000
Portable Charger	\$350 x 40 =\$14,000			\$14,000
			Sub-total	\$ 401,980
<u>Teaching/Knowledge transfer activities</u>				
Supplementary teaching materials - purchasing of copyrighted items (images etc.) - editing costs - Publishing costs (web-based materials, multimedia)	\$20,000	\$10,000		\$30,000
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
- Recruitment of student helpers for the events (6 workers per workshop, 12 hours per worker)	\$60/hr x 12 hr x 6 students x 2 events = \$8,640	\$8,640		\$17,280
			Sub-total	\$51,280
<u>General Expenses</u>				
Reference books	\$2,500	\$2,500		\$5,000
Publication and publicity - Posters, pamphlets, banners	\$2,042	\$6,000		\$8,042
Final Report production		\$2,000		\$2,000
Audit Fee		\$15,000		\$15,000
			Sub-total	\$30,042
<u>Contingency</u>				
Contingency				\$14,498
			Sub-total	\$14,498
			Project total	\$1,988,800

Duty of Project Assistants

Project Assistant 1

Main Duties

Build up the microcontroller interface and sensors (hardware related)

Construct and design experiments

Provide technical support for schools

Assist Project leader to monitor the progress of the project

Liaise with secondary school (x2)

Qualification

A higher degree in Science, Engineering or related disciplines

Minimum 2 years of relevant work experience

Solid knowledge in technical aspects of system design and implementation

Experience in developing relevant project an advantage

Good communication, interpersonal and management skills

Good command of both written and spoken English and Chinese

Project Assistant 2

Main Duties

Build up the smartphone application for communicate between the smartphone, microcontroller and sensor

Webpage construction and maintenance

Provide technical support for schools

Liaise with secondary school (x2)

Qualification

A degree in Science, Engineering Computer Science, Computing Engineering or related disciplines

Minimum 2 years of relevant work experience

Knowledge of

At least one year's experience in mobile phone applications and web development

Experience in developing relevant project an advantage

Good communication, interpersonal and management skills

Good command of both written and spoken English and Chinese

Project Assistant 3

Main Duties

Liaise with secondary school (x6)

Assist in developing hardware/software learning packs for the project

Develop the survey and collect feedback from teachers and students.

Analysis the feedback and support the promotion activities

Qualification

A degree in Science, Engineering or related disciplines

A higher degree in Education, Sociology or related disciplines an advantage

Minimum 2 years of relevant work experience

Experience in developing relevant project an advantage

Good communication, interpersonal and management skills

Good command of both written and spoken English and Chinese

Asset Usage Plan:

Category	Item/Description	No. of Units	Total Cost	Proposed Plan for Deployment
Equipment	Microcontroller-based experiments	40	\$201,600	PolyU : the platform will be maintained at PolyU so that secondary schools can continuously access the platform for teaching purpose for free
Equipment	Equipment to perform sensors calibration	1	\$140,000	PolyU
Equipment	Server-grade computer	1	\$10,980	PolyU
Equipment	Standalone desktops	2	\$11,000	PolyU
Equipment		40	\$4,400	PolyU
Equipment	Mobile Phone	4	\$20,000	PolyU
Equipment	Portable Charger	40	\$14,000	PolyU

Report Submission Schedule

My department commits to submit proper reports in strict accordance with the following schedule:

Project Management		Financial Management	
Type of Report and covering period	Report due day	Type of Report and covering period	Report due day
Progress Report 01/03/2018 - 31/08/2018	30/09/2018	Interim Financial Report 01/03/2018 - 31/08/2018	30/09/2018
Progress Report 01/09/2018 - 28/02/2019	31/03/2019	Interim Financial Report 01/09/2018 - 28/02/2019	31/03/2019
Progress Report 01/03/2019 - 31/08/2019	30/09/2019	Interim Financial Report 01/03/2019 - 31/08/2019	30/09/2019
Final Report 01/03/2018 - 29/02/2020	31/5/2020	Final Financial Report 01/09/2018 - 29/02/2020	31/05/2020

References:

- [1] <http://www.policyaddress.gov.hk/2017/eng/index.html>
- [2] Jong, T.D., Linn, M., Zacharia, Z.C., "Physical and Virtual Laboratories in Science and Engineering Education", *Science* vol. 340, Issue 6130 (2013).
- [3] <http://www.youtube.com/user/HongKongPolyU>.
- [4] M. A. Ruiz-Primo, D. Briggs, H. Iverson, R. Talbot, and L. A. Shepard, "Impact of Undergraduate Science Course Innovations on Learning," *Science*, vol. 331, pp. 1269-1270, (2011).

Appendix 1 - Sample teaching materials

