優質教育基金
Quality Education Fund

M:FR/E

Final Report of Project	**Project No. : 2016/1098**

Part A

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

Name of Organization/School: Department of Applied Physics, The Hong Kong Polytechnic University

Project Period: From Mar 2018 *(month/year)* to May 2020 *(month/year)*

Part B

*Please read the **Guidelines to Completion of Final Report of Quality Education Fund Projects** before completing this part of the report.*

Please use separate A4-size sheets to provide an overall report with regard to the following aspects:

1. Attainment of objectives
2. Project impact on learning effectiveness, professional development and school development
3. Cost-effectiveness – a self-evaluation against clear indicators and measures
4. Deliverables and modes of dissemination; responses to dissemination
5. Activity list
6. Difficulties encountered and solutions adopted

Name of Project Leader: ____ _____ Name of Grantee*: _____

Signature: ___ Signature: __ ___

Date: __ Date: ___ _

** Final Report of Project should be submitted via "Electronic Project Management System" (EPMS). Once submitted, these reports are regarded as already endorsed by the supervisor of the school/the head of the organization or the one who signed the Quality Education Fund Agreement for allocation of grant on behalf of the organization.*

This form/guidelines can be downloaded from the QEF webpage at http://qef.org.hk.

Final Report (1 September 2018 – 28 February 2020)

Lab in Your Pocket (LYP) is a project to introduce a platform using smartphones connected onto a micro-controller system (such as) as the measuring tool, to provide more opportunities in gaining experimental experiences in high school level. LYP was launched in September 2018. and his team (the team) implemented the project in various partner school, offered teacher's training and school visits.
Upon the completion of LYP project, main deliverables are LYP mobile apps, 9 sensor modules for eight experiments with comprehensive laboratory manuals and worksheet, as well as a web page !(Department of Applied Physics, 2020). The latest version of mobile app is *LYP version 2.6.2* with more colorful and attractive design is shown in Fig. 1 and eight portable sensors modules are shown in Fig. 2.

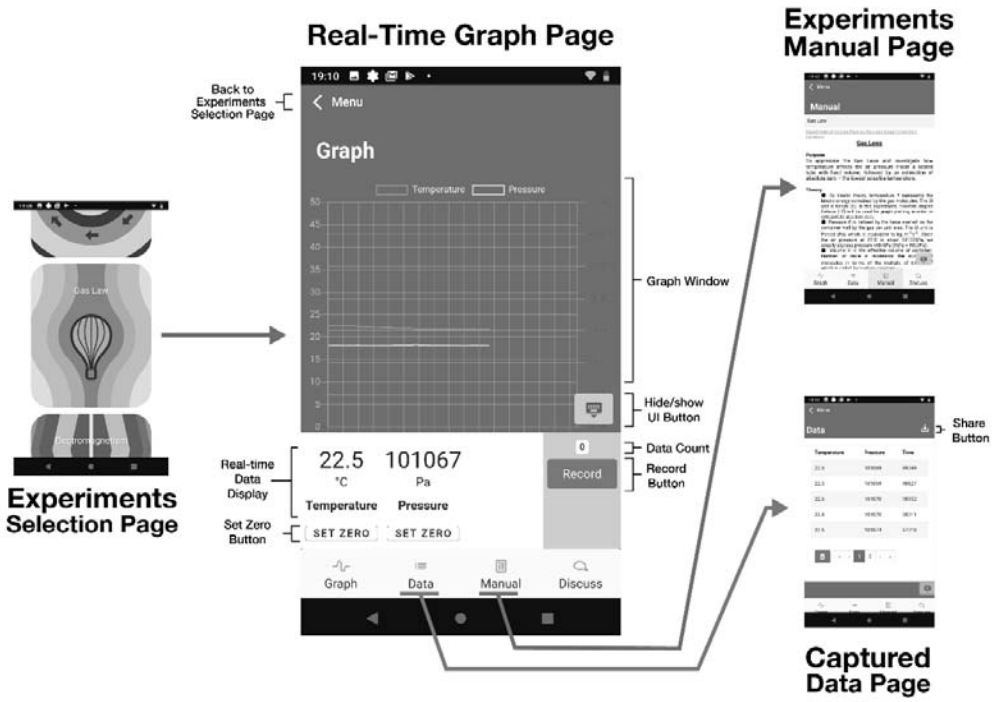
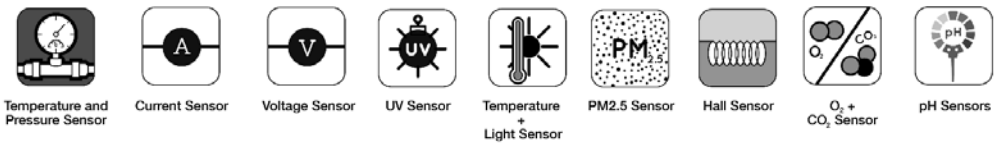


Figure 1. User interface of LYP.



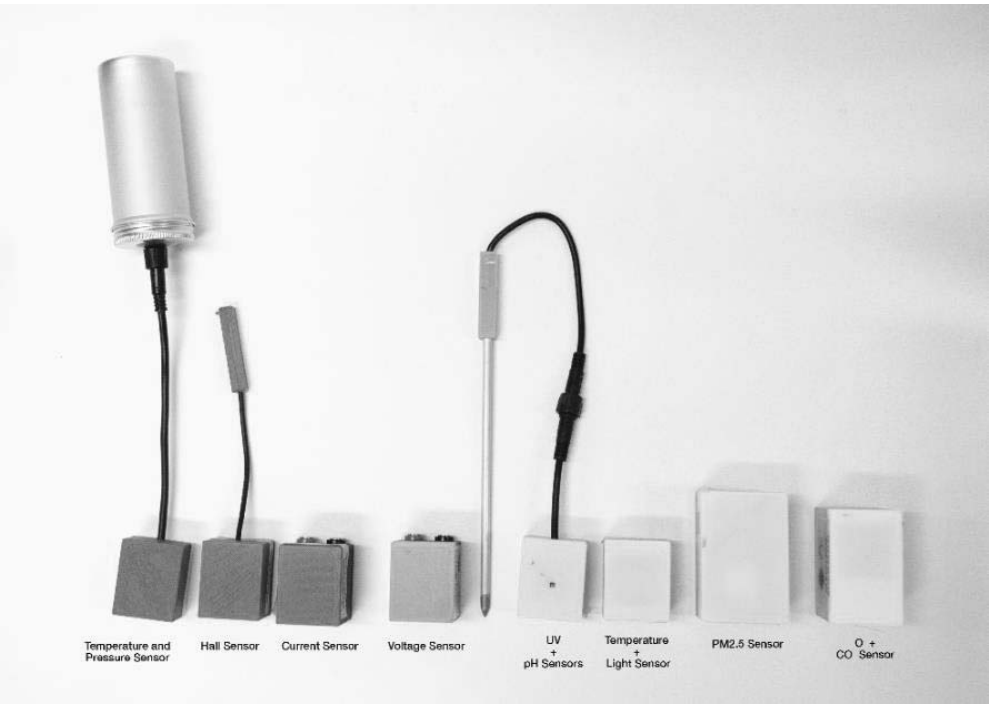


Figure 2. Eight developed sensor modules

Implementation

Invitation was first sent to schools and consent of school and students were obtained. Students conducted experiment with LYP as intervention. Seven partner schools were invited in first pilot with *LYP version 1.0.0* between October and December 2018. During the first semester, 5 schools and 4 schools using the setup of *gas laws* and *magnetic field strength of solenoid* respectively. Approximately 200 students have conducted experiment with LYP.

Second pilot was held between mid of January and August 2019 with LYP *version 1.2.5.r2*. 12 new schools participated in the scheme. 8 schools and 9 schools performed experiment on *gas laws* and measuring *magnetic field strength* using LYP respectively. Also, 4 schools utilized LYP on *environmental experiment*. LYP has reached approximately 400 students.

Between 1 September 2019 – 29 February 2020, 3 schools and 2 schools performed experiment on *gas laws* and measuring *magnetic field strength* using LYP *version 2.6.1*. Also, 1 school utilized LYP on *environmental monitoring* and *ohm's law*. Approximately 150 students were reached. However, the service was stopped in mid-November due to unrest situation in Hong Kong and COVID-19.

Learning Impact

Participants committed around 1 hour in the laboratory session, to conduct an experiment utilizing LYP. Pre-test and post-test of 1) understanding in gas laws and 2) students' motivation towards science learning (SMSL) were administered either on paper or online before and after the laboratory session. User survey was also collected after the session to understand the perspective of students on LYP (See Appendix A).

For gas laws, 119 students (88 Male and 30 Female) aged between 15 and 19 from 6 secondary schools participated in the study. Students improved significantly in their understandings of gas laws in terms of the concept, experimental skills and total of gas laws. Also, self-efficacy in SMSL is improved significantly.

For E&M, 106 students (82 Male and 22 Female) aged between 16 and 19 from 5 secondary schools participated in the study. Only experimental skill improved significantly. Others are most likely the same. Probably, the topic of E&M is more difficult in Physics and cannot be changed in single event easily. However, hands-on experience brings direct effect on understanding in experimental skills.

In short, scientific knowledge have be improved significantly in both experiments. Learning motivation does not, probably motivation is a more stable trait that cannot be changed significantly in one single event. More systematic program and time is needed.

User Experience

Meanwhile, students completed user survey and provided valuable feedback on Learning and Teaching (L&T) materials, learning experience and overall rating (Appendix B). In general, results revealed participants were positive toward LYP. 19 out of 22 items received over 80% positive feedback, i.e., response falling between 3 (Neutral) and 5 (Strongly Agree). The learning tool is user-friendly, portable and easy to connect sensors with the mobile app. Some of them proposed to simplify procedure of installation, such as downloading via Play Store and develop an iOS version.

For learning experience, students were satisfied and expressed that LYP enhanced their understanding in specific topic, raised their interests in physics and conducting experiment. It encouraged them to further study on related topics and helped them to learn new things. Also, teachers have positive feedback and satisfied in our platform, which facilitates them in teaching. They shared their experience in different settings, such as Physics SBA conference !(HKEAA, 2018) or EDB workshops. They appreciate the set-up is precise and accurate, versatile and flexible. Students improved in experimental skills, treatment of data and understanding in specific topic. The setup can be adapted to carry out investigation or SBA experiment.

Last but not least, students cooperated well with other classmates. These results imply that LYP is a good tool to implement cooperative learning that students are responsible for their own learning and interact with each other to complete a task or achieve a goal. Our team look forward to see L&T in secondary school shifts from teacher-oriented to learner-centered model, from standard experiments in the syllabus to performing inquiry-based learning investigations on their interested topics. As a result, L&T will be more fascinating and learning motivation will be enhanced.

Table 1: Attainment of Objectives

In this project, three objectives have been proposed:

1) To implement a platform that utilizes the arduino-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 arduino-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.

Objective statement	Activities related to the objective	Extent of attainment of the objective	Evidence or indicators of having achieved the objective	Reasons for not being able to achieve the objective, if applicable
Objective 1	Activities 1 - 11	Fully achieved	LYP has reached approximately 750 students from 20 schools.	
Objective 2	Activities 1, 2, 3, 4, 5, 6 and 11	Fully achieved	User survey was also collected after the session to understand the perspective of students on LYP (See Appendix A)	
Objective 3	Activities 2, 5 and 8	Fully achieved	User survey was also collected after the session to understand the perspective of students on LYP (See Appendix A)	

Table 2: Budget Checklist

Budget Items *(Based on Schedule II of Agreement)*	**Approved Budget (a)**	**Actual Expense (b)**	**Change [(b)-(a)]/(a) +/- %**
Staff Cost			
Equipment			
Service			
General Expenses			
Contingency			

Table 3: Dissemination Value of Project Deliverables

Item description (e.g. type, title, quantity, etc.)	Evaluation of the quality and dissemination value of the item	Dissemination activities conducted (e.g. mode, date, etc.) and responses	Is it worthwhile and feasible for the item to be widely disseminated by the QEF? If yes, please suggest the mode(s) of dissemination.
LYP mobile apps		Around 750 students from 20 schools	

Nine sensor modules		Around 750 students from 20 schools	
Eight experiments with laboratory manuals and worksheet		Around 750 students from 20 schools	
LYP Website		Around 750 students from 20 schools	

Table 4: Activity List

	Types of activities *(e.g. seminar, performance, etc.)*	**Brief description** *(e.g. date, theme, venue, etc.)*	**No. of participants**				**Feedback from participants**
			schools	teachers	students	others (Please specify)	
1	Seminar	3/11/2018 School-based Assessment (SBA) Annual Conference 2018 by HKEAA		300			
2	School Visit	7/11/2018	1		40		
3	STEM Day	18/12/2018	2		40		
4	Teachers' Training	9/1/2019, 26/6/2019 *Learning and Teaching Strategies Series: Using Mobile Phone Applications and "Microcontroller(Arduino)-Smartphone Platform" for Physics Experiments* by Education Bureau (EDB)		50			
5	School Visit	7/3/2019	1		30		

6	Workshop	10/4/2019 "Train the trainer" by		40			
7	Kick-off Ceremony	12/6/2019 Quality Education Fund Project Kick-off Ceremony at		20			
8	Interview	5/10/2019 By "Heart to class", Radio Television Hong Kong (RTHK)					
9	Conference presentation	9/12/2019 Shortlisted Best Educational App in QS Reimagine Education and showcased in the conference at London					
10	Learning and Teaching Expo	11/12/2019 Hong Kong Convention and Exhibition Centre					
11	Training Workshop	13/1/2020, 20/1/2010 Strategies for Enriching the Learning and Teaching of Physics (S4-6) by EDB		30			

Reference

Department of Applied Physics, H. K. P. U. (2020). Lab in Your Pocket. Retrieved from https://stem-ap.polyu.edu.hk/lyp

HKEAA. (2018). Try out of Pressure Law experiment. Retrieved from http://www.hkeaa.edu.hk/DocLibrary/SBA/HKDSE/PowerPoint-PHY-1118-03.pdf

Appendix A: Learning Effectiveness of LYP on students

To investigate the learning impact of LYP on students, pre- and post-test were administered among students before and after utilizing LYP. The assessment consists of concept and experimental skills. Full marks of gas laws and magnetism are 11 and 12 respectively. 119 and 105 students completed the assessment of gas laws and electro-magnetism. Paired sample *t*-tests were conducted and their result is tabulated below.

Gas laws

Students improved significantly in their understandings of gas laws in terms of the concept ($t(107) = 2.08$, $p = .040$), experimental skills ($t(107) = 4.88$, $p < .001$) and total of gas laws ($t(107) = 4.17$, $p < .001$). On SMSL, only self-efficacy improved significantly ($t(95) = 3.45$, $p = .001$).

Table 1.

Paired Sample t-test Comparing Students' Performance and Learning Motivation before and after using LYP on gas laws

	Pre-test		Post-test		
	M	*SD*	*M*	*SD*	*t*-test
Gas Laws					
1 Concept	2.92	1.70	3.23	1.52	2.08*
2 Experimental Skills	2.98	1.58	3.72	1.50	4.88**
Total	5.90	2.93	6.95	2.56	4.17**
SMSL					
A Self Efficacy	20.74	7.65	23.35	4.35	3.45*
B Active Learning Strategies	30.47	4.11	30.27	4.32	-0.37
C Science Learning Value	19.49	2.82	18.91	3.34	-1.70
D Performance Goal	12.72	3.26	12.78	3.53	0.15
E Achievement Goal	19.44	2.94	18.95	3.28	-1.10
F Learning Environment Stimulation	21.35	3.40	21.30	3.90	-0.12
Total	124.21	14.73	125.56	14.18	0.71

*$p < .05$ **$p < .001$

Electro-magnetism

Students improved significantly in experimental skills ($t(98) = 2.40$, $p = .018$). Other parts of scientific knowledge and SMSL are not improved significantly, they are most likely the same.

Table 2.

Paired Sample t-test Comparing Students' Performance and Learning Motivation before and after using LYP on electro-magnetism

	Pre-test		Post-test		
	M	*SD*	*M*	*SD*	*t*-test
Electromagnetism					
1 Concept	3.10	1.63	3.13	1.87	0.19

2 Experimental Skills	2.95	1.51	3.33	1.52	2.40*
Total	6.05	2.69	6.46	3.01	1.70
SMSL					
A Self Efficacy	24.72	4.95	24.81	5.14	0.22
B Active Learning Strategies	30.78	5.62	30.98	4.85	0.41
C Science Learning Value	19.94	3.84	19.35	3.50	-1.54
D Performance Goal	12.99	3.42	12.83	3.39	-0.49
E Achievement Goal	19.56	4.58	19.43	3.51	-0.27
F Learning Environment Stimulation	21.84	3.83	22.06	3.97	0.54
Total	129.83	15.36	129.45	16.77	-0.25

*$p < .05$

Appendix B: Students' Evaluation on LYP

Across the whole project, 199 students (152 Male and 47 Female) aged between 15 and 19 from 9 secondary schools completed user survey and provided valuable feedback. In general, results revealed participants were positive. 19 out of 22 items received over 80% positive feedback, i.e., response falling between 3 (Neutral) and 5 (Strongly Agree).

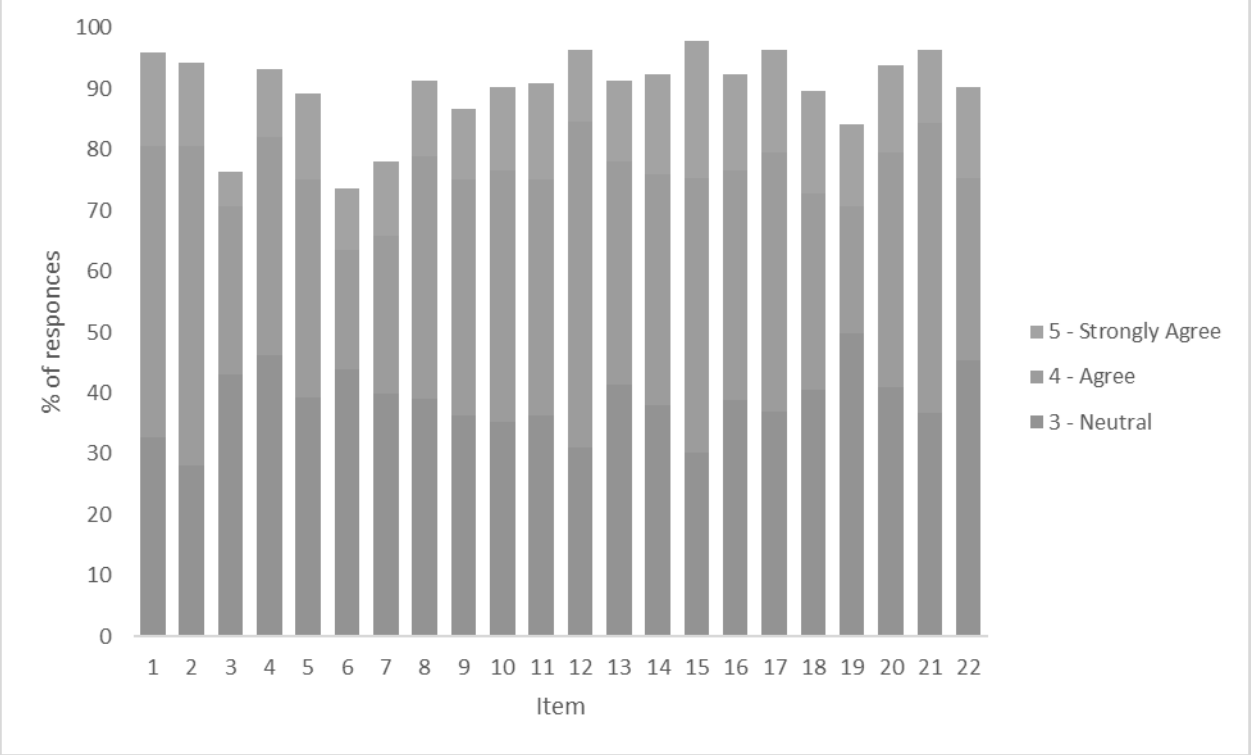


Figure 1. User Evaluation on LYP

As demonstrated in Table 2, students' feedback on Learning and Teaching (L&T) materials were positive. About 65% of students agreed and strongly agreed the experiment procedure and theory were comprehensive to follow and understand. 50% students agreed and strongly agreed the app was comprehensive to use, the interface was easy to read. More than 50% appreciated the sensors were in well condition and easy to connect. However, 21-25% students thought the LYP app was complicated to install and unstable to conduct experiment.

Throughout the experimental activity, more than 50% students agreed and highly agreed that they received enough support and satisfied in current learning experience. Students reflected the experiment have helped them to understand the specific topic (65%), and helped them to learn new things (59%). About 50% students' interest in physics and conducting experiment were enhanced and most importantly, students have cooperated well with other classmates (67%).

Table 2. *Students' feedback on Learning and Teaching Material*

Items	Strongly	Agree	Neutral	Disagree	Strongly

	Agree (%)	(%)	(%)	(%)	Disagree (%)
I. Learning and Teaching Material					
Lab Manual					
1. The experiment procedure was comprehensive to follow.	15.31	47.96	32.65	3.57	0.51
2. The theory behind was comprehensive to understand.	13.78	52.55	28.06	5.10	0.51
3. The questions in the laboratory manual were complicated to answer. *	5.64	27.69	43.08	18.97	4.62
4. The questions in the laboratory manual encouraged me to think.	11.28	35.90	46.15	6.67	0.00
LYP app and equipment LYP					
5. The LYP app was comprehensive to use.	14.29	35.71	39.29	7.65	3.06
6. The installation of LYP app was complicated.*	10.31	19.59	43.81	19.59	6.70
7. LYP app was stable to conduct experiment.	12.24	26.02	39.80	18.37	3.57
8. The readability of LYP app was good.	12.31	40.00	38.97	6.15	2.05
9. Sensors were in well condition.	11.73	38.78	36.22	11.22	2.04
10. Sensors were easy to connect.	13.78	41.33	35.20	6.12	3.57
11. Time is enough to conduct the experiment.	15.82	38.78	36.22	8.67	0.51
II. Learning Experience					
12. The experiment helped me to understand the topic.	11.73	53.57	31.12	3.06	0.51
13. The experiment raised my interest in physics.	13.27	36.73	41.33	8.16	0.51
14. The experiment raised my interest in conducting experiment.	16.41	37.95	37.95	7.69	0.00
15. I cooperated well with other classmates.	22.56	45.13	30.26	2.05	0.00
16. The experiment encouraged me to study on related topics.	15.82	37.76	38.78	7.65	0.00
17. The experiment helped me to learn new things.	16.92	42.56	36.92	3.59	0.00
III. Overall Rating					
18. This experiment was innovative.	16.92	32.31	40.51	8.21	2.05
19. I become more creative after conducting this experiment.	13.33	21.03	49.74	14.87	1.03
20. I was satisfied in this learning experience.	14.36	38.46	41.03	3.59	2.56
21. I was able to receive support for this experiment.	11.92	47.67	36.79	2.59	1.04
22. I would recommend this activity to other.	14.95	29.90	45.36	7.73	2.06

Based on the students' answers to open-ended questions on comment and suggestions, the main themes were

extracted. The main strengths and benefits were user friendly that students can easily operate anytime/anywhere, good learning and teaching experience in enhancing physics knowledge and having good teamwork, LYP is advanced and creative. Major weaknesses include unattractive user interface, complicated installation and poor connection between sensor and the app. Lastly, students suggested other experiments to be conducted with LYP mainly under the topic of mechanics, electromagnetism and optics.