

# Improving Students' Self-Regulated Learning Abilities, Learning Performance and Science Process Skills Through a Modified Flipped Classroom with the Use of a Technology-Enhanced Predict-Observe-Explain Strategy



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# Introduction - Background of research

1. Problems of Teaching and Learning Science in Hong Kong Secondary Schools
  - **spoon-feeding** to drill for examination (Yuen, 2017)
  - **insufficient teaching time** (Cheng, So, & Cheung, 2000; Cheung, 2007)
2. The Strategy of Using Information Technology in Education
  - **strengthening students' self-directed learning** (EDB, 2014)
  - exemplify and promote the use of **Flipped Classroom (FC)** (EDB, 2014; 2020)
3. Science Education in Hong Kong
  - **knowledge of science** and **science process skills** → science literacy (CDC, 2017a; 2017b)
  - develop students to become **self-directed** lifelong **learners** (CDC, 2017a)
  - promote the use of **Flipped Classroom (FC)** (CDC, 2017a)

# Introduction - Background of research

Is flipped classroom (FC) approach effective for science education?



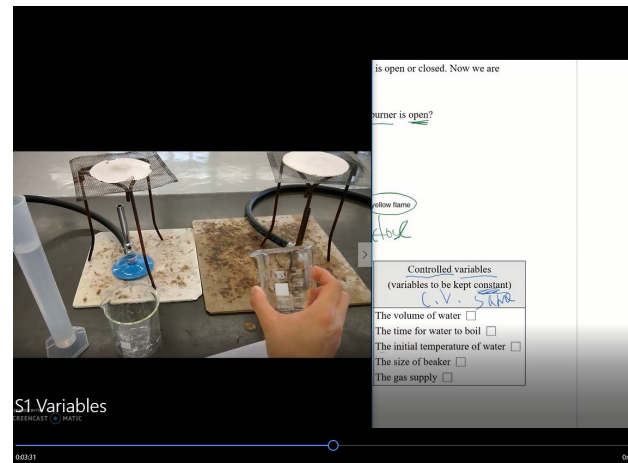
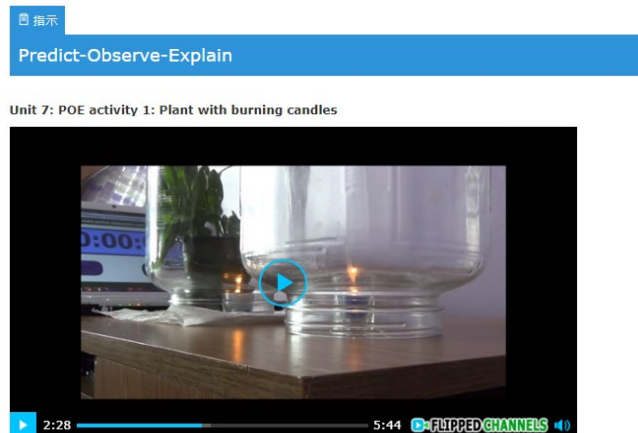
2019-DSE-BIO-1A  
11. Solution of different concentrations of a solute with a small molecular size were prepared and some plant cells were immersed in each of the solutions. Which of the following graphs shows the initial rate of uptake of the solute by means of diffusion? (Note: X is the concentration of the solute inside the plant cells)

Initial rate of uptake

Concentration of the external solution

BIO HKDSE 2019 Paper 1A Q11  
1,503 views · Dec 11, 2019

KYC Science  
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# Research Gap

- Lack of research on the impacts of FC in Hong Kong secondary science education
- Lack of research on the impact of promoting students' **science process skills (SPS)** / **self-regulated learning (SRL) ability** through FC in secondary science education
- **Contradictive findings:**
  - Significant effect (e.g., Çetinkaya, 2017; Lo et al., 2018)
  - No significant effect (e.g., Jensen, Kummer, & Godoy, 2015; Kirvan, Rakes, & Zamora, 2015)
  - **Different levels of achievers perform differently** (Nouri, 2016) / **similarly** (Stratton et al., 2019)

# Research Questions

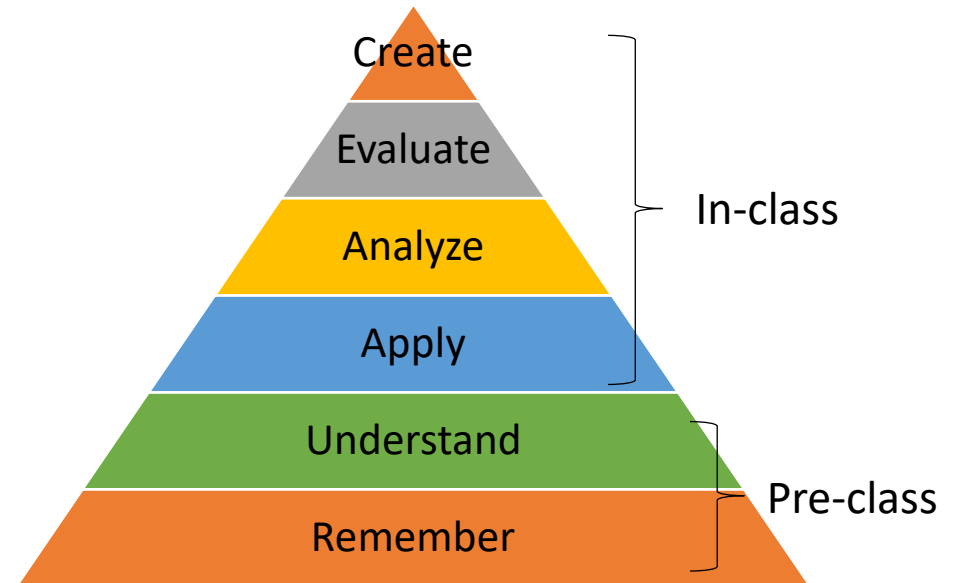
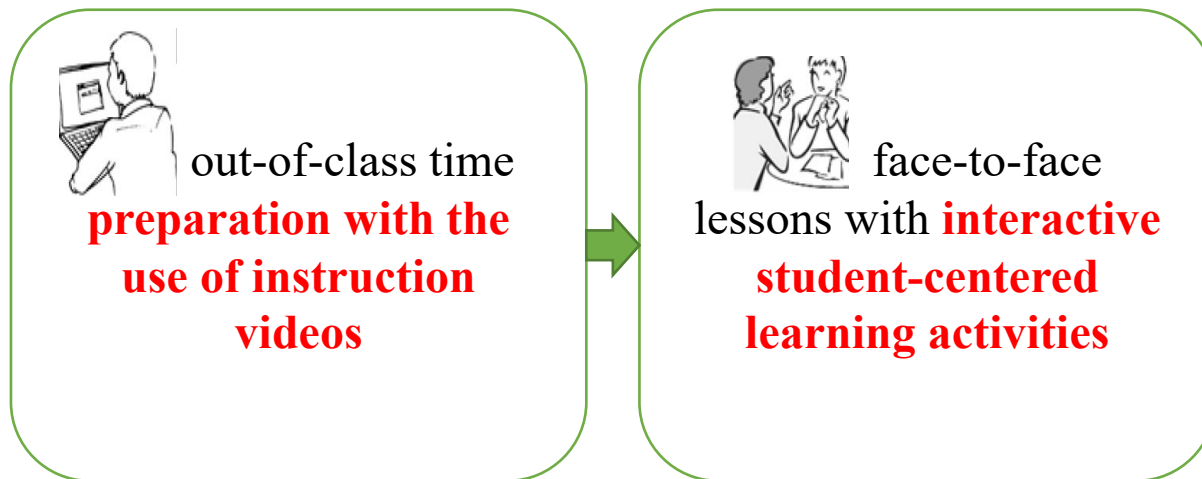
- RQ1: **Can the FPOE improve students' Self-regulated learning (SRL) abilities, Learning achievement (LA), and Science Process Skills (SPS) in comparison with the TFC?**
- RQ2: **Do student learning abilities (lower and higher) affect the improvements of their SRL abilities, LA, and SPS in different flipped pedagogical approaches (FPOE and TFC)?**
- RQ3: **How and to what extent do the FPOE and TFC help students with different learning abilities to improve their SRL abilities, LA, and SPS?**

QUAN

Qual

# 1. Definition of Flipped Classroom (FC)

- **Pre-recorded lectures at home** and are involved in learning **activities at school** (Bergmann & Sams, 2012)
- FC requires (a) the **use of instructional videos** to teach knowledge content in out-of-class time; and (b) **interactive student-centered learning activities** in face-to-face lessons (Bishop & Verleger, 2013)



# 2. A Scoping Review of Flipped Classrooms in K-12 Science Education

*Jl. of Computers in Mathematics and Science Teaching (2021) 40(1), 65-97*

**A Scoping Review of Flipped Classrooms in K-12 Science Education: Implications and Recommendations for Future Research and Practice**

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The flipped classroom pedagogy has gained prominence in various educational contexts by reorganising the lectures of content knowledge via instructional videos, and squeezing in more time for class activities. Although there have been numerous studies of the design, implementation, and evaluation of the flipped approach, their outcomes varied in different disciplines. A pioneering scoping review was conducted to examine and illustrate existing research in K-12 science education. This study identified 358 peer-reviewed articles 15 of which were selected for analysis using a rigorously established five-stage scoping framework. The results indicated an overall positive impact from flipped classrooms, on motivation, engagement, and attitude, but there were mixed findings regarding academic performance. As in other flipped learning reviews, several student-related, faculty-related, and operation-related challenges were also identified in K-12 science education. To explore the current research gaps for flipping science classes, the identified studies were further analysed using a refined Spector's six pillars, and the synergetic incorporation of self-regulated and technology-enhanced predict-observe-explain (POE) strategies into flipped classrooms in K-12 science education was proposed.

- The search terms identified **358 peer-reviewed articles** as of February 14, 2020, **15 articles** were scoped
- Findings:
  - Lack of research measuring **SPS** ( $n=1$ ) and **SRL ability** ( $n=0$ )
  - Lack of research investigating the effect of **learning abilities** ( $n=1$ )
  - Lack of **grounding of frameworks** for the FC
  - Intervention from **2 weeks to 4 months** (possibility of novelty effect)
  - **Contradictive findings** on the impacts of **LA**
  - Some studies are lacking **valid controls**

**Keywords:** flipped classroom, scoping review, K-12, science education, technology-enhanced learning

# 3. Learning Activities of the Modified Flipped Classroom

- Predict-Observe-Explain (POE) pedagogical approach (White & Gunstone 1992):

**predict** the results of certain science events or scenarios to probe understanding of scientific phenomena

**observe** and describe the scientific processes to see if their predictions and observations are contradicting

**explain** and reconcile such conflicts to clarify so that students' misconceptions

- Empirical findings on the **benefits of POE** in Science Education:
  - Improve the learning of science concept by **clarify misconception** in Biology (Cinici & Demir, 2013; Güngör & Özkan, 2016; Wu & Tsai, 2005)
  - Improve **understanding the titration concepts and principles** in Chemistry (Smith, Edionwe & Michel (2010)
  - Enhanced the **reasoning skills** in Physics (Chang et al., 2013)
  - Improve **student SPS, e.g., making predictions, observations** in computer-based POE (Kearney, 2004)
  - Improve student **learning performance** in Chemistry inquiry-based learning (Lati, Supasorn & Promarak, 2012)

# Methodology

- Research Context


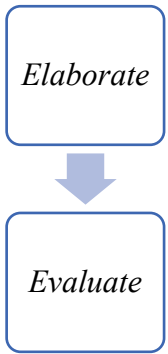
- Background of Participants

- 187 Form 2 (Grade 8) students, aged 13–14, from a Hong Kong secondary school
    - Top-band and middle-band students
    - 95 male 92 female
    - Students were assigned into classes with higher / lower learning ability by the school based on their previous academic achievement in all subjects

Group	Pedagogy	Class	Learning ability	Teacher	N (male: female)	Year	Sig. (two-tailed)
Experimental (n =63)	FPOE	2A	Higher	Researcher	32 (15:17)	2018–2019	.00
		2C	Lower	Teacher A	31 (14: 17)		
Control (n =61)	TFC	2B	Higher	Teacher B	31 (18:13)	2018–2019	.00
		2D	Lower	Researcher	30 (16:14)		

← t-tests

Significant difference

	<b>FPOE (2018–2019)</b>	<b>TFC (2018–2019)</b>
Modified 5E framework (Lo, 2018)	Activities	Activities
<b><i>Pre-class activities</i></b>		
	<ol style="list-style-type: none"> <li>1. Carry out POE activities with videos and real-time experiments using mobile loggers</li> <li>2. Clarify misconceptions</li> <li>3. Watch videos</li> <li>4. Quizzes on videos with instant feedback</li> </ol>	<ol style="list-style-type: none"> <li>1. Watch videos</li> <li>2. Quizzes on videos with instant feedback</li> </ol>
<b><i>In-class activities</i></b>		
	<ol style="list-style-type: none"> <li>1. Short briefing about pre-class activities</li> <li>2. Mini lecture</li> <li>3. Collaborative scientific inquires</li> </ol>	<ol style="list-style-type: none"> <li>1. Short briefing about pre-class activities</li> <li>2. Mini lecture</li> <li>3. Traditional POE activities</li> <li>4. Collaborative scientific inquires</li> </ol>
<b><i>After-class activities</i></b>		
Homework assessment related to the in-class scientific inquiries		

# Methodology

- Research Context

- Pre-class activities for **FPOE and TFC**: Instructional videos and quizzes

The screenshot displays the PowerLesson 2 interface. On the left, a sidebar shows the course structure for Unit 9.1 Common acids and alkalis, including PowerPoint 9.1 and Experimental videos. The main content area features a video player with a cartoon character and a speech bubble explaining common alkalis: sodium hydroxide (氫氧化鈉), ammonia solution (氨溶液), and calcium hydroxide (limewater) (氫氧化鈣 (石灰水)). Below the video, a text prompt asks the user to watch the video and answer questions. Three multiple-choice questions are listed, followed by a 'T or F' question. On the right, a statistics panel shows the results for five questions, including the number of attempts, statistics, and percentage for each answer choice.

Unit 9.1 Common acids an...  
125  
Pre In Post  
Period: 2019-02-23 to 2019-03-23  
Unit 9.1 Common acids and alkalis  
PowerPoint 9.1  
Experimental videos

PowerLesson 2

9.1 Common acids and alkalis  
Watch later Share  
The alkalis commonly used including sodium hydroxide (氫氧化鈉), ammonia solution (氨溶液) and calcium hydroxide (limewater) (氫氧化鈣 (石灰水)).  
2:23 / 5:21  
YouTube

Text & graphics  
Watch the Flipped classroom video and then answer the following questions.

1. Which of the following contains alkalis?  
A. Body lotion B. Kitchen cleaner C. Spinach D. Tea
2. Which of the following is NOT the property of acids?  
A. Acids have a sour taste. B. Acidic solutions can conduct electricity.  
C. Acids have a slippery feel. D. Acids react with alkalis.
3. Both acids and alkalis can be used to remove stains.  
T or F

Question	Answer	No. of attempts	Statistics	%
1	A	35		32
	B	45		42
	C	12		11
	D	16		15
2	A	19		18
	B	30		28
	C	48		44
	D	11		10
3	T	65		60
	F	43		40
4	T	67		62
	F	41		38
5	A	18		17
	B	28		26

Start lesson

# Methodology

- Research Context
  - Pre-class activities for **FPOE**: **POE activities using videos**


PowerLesson 2

Unit 7 Predict-Observe-Explain Activity 1:A pot of plant with burning candle

指示 Predict-Observe-Explain

**Predict**

Unit 7: POE activity 1: Plant with burning candles



2:13 5:44 FLIPPED CHANNELS

1 2 3 4 5 6

顯示答案 顯示統計

問題 1 (短答題)

**Predict:**  
Watch the video about gas jar A (A pot of plant with a burning candle) and gas jar B (a burning candle).  
Make a prediction and describe what will happen to the burning candles in the two gas jars A and B after several minutes.

Unit 7 Predict-Observe-Explain Activity 1:A pot of plant with burning candle

指示 Predict-Observe-Explain

**Observe**

Unit 7: POE activity 1: Plant with burning candles



2:28 5:44 FLIPPED CHANNELS

1 2 3 4 5 6

參考資料


**Observe:**  
Make observation carefully.

Unit 7 Predict-Observe-Explain Activity 1:A pot of plant with burning candle

指示 Predict-Observe-Explain

**Explain**

Unit 7: POE activity 1: Plant with burning candles



4:38 5:44 FLIPPED CHANNELS

1 2 3 4 5 6

顯示答案 顯示統計

問題 2 (短答題)

**Explain:**  
Explain what your observation on the burning candles in gas jars A and B.

問題 1 (短答題) 分數: 1 0%

**Predict:**  
 Watch the video about **gas jar A (A pot of plant with a burning candle)** and **gas jar B (a burning candle)**.  
 Make a prediction and describe what will happen to the burning candles in the two gas jars A and B after several minutes.

Burning candle in gas jar B will go out first.

作答總數: 27 ☰ 👤

學生	答案	分數
2A - 1	陳朗曦 the candle in jar B will burn out faster than the candle in gas jar A	0
2A - 2	陳泳嘉 gas jar A candle will keep bright and gas jar B candle will Extinguished.	0
2A - 3	陳睿孜 After a few minutes, A's candle in the can will burn longer in the candle in the B tank.	0
2A - 6	張智深 one will go out and one will burn	0
2A - 7	張栢明 the burning candle in gas jar B will glow	0
2A - 8	張茵棋 fire burns out	0
2A - 9	莊萬婷 a candle in a closed goes out. a candle with a plant stays alight.	0
2A - 10	鍾嘉豪 jar A will be burn more brightly. Jar B will be goes out.	0
2A - 11	范成孝 the candle in jar B will goes out faster	0
2A - 12	傅雅雯 They are still lighting up	0

問題 2 (短答題) 分數: 1 0%

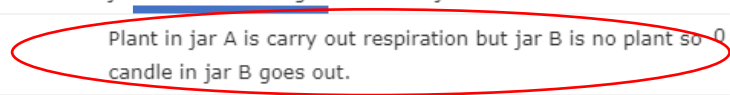
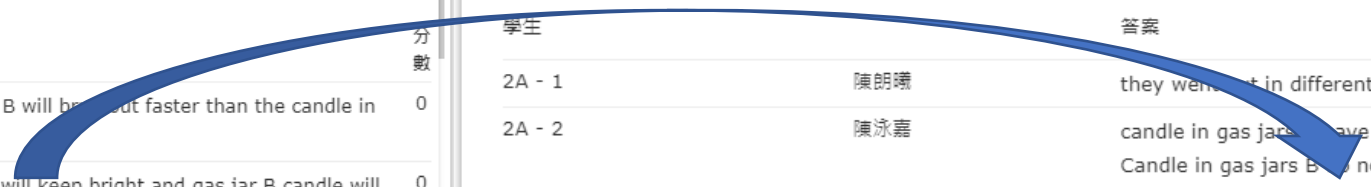
**Explain:**  
 Explain what your observation on the burning candles in gas jars A and B.

In A, the plant gives out oxygen in photosynthesis. So there is more oxygen in gas jar A to support the candle to burn for a longer time.

Most students are weak in explaining in a scientific way!

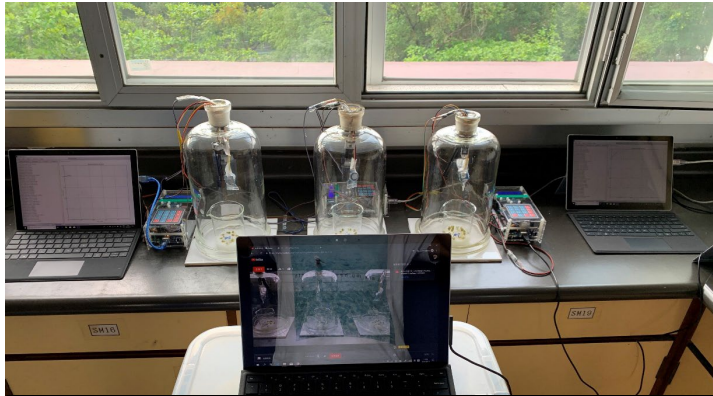
作答總數: 27 ☰ 👤

學生	答案	分數
2A - 1	陳朗曦 they went out in different times	0
2A - 2	陳泳嘉 candle in gas jars have oxygen . Candle in gas jars B not have oxygen.	0
2A - 3	陳睿孜 <u>The last two will be extinguished</u>	0
2A - 6	張智深 one goes out and one burn	0
2A - 7	張栢明 the burning candle in gas jar A is still burning but the burning candle in gas jar B glows	0
2A - 8	張茵棋 have oxygen	0
2A - 9	莊萬婷 <u>jar a candle melting slower than jar b candle</u>	0
2A - 10	鍾嘉豪 Plant in jar A is carry out respiration but jar B is no plant so candle in jar B goes out.	0
2A - 11	范成孝 because a fire need more oxygen	0
2A - 12	傅雅雯 The candle in jar b <u>Light out.</u>	0
2A - 13	馮志毅 the burning candle in jar a and b goes out in different time	0

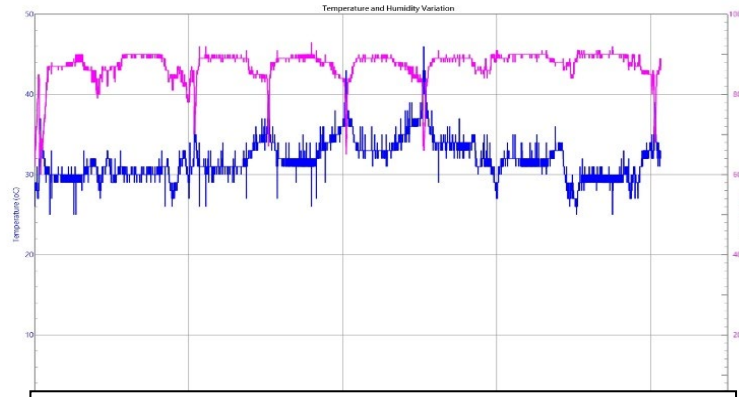


# Methodology

- Research Context
  - Pre-class activities for **FPOE** only: **POE** activities using **real-time investigations using mobile loggers**



setup of the mobile data logger



automatic graph-plotting function



*images of the growth of seedlings during student observations*



# Methodology

- Pre-class activities for **FPOE only**: **POE activities using real-time investigations using mobile loggers**

**Predict**

Teacher's comment (Enter comment)

**Observe**

SESlogger (PC)

File Edit Action Function Graph to Plot

Search BT devices Bluetooth available Select a type of data to log

```
#You are now connected to MLGKY09@CC
2019-04-25 15:20:24.299
#Command@15:22:05.050>Auto Measure
15:22:05.068>#Enable Multisensors
15:22:06.782>T=32.2oC H= 74.6%
15:22:10.640>T=32.1oC H= 74.6%
15:22:16.841>T=32.1oC H= 74.5%
15:22:24.771>L= 1879 lx Light Intensity
15:22:29.638>L= 1892 lx Light Intensity
15:22:34.512>L= 1897 lx Light Intensity
15:22:47.502>CO2=401ppm
15:22:57.439>CO2=402ppm
15:23:07.367>CO2=401ppm
15:23:14.650>O2=21.24Vol%
15:23:18.878>O2=21.82Vol%
15:23:23.101>O2=21.96Vol%
15:23:24.743>#End of Multisensor Cycle#
15:24:02.060>T=32.2oC H= 75.3%
15:24:05.919>T=32.2oC H= 75.4%
15:24:10.271>T=32.2oC H= 75.3%
15:24:18.197>L= 1725 lx Light Intensity
15:24:23.069>L= 1724 lx Light Intensity
15:24:27.931>L= 1723 lx Light Intensity
15:24:40.924>CO2=404ppm
15:24:50.864>CO2=404ppm
15:25:00.791>CO2=403ppm
15:25:08.070>O2=21.24Vol%
15:25:12.298>O2=21.11Vol%
```

**Explain**

Teacher's comment (Enter comment)

Total mark(s): 4/7 57.1%

**Explain**

Text & graphics

**Questions:**

1. **Describe** and **explain** the changes in light intensity in the first 24 hours inside the gas containers.
2. **Describe** and **explain** the relationship between the temperature and relative humidity inside the gas containers.
3. **Describe** and **explain** the changes in concentration of oxygen and concentration of carbon dioxide inside the three gas containers with (a) pH 3, (b) pH 5, and (c) pH 7 solution during the 14-days period. (You need to give reasonable explanation on your prediction in each case)
4. With reference from your observation, **state** and **explain** which pH is the most suitable for the seeds to develop into plants.

Back

1 In the morning , the light intensity will increase .At night ,concentration will decrease . 0.5 /1  
No text content

2 When the temperature rises , the air vapor will increase so the relative humidity will decrease .The lower the temperature, the higher the relative humidity. 0.5 /1  
No text content

3 a The concentration of carbon dioxide increase because the pH value effect 0.5 /1

Time in Days

# Methodology

- Predict-Observe-Explain approach with the integration of Arduino datalogger

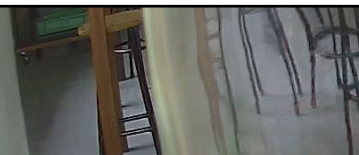
Predict

Observe

Explain

Online Data:

<https://drive.google.com/drive/folders/1dpTq75X61EBhhdFd15bVF1fM4Bq7-V?usp=sharing>



**Misconceptions:**

Higher temperature → Higher relative humidity (∴ evaporation of water)

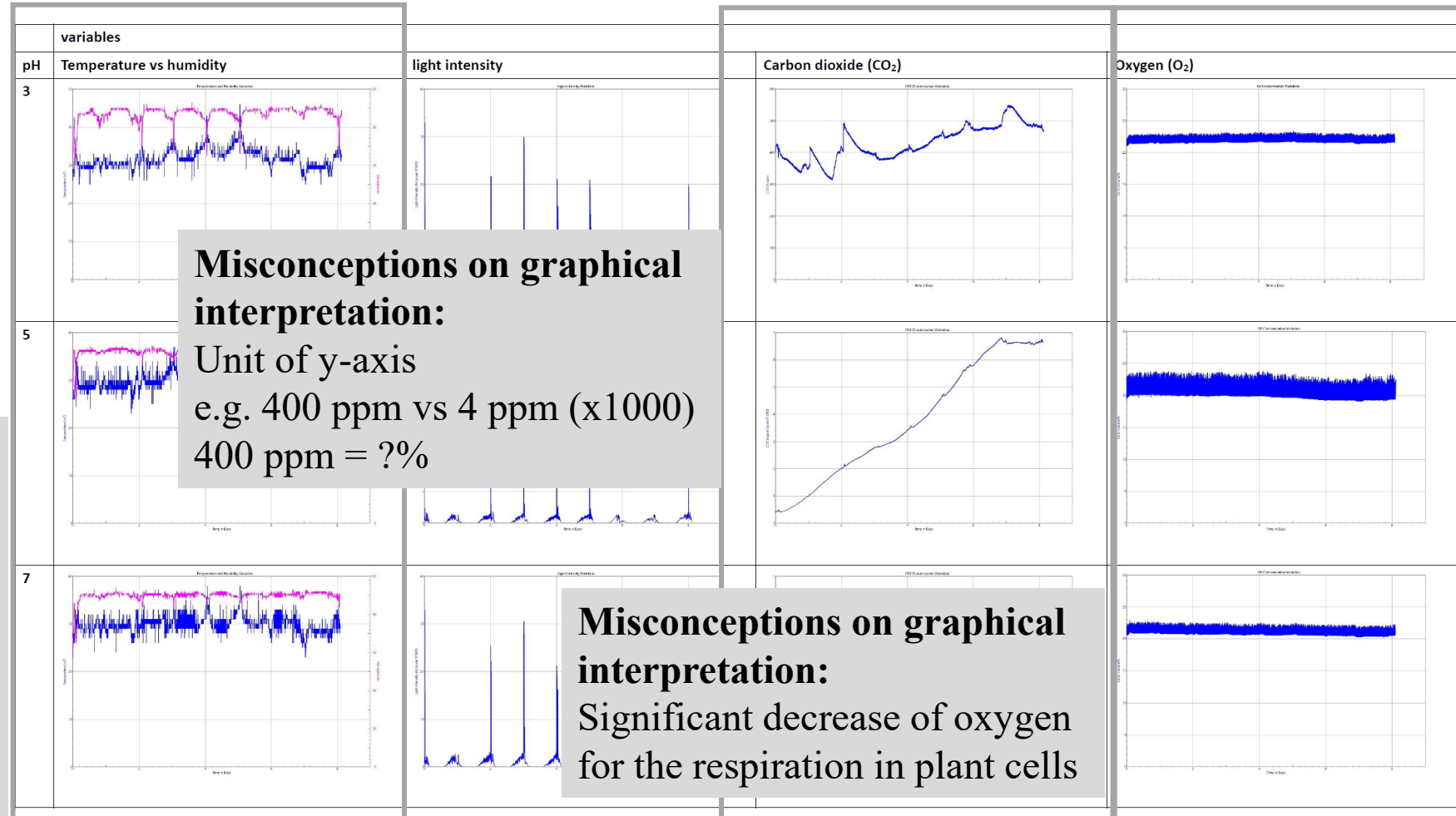
**Correct answers:**

Higher temperature → higher moisture holding capacity of air

**Misconceptions on graphical interpretation:**

Unit of y-axis  
e.g. 400 ppm vs 4 ppm (x1000)  
400 ppm = ?%

**Misconceptions on graphical interpretation:**  
Significant decrease of oxygen for the respiration in plant cells



# Methodology

## • Research Context

- From October 2018 to April 2019
- The suggested lesson time allocation (CDC, 2017b)
  - 26 hours for Unit 7
  - 27 hours for Unit 8
  - 17 hours for Unit 9
- **9 scientific inquiries**
  - 100 mins x 3 = 5 hours for each unit
  - Total 15 hours
  - ~21% of the total lesson time
- **24 instructional videos, 24 quizzes**
- **6 POE activities**

*Summary of the teaching materials and activities of the school curriculum incorporated with the FCs*

Sub-unit	Topic	FPOE		TFC		In-class learning Scientific inquiry
		POE video*	POE real-time*	Out-of-class learning Instructional video	Quiz	
7.1	Air			✓	✓	
7.2 A	Photosynthesis			✓	✓	
7.2 B-C	Tests / factors of photosynthesis			✓	✓	✓
7.2 D	Significance of photosynthesis			✓	✓	
7.3	Respiration			✓	✓	
7.4 A	Gas exchange in plants	✓#		✓	✓	✓
7.4 B-1	Gas exchange in animals	✓#	✓	✓	✓	✓
7.4 B-2	Effects of smoking in humans			✓	✓	
7.5	Balance of carbon dioxide and oxygen in nature			✓	✓	
7.6	Air quality			✓	✓	
8.1	Introducing simple circuits			✓	✓	
8.2	Circuit diagrams			✓	✓	
8.3A-B	Basic ideas of an electric current			✓	✓	
8.3 C	Heating and magnetic effects	✓		✓	✓	✓
8.4	Voltage			✓	✓	
8.5	Resistance			✓	✓	✓
8.6	Series and parallel circuits	✓		✓	✓	✓
8.7	Our household electricity			✓	✓	
8.8	Electricity safety			✓	✓	
9.1	Common acids and alkalis			✓	✓	
9.2	Acid-alkali indicators and pH			✓	✓	✓
9.3	Neutralization			✓	✓	✓
9.4	Corrosive nature of acids		✓	✓	✓	
9.5	Potential hazards to their use	✓		✓	✓	✓

# = activities for crossing subunits, \* = only available for FPOE

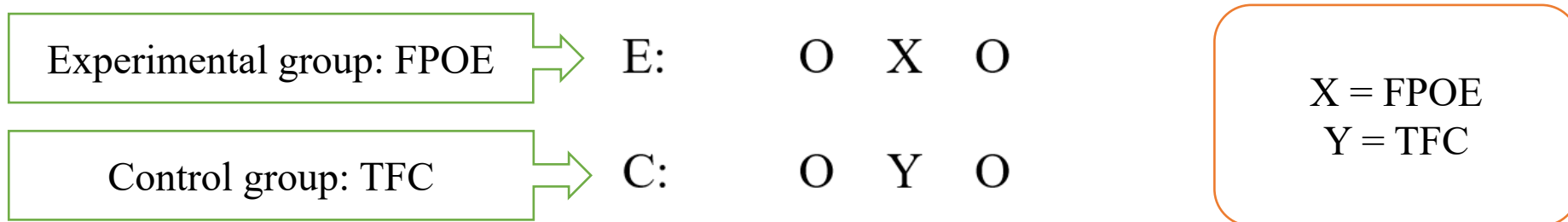
# Methodology

- Research Method
  - A **sequential explanatory design** (Creswell, 2009; Creswell & Plano Clark, 2007)



*Figure 3.6. The convergence model of triangulation for this mixed-methods research*

- Research Design
  - A non-equivalent control group pre-test–post-test design of a **quasi-experiment** (Campbell et al., 1963)



*The convergence model of triangulation for this mixed-methods research*

# Methodology

- Instruments

Instruments	Original source	Items	Reliability (Cronbach's alpha) from original study	Reliability (Cronbach's alpha) in this study	Reliability (Cronbach's alpha) in this study
				Pre test	Post test
Self-Regulated Learning Questionnaire	Online Self-Regulated Learning Questionnaire (OSLQ) (Barnard et al., 2009)	24 items with a 5-point Likert response format	.92	.918	.919
Science Process Skills Tests	Test of Basic Process Skills in Science (BAPS)	36 Multiple-choice questions	.82	.703	.697
	Test for Integrated Process Skills II (TIPS-II).	36 Multiple-choice questions	.86	.771	.749
Learning Achievement Test	N/A	20 Multiple-choice questions	N/A	.762	.801
		10 fill-in-the-blank questions		.776	.721
		2 matching questions		.714	.792
		6 structured questions		.791	.745
		3 long questions		.770	.763

# Methodology

## • Data Collection and Analysis

Pedagogy:  
FPOE  
(experimental)  
( $N = 63$ ):

Data:  
**Pre-scores** of  
SRL abilities,  
LA, and SPS

**RQ1**

*Paired sample t-tests*

$O_1 \longleftrightarrow O_2$

TFC  
(control)  
( $N = 61$ ):

**Pre-scores** of  
SRL abilities,  
LA, and SPS

**RQ1**

*Paired sample t-tests*

$O_1 \longleftrightarrow O_2$

Data:  
**Post-scores** of  
SRL abilities,  
LA, and SPS

**RQ1**

$O_1 \longleftrightarrow O_2$

*Independent sample t-tests on gain scores*

**Post-scores** of  
SRL abilities,  
LA, and SPS

Data:  
**Gain scores**  
of SRL  
abilities, LA,  
and SPS

**RQ1**

$O_1 \longleftrightarrow O_2$

*Independent sample t-tests on gain scores*

**RQ2**

Learning ability:  
Lower:  
( $N=31$ )

$O_1 \longleftrightarrow O_2$

*Independent sample t-tests on gain scores*

Higher:  
( $N=32$ )

$O_1 \longleftrightarrow O_2$

*ANOVAs/MANOVAs*

Lower:  
( $N=30$ )

$O_1 \longleftrightarrow O_2$

*Independent sample t-tests on gain scores*

Higher  
( $N=31$ )

$O_1 \longleftrightarrow O_2$

# Results

- Quantitative findings addressing RQ1 (FPOE vs TFC) can be supported by the amount of qualitative evidence
- Paired sample *t*-tests: time management was significantly improved following the FPOE ( $p = .036$ )

## Time Management

“More time was spent on the weekend participating in the online experiment. I even gave up some shopping time with my close friends...” (FPOE-H-N-1)

“Since we should observe the seedling growth every day, I set an alarm on my phone to remind me to look at the live-streaming and to plot the graphs. (FPOE-H-P-2)

Table 4.40  
Matrix of the counts of categories and codes identified at different approaches

		FPOE			TFC			
		Lower ability	Higher ability	Sub-total	Lower ability	Higher ability	Sub-total	Total
<b>Category</b>	<b>Benefits to SRL ability</b>	<u>8</u>	<u>17</u>	<u>25</u>	<u>6</u>	<u>4</u>	<u>10</u>	<u>35</u>
Code	ES	0	1	1	0	2	2	3
Code	TS	3	3	6	1	2	6	9
Code	TM	2	7	9	0	1	1	10
Code	SE	3	6	9	3	1	4	13
<b>Category</b>	<b>Benefits to LA</b>	<u>10</u>	<u>20</u>	<u>30</u>	<u>5</u>	<u>12</u>	<u>17</u>	<u>47</u>
Code	ST	2	6	8	0	4	4	12
Code	LK	1	3	4	2	3	5	9
Code	RF	3	4	7	1	1	2	9
Code	MC	4	7	11	2	4	6	17
<b>Category</b>	<b>Benefits to SPS</b>	<u>20</u>	<u>30</u>	<u>50</u>	<u>6</u>	<u>9</u>	<u>15</u>	<u>65</u>
	<b>BSPS</b>	<u>10</u>	<u>13</u>	<u>23</u>	<u>3</u>	<u>6</u>	<u>9</u>	<u>32</u>
Code	O	4	5	9	0	2	2	11
Code	M	2	5	7	1	3	3	11
Code	P	2	2	4	1	1	2	6
Code	I	2	1	3	1	0	1	4
	<b>ISPS</b>	<u>10</u>	<u>17</u>	<u>27</u>	<u>3</u>	<u>3</u>	<u>6</u>	<u>33</u>
Code	IV	4	6	10	1	2	3	13
Code	SH	1	3	4	0	0	0	4
Code	DI	2	2	4	2	1	3	7
Code	GD	3	6	9	0	0	0	9
<b>Category</b>	<b>Challenges</b>	<u>2</u>	<u>2</u>	<u>4</u>	<u>3</u>	<u>3</u>	<u>6</u>	<u>10</u>
Code	SC	2	1	3	3	3	6	9
Code	OC	0	1	1	0	0	0	1

# Results

- Paired sample *t*-tests: LA was significantly improved following the FPOE ( $p < .001$ ) and the TFC ( $p < .001$ )

## Sufficient Time

“After finishing the investigations in the lessons, Miss Wong often gave us more time and guidance to work on the workbook exercises” (TFC-H-P-2)

## Learning new knowledge

“The online learning [activities] were new and not only related to the content in the textbook. I really worked like a scientist on monitoring the growth of seedlings under different pH.” (FPOE-H-P-2)

Table 4.40  
Matrix of the counts of categories and codes identified at different approaches

		FPOE			TFC			Total
		Lower ability	Higher ability	Sub-total	Lower ability	Higher ability	Sub-total	
<b>Category</b>	<b>Benefits to SRL ability</b>	<b>8</b>	<b>17</b>	<b>25</b>	<b>6</b>	<b>4</b>	<b>10</b>	<b>35</b>
Code	ES	0	1	1	0	2	2	3
Code	TS	3	3	6	1	2	6	9
Code	TM	2	7	9	0	1	1	10
Code	SE	3	6	9	3	1	4	13
<b>Category</b>	<b>Benefits to LA</b>	<b>10</b>	<b>20</b>	<b>30</b>	<b>5</b>	<b>12</b>	<b>17</b>	<b>47</b>
Code	ST	2	6	8	0	4	4	12
Code	LK	1	3	4	2	3	5	9
Code	RF	3	4	7	1	1	2	9
Code	MC	4	7	11	2	4	6	17
<b>Category</b>	<b>Benefits to SPS</b>	<b>20</b>	<b>30</b>	<b>50</b>	<b>6</b>	<b>9</b>	<b>15</b>	<b>65</b>
	<b>BSPS</b>	<b>10</b>	<b>13</b>	<b>23</b>	<b>3</b>	<b>6</b>	<b>9</b>	<b>32</b>
Code	O	4	5	9	0	2	2	11
Code	M	2	5	7	1	3	3	11
Code	P	2	2	4	1	1	2	6
Code	I	2	1	3	1	0	1	4
	<b>ISPS</b>	<b>10</b>	<b>17</b>	<b>27</b>	<b>3</b>	<b>3</b>	<b>6</b>	<b>33</b>
Code	IV	4	6	10	1	2	3	13
Code	SH	1	3	4	0	0	0	4
Code	DI	2	2	4	2	1	3	7
Code	GD	3	6	9	0	0	0	9
<b>Category</b>	<b>Challenges</b>	<b>2</b>	<b>2</b>	<b>4</b>	<b>3</b>	<b>3</b>	<b>6</b>	<b>10</b>
Code	SC	2	1	3	3	3	6	9
Code	OC	0	1	1	0	0	0	1

# Results

- Paired sample *t*-tests: the **FPOE** significantly improved **measurement skill** ( $p < .001$ ) and **overall BSPS** ( $p = .035$ )
- the improvement of **overall BSPS**:
- **FPOE > TFC** ( $p = .051$ )

Measurement

“...using mathematical method [skills] in a lot of experiments like finding the electric current, voltage, and resistance in different circuits...” (FPOE-L-N-1)

“The use of a mobile logger instead of an indicator for the measurement of gas released from mealworms was more useful and direct.” (FPOE-H-P-1)

Table 4.40  
Matrix of the counts of categories and codes identified at different approaches

		FPOE			TFC			Total
		Lower ability	Higher ability	Sub-total	Lower ability	Higher ability	Sub-total	
Category	Benefits to SRL ability	<u>8</u>	<u>17</u>	<u>25</u>	<u>6</u>	<u>4</u>	<u>10</u>	<u>35</u>
Code	ES	0	1	1	0	2	2	3
Code	TS	3	3	6	1	2	6	9
Code	TM	2	7	9	0	1	1	10
Code	SE	3	6	9	3	1	4	13
Category	Benefits to LA	<u>10</u>	<u>20</u>	<u>30</u>	<u>5</u>	<u>12</u>	<u>17</u>	<u>47</u>
Code	ST	2	6	8	0	4	4	12
Code	LK	1	3	4	2	3	5	9
Code	RF	3	4	7	1	1	2	9
Code	MC	4	7	11	2	4	6	17
Category	Benefits to SPS	<u>20</u>	<u>30</u>	<u>50</u>	<u>6</u>	<u>9</u>	<u>15</u>	<u>65</u>
	<u>BSPS</u>	<u>10</u>	<u>13</u>	<u>23</u>	<u>3</u>	<u>6</u>	<u>9</u>	<u>32</u>
Code	O	4	5	9	0	2	2	11
Code	M	2	5	7	1	3	3	11
Code	P	2	2	4	1	1	2	6
Code	I	2	1	3	1	0	1	4
Category	Benefits to ISPS	<u>10</u>	<u>17</u>	<u>27</u>	<u>3</u>	<u>3</u>	<u>6</u>	<u>33</u>
Code	IV	4	6	10	1	2	3	13
Code	SH	1	3	4	0	0	0	4
Code	DI	2	2	4	2	1	3	7
Code	GD	3	6	9	0	0	0	9
Category	Challenges	<u>2</u>	<u>2</u>	<u>4</u>	<u>3</u>	<u>3</u>	<u>6</u>	<u>10</u>
Code	SC	2	1	3	3	3	6	9
Code	OC	0	1	1	0	0	0	1

# Results

## Observation

*“This was the first time for me to make observations in a science experiment through YouTube. It was a wonderful experience as I could even watch the growth of the seedlings at midnight!” (FPOE-H-P-2)*

## Prediction

*“The online experiment required us to make reasonable predictions by ourselves in different situations.” (FPOE-L-N-1)*

## Inference

*“...helped me to explain how the seedlings grew with the change of temperature, light [intensity], and gas [content], and hence I could know which pH was the most suitable for the seedlings...” (FPOE-L-N-2)*

Table 4.40

Matrix of the counts of categories and codes identified at different approaches

		FPOE			TFC			Total
		Lower ability	Higher ability	Sub-total	Lower ability	Higher ability	Sub-total	
<b>Category</b>	<b>Benefits to SRL ability</b>	<b>8</b>	<b>17</b>	<b>25</b>	<b>6</b>	<b>4</b>	<b>10</b>	<b>35</b>
Code	ES	0	1	1	0	2	2	3
Code	TS	3	3	6	1	2	6	9
Code	TM	2	7	9	0	1	1	10
Code	SE	3	6	9	3	1	4	13
<b>Category</b>	<b>Benefits to LA</b>	<b>10</b>	<b>20</b>	<b>30</b>	<b>5</b>	<b>12</b>	<b>17</b>	<b>47</b>
Code	ST	2	6	8	0	4	4	12
Code	LK	1	3	4	2	3	5	9
Code	RF	3	4	7	1	1	2	9
Code	MC	4	7	11	2	4	6	17
<b>Category</b>	<b>Benefits to SPS</b>	<b>20</b>	<b>30</b>	<b>50</b>	<b>6</b>	<b>9</b>	<b>15</b>	<b>65</b>
	<b>BSPS</b>	<b>10</b>	<b>13</b>	<b>23</b>	<b>3</b>	<b>6</b>	<b>9</b>	<b>32</b>
Code	O	4	5	9	0	2	2	11
Code	M	2	5	7	1	3	3	11
Code	P	2	2	4	1	1	2	6
Code	I	2	1	3	1	0	1	4
	<b>ISPS</b>	<b>10</b>	<b>17</b>	<b>27</b>	<b>3</b>	<b>3</b>	<b>6</b>	<b>33</b>
Code	IV	4	6	10	1	2	3	13
Code	SH	1	3	4	0	0	0	4
Code	DI	2	2	4	2	1	3	7
Code	GD	3	6	9	0	0	0	9
<b>Category</b>	<b>Challenges</b>	<b>2</b>	<b>2</b>	<b>4</b>	<b>3</b>	<b>3</b>	<b>6</b>	<b>10</b>
Code	SC	2	1	3	3	3	6	9
Code	OC	0	1	1	0	0	0	1

# Results

- **Paired sample *t*-tests:** the **FPOE** significantly improved **all the subscales of ISPS**:
  - **identifying variables** ( $p < .001$ ), **stating hypotheses** ( $p < .001$ )
  - **operational defining** ( $p = .009$ ), **designing investigation** ( $p < .001$ )
  - **graphing and interpreting data** ( $p < .001$ ), **overall ISPS** ( $p < .001$ )
- **Paired sample *t*-tests:** the **TFC** approach significantly improved the skills of:
  - **identifying variables** ( $p < .001$ ), **operational defining** ( $p = .030$ )
  - **designing investigation** ( $p = .001 < .05$ ), **overall ISPS** ( $p < .001$ )
- **Independent sample *t*-tests on gain scores by flipped approach :**
  - **FPOE > TFC**
  - **stating hypotheses** ( $p < .001$ )
  - **graphing and interpreting data** ( $p < .037$ )
  - **overall ISPS** ( $p = .001$ )

*Summary of the quantitative results (p(two-tailed)) for addressing RQ1*

Research Question	RQ1		
Approach	FPOE	TFC	
Ability	/	/	
Type of test	paired <sup>1</sup>	paired <sup>1</sup>	gain <sup>2</sup>
Goal setting	.196	.992	.389
Environmental structuring	.462	.460	.296
Task strategies	.571	.831	.583
Time management	<b>.036*</b>	.300	.445
Help seeking	.511	.868	.719
Self-evaluation	.104	.341	.539
Average SRL ability	.107	.825	.313
LA	<b>.000**</b>	<b>.000**</b>	.744
Observation	.499	.333	.870
Communication	.939	.058	.232
Classification	.123	.257	.057
Measurement	<b>.000*</b>	.063	.085
Prediction	.076	.272	.605
Inference	.503	.362	.265
Overall Basic SPS	<b>.035*</b>	.568	<b>.051#</b>
Identifying variables	<b>.000**</b>	<b>.000*</b>	.199
Stating hypotheses	<b>.000**</b>	.251	<b>.000**</b>
Operational defining	<b>.009*</b>	<b>.030*</b>	.605
Designing investigation	<b>.000**</b>	<b>.001*</b>	.997
Graphing and interpreting data	<b>.000**</b>	.075	<b>.037*</b>
Overall Integrated SPS	<b>.000**</b>	<b>.000*</b>	<b>.001*</b>

\* = Significant at  $p < .05$ . \*\* = Significant at  $p < .001$ . # = marginal significant case. 1 = paired sample *t*-test between pre-and post-scores. 2 = independent sample *t*-test of gain scores.

# Results

- improvement of **stating hypotheses** ( $p < .001$ ), **graphing and interpreting data** ( $p < .037$ ): **FPOE > TFC**

## Stating hypothesis

*“It was so surprising that what I predicted in the first online [POE] activity of burning candles was totally different from what I had observed. This helped me to think more thoroughly to make a more reasonable explanation.” (FPOE-H-P-2)*

## Graphing and interpreting data

*“The change of light and the concentration of carbon dioxide [dependent variables] could be seen through the real-time plotted graph at different times.” (FPOE-H-P-1)*

Table 4.40

Matrix of the counts of categories and codes identified at different approaches

		FPOE			TFC			Total
		Lower ability	Higher ability	Sub-total	Lower ability	Higher ability	Sub-total	
<b>Category</b>	<b>Benefits to SRL ability</b>	<b>8</b>	<b>17</b>	<b>25</b>	<b>6</b>	<b>4</b>	<b>10</b>	<b>35</b>
Code	ES	0	1	1	0	2	2	3
Code	TS	3	3	6	1	2	6	9
Code	TM	2	7	9	0	1	1	10
Code	SE	3	6	9	3	1	4	13
<b>Category</b>	<b>Benefits to LA</b>	<b>10</b>	<b>20</b>	<b>30</b>	<b>5</b>	<b>12</b>	<b>17</b>	<b>47</b>
Code	ST	2	6	8	0	4	4	12
Code	LK	1	3	4	2	3	5	9
Code	RF	3	4	7	1	1	2	9
Code	MC	4	7	11	2	4	6	17
<b>Category</b>	<b>Benefits to SPS</b>	<b>20</b>	<b>30</b>	<b>50</b>	<b>6</b>	<b>9</b>	<b>15</b>	<b>65</b>
	<b>BSPS</b>	<b>10</b>	<b>13</b>	<b>23</b>	<b>3</b>	<b>6</b>	<b>9</b>	<b>32</b>
Code	O	4	5	9	0	2	2	11
Code	M	2	5	7	1	3	3	11
Code	P	2	2	4	1	1	2	6
Code	I	2	1	3	1	0	1	4
	<b>ISPS</b>	<b>10</b>	<b>17</b>	<b>27</b>	<b>3</b>	<b>3</b>	<b>6</b>	<b>33</b>
Code	IV	4	6	10	1	2	3	13
Code	SH	1	3	4	0	0	0	4
Code	DI	2	2	4	2	1	3	7
Code	GD	3	6	9	0	0	0	9
<b>Category</b>	<b>Challenges</b>	<b>2</b>	<b>2</b>	<b>4</b>	<b>3</b>	<b>3</b>	<b>6</b>	<b>10</b>
Code	SC	2	1	3	3	3	6	9
Code	OC	0	1	1	0	0	0	1

# Results

- the improvement of overall ISPS : **FPOE >TFC** ( $p = .001$ )

## Identifying variable

*“In the online learning [of the FPOE], I needed to predict the effect of light [intensity] on the [relative] humidity, as well as other independent variables such as the effect of pH on the height of seedlings, etc... It was a bit difficult at the beginning, but it enhanced my ability to find [identify] variables for the investigation.” (FPOE-L-N-2)*

## Designing investigation

*“The videos guided me through some experimental procedures, such as the steps for boiling a leaf in the iodine test...and helped me to design a fair test for photosynthesis.” (TFC-L-P-1)*

Table 4.40

Matrix of the counts of categories and codes identified at different approaches

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Code	TM	2	7	9	0	1	1	10
Code	SE	3	6	9	3	1	4	13
<b>Category</b>	<b>Benefits to LA</b>	<b>10</b>	<b>20</b>	<b>30</b>	<b>5</b>	<b>12</b>	<b>17</b>	<b>47</b>
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Code	RF	3	4	7	1	1	2	9
Code	MC	4	7	11	2	4	6	17
<b>Category</b>	<b>Benefits to SPS</b>	<b>20</b>	<b>30</b>	<b>50</b>	<b>6</b>	<b>9</b>	<b>15</b>	<b>65</b>
	<b>BSPS</b>	<b>10</b>	<b>13</b>	<b>23</b>	<b>3</b>	<b>6</b>	<b>9</b>	<b>32</b>
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Code	I	2	1	3	1	0	1	4
	<b>ISPS</b>	<b>10</b>	<b>17</b>	<b>27</b>	<b>3</b>	<b>3</b>	<b>6</b>	<b>33</b>
Code	IV	4	6	10	1	2	3	13
Code	SH	1	3	4	0	0	0	4
Code	DI	2	2	4	2	1	3	7
Code	GD	3	6	9	0	0	0	9
<b>Category</b>	<b>Challenges</b>	<b>2</b>	<b>2</b>	<b>4</b>	<b>3</b>	<b>3</b>	<b>6</b>	<b>10</b>
Code	SC	2	1	3	3	3	6	9
Code	OC	0	1	1	0	0	0	1

# Results

Quantitative findings addressing RQ2 (**learning ability**) can be supported by the qualitative evidence

- independent sample *t*-tests of the gain scores
- SRL ability
  - FPOE: no significant difference
  - TFC: the gain score of **environmental structuring ability: HL > LL** ( $p = .033$ )
- LA
  - FPOE: the gain score of **LA: HL > LL** ( $p = .005$ )
  - TFC: the gain score of **LA: HL > LL** ( $p = .008$ )
- SPS
  - FPOE: the gain score of **stating hypotheses skill: HL > LL** ( $p < .001$ )
  - TFC: the gain score of **designing investigation skill: LL > HL** ( $p = .033$ )
- *Two-way ANOVAs / MANOVAs: No interaction effect*

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		Lower ability	Higher ability	Sub-total	Lower ability	Higher ability	Sub-total	
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<b>Category</b>	<b>Benefits to LA</b>	<u>10</u>	<u>20</u>	<u>30</u>	<u>5</u>	<u>12</u>	<u>17</u>	<u>47</u>
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Code	MC	4	7	11	2	4	6	17
<b>Category</b>	<b>Benefits to SPS</b>	<u>20</u>	<u>30</u>	<u>50</u>	<u>6</u>	<u>9</u>	<u>15</u>	<u>65</u>
	<b>BSPS</b>	<u>10</u>	<u>13</u>	<u>23</u>	<u>3</u>	<u>6</u>	<u>9</u>	<u>32</u>
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Code	P	2	2	4	1	1	2	6
Code	I	2	1	3	1	0	1	4
	<b>ISPS</b>	<u>10</u>	<u>17</u>	<u>27</u>	<u>3</u>	<u>3</u>	<u>6</u>	<u>33</u>
Code	IV	4	6	10	1	2	3	13
Code	SH	1	3	4	0	0	0	4
Code	DI	2	2	4	2	1	3	7
Code	GD	3	6	9	0	0	0	9
<b>Category</b>	<b>Challenges</b>	<u>2</u>	<u>2</u>	<u>4</u>	<u>3</u>	<u>3</u>	<u>6</u>	<u>10</u>
Code	SC	2	1	3	3	3	6	9
Code	OC	0	1	1	0	0	0	1

# Discussion – FPOE vs TFC

## *Time management improved in FPOE but not in TFC*

- SRL FC: **higher awareness of time management** (Lai & Hwang, 2016)
- POE using **mobile dataloggers** → long-lasting investigations → requires making observations and recording data via an online system **through own initiatives** (Tho & Yeung, 2018)

## *Gain of LA: FPOE = TFC*

- contradict the findings from some similar studies: modified FC > TFC (e.g., Çetinkaya, 2017, Lai & Hwang, 2016; Zainuddin, 2018)
- online video and quizzes, and scientific inquiry → Improves LA in similar degree in FPOE and TFC
- online **POE activities** in the FPOE approach → **Improves LA in smaller extent**

# Discussion - FPOE vs TFC

## *Gain of Overall BSPS : FPOE > TFC*

- Qualitative evidence:
  - **POE activities** enhance **prediction skills** (Kearney et al., 2001)
  - **POE activities** enable students to **observe accurate** and **repeated replica** of scientific demonstrations (Kearney et al., 2001)
  - **real-time streaming features** allowed them to **observe anytime** and **anywhere** (Tho & Yeung, 2018)
  - **remote laboratory** → **measuring and gathering data** from the online investigations (Tho & Yeung, 2018)
  - **computer-simulated experiments** → **measurement and data collection** (Geban et al., 1992)

# Discussion - FPOE vs TFC

## *Gain of Overall ISPS: FPOE > TFC*

- **online interactive tasks of POE:** more opportunities to **revisit and modify their ideas** / revise **proposed hypotheses** to make them more scientific (Kramer et al., 2018)
- **a remote and computer-mediated experiment using mobile loggers:**
  1. provide **precise data** and clear **graphs in real time** to illustrate the results and **visualize the variables** (Tho et al., 2015)
  2. **save the time needed for routine procedure** of plotting data for meaningful educational activities, such as interpreting results (Tho & Yeung, 2016) or clarify students' misinterpretations (Lati et al., 2012)

# Discussion –learning ability

## *HL = LL in FPOE*

- Students, regardless of their learning ability, need to learn and apply similar strategies of **regular observations and monitoring** on the **real-time POE** (Tho & Yeung, 2015)

## *Gain in LA: HL > LL in both TFC and FPOE*

- higher achievers with lower attitude towards FC (Nouri, 2016) were still more driven by the **examination-oriented** school culture in terms of understanding and remembering than the lower achievers

# Future implementation

- Remote laboratory
- YouTube Livestreaming
- Google-Drive cloud-storage and synchronization

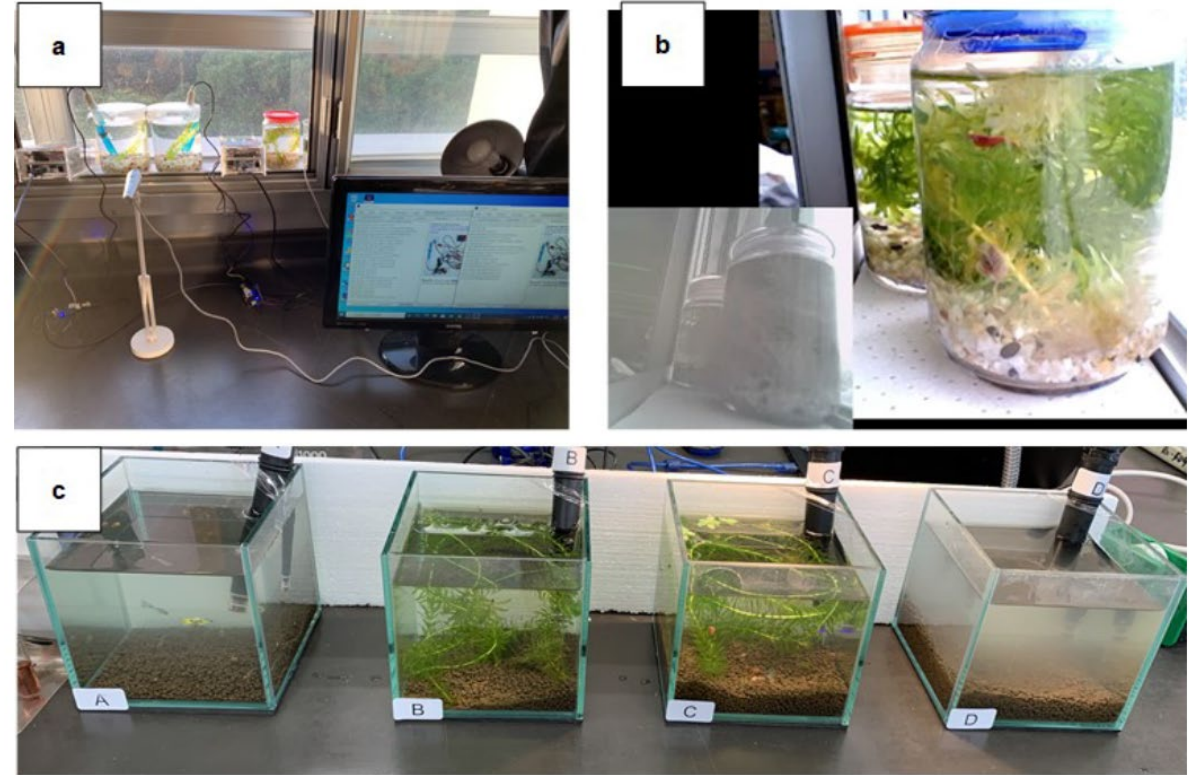


Figure 4. Another example of MFC with the integration of a simplified remote laboratory using two mobile dataloggers: (a) setup of the mobile dataloggers for the MFC in a science laboratory; (b) image of the behaviours of the aquatic organisms during student observations using YouTube livestreaming; (c) setup of an in-class follow-up experiment for clarifying students' misconceptions about the gas exchange of organisms in natural situation.

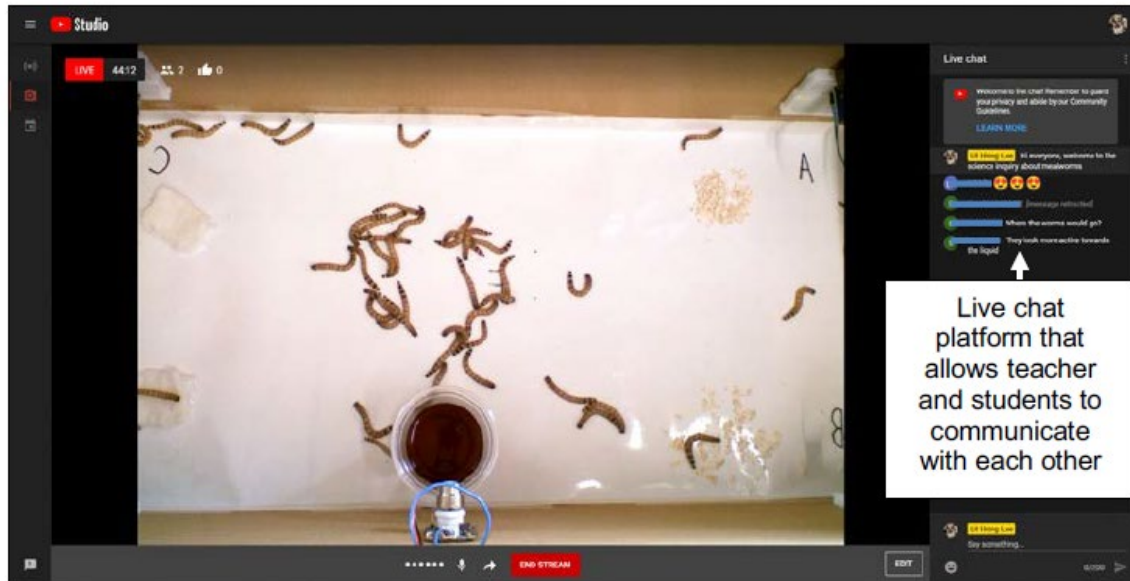


Figure 7. Screenshot of YouTube livestreaming of the remote laboratory studying the gaseous exchange and the effects of different factors on the behaviour of mealworms.

# THANK YOU

