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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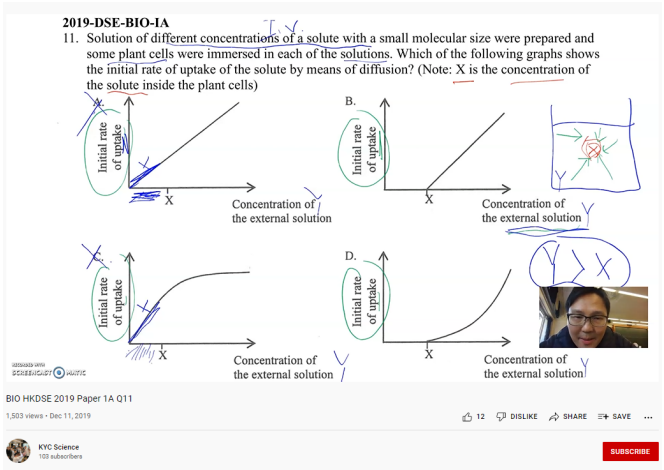
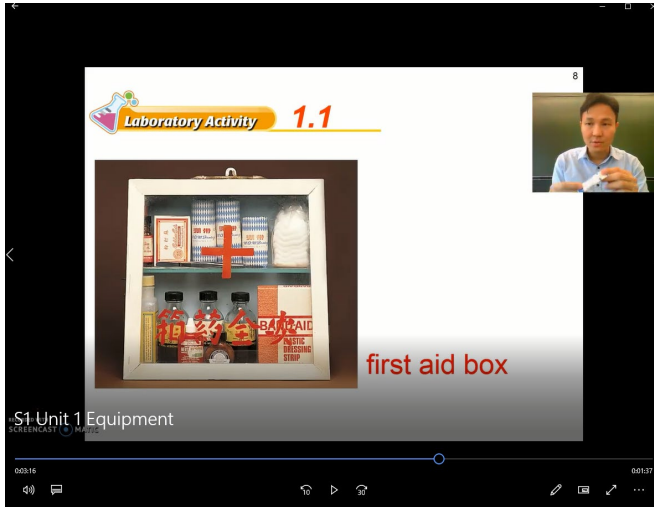
Introduction - Background of research

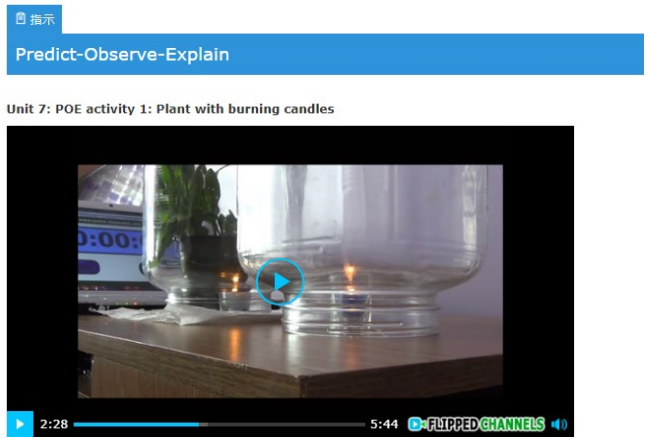
1. Problems of Teaching and Learning Science in Hong Kong Secondary Schools
   - **spoon-feeding** to drill for examination (Yuen, 2017)
   - **insufficient teaching time** (Cheng, So, & Cheung, 2000; Cheung, 2007)
2. The Strategy of Using Information Technology in Education
   - **strengthening students' 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)

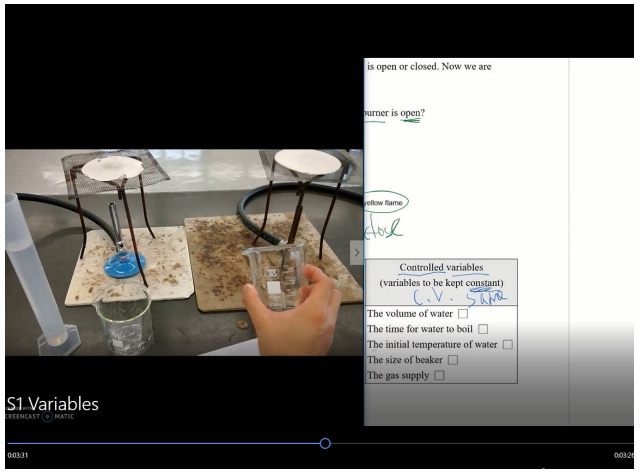
Introduction - Background of research

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









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 though 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

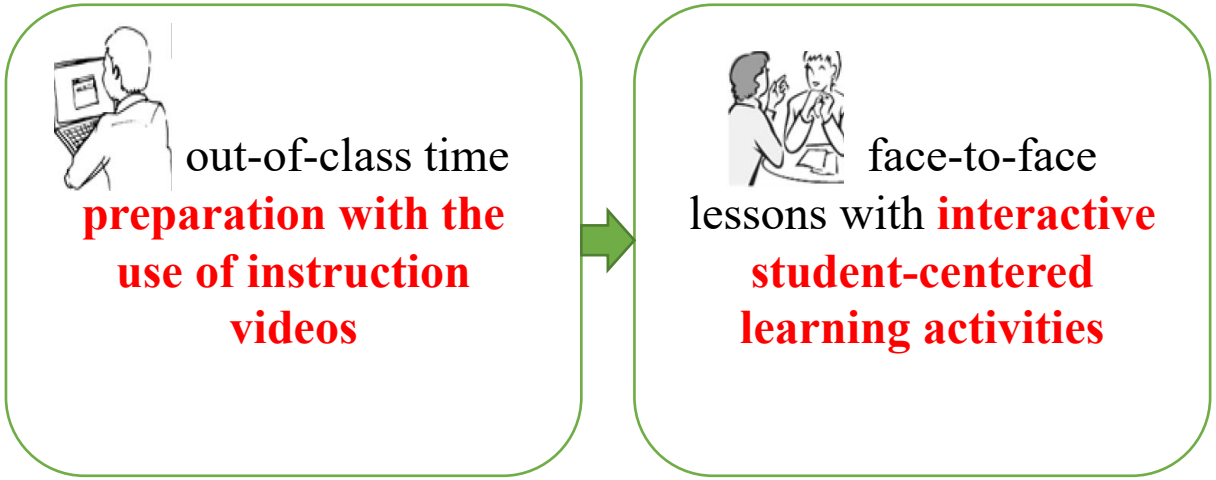
- RQ1: **Can** the **FPOE** improve students' **Self-regulated learning (SRL) abilities**, **Learning achievement (LA)**, and **Science Process Skills (SPS)** in comparison with the **TFC**?
- RQ2: **Do student learning abilities (lower and higher)** affect the improvements of their SRL abilities, LA, 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?

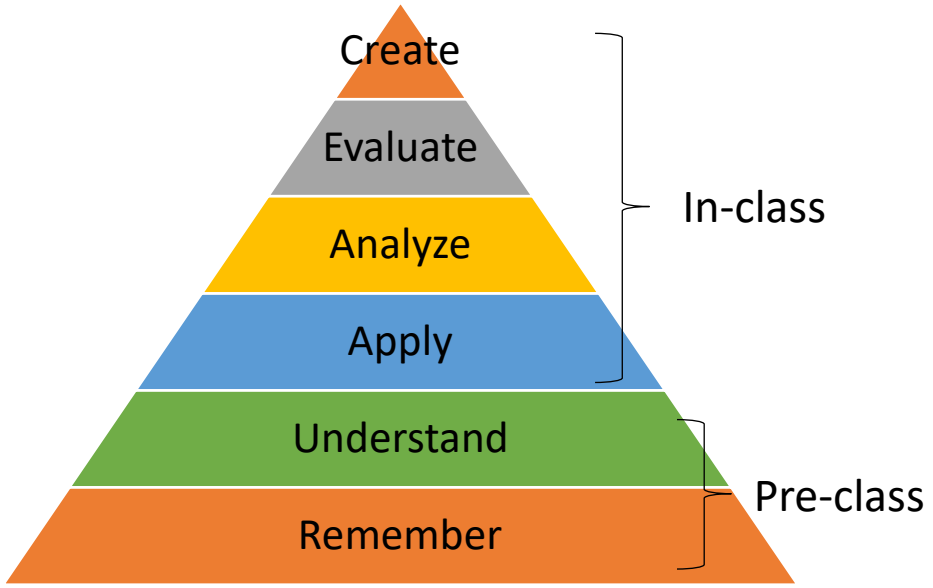
QUAN

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

- 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

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

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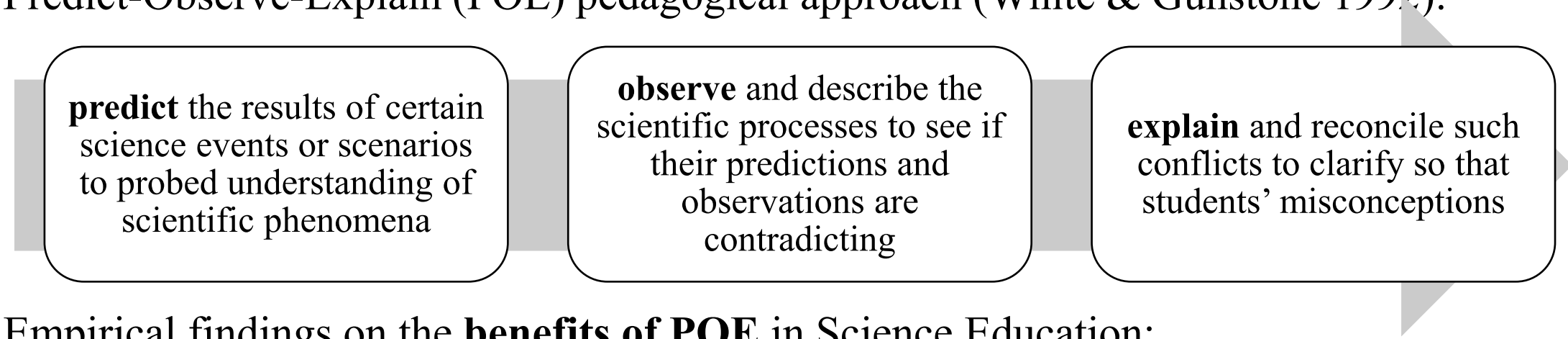
The flipped classroom pedagogy has gained prominence in various educational contexts by reorganising the lectures of content knowledge via instructional videos, and squeezing in more time for class activities. Although there have been numerous studies of the design, implementation, and evaluation of 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.

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):



- 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)		

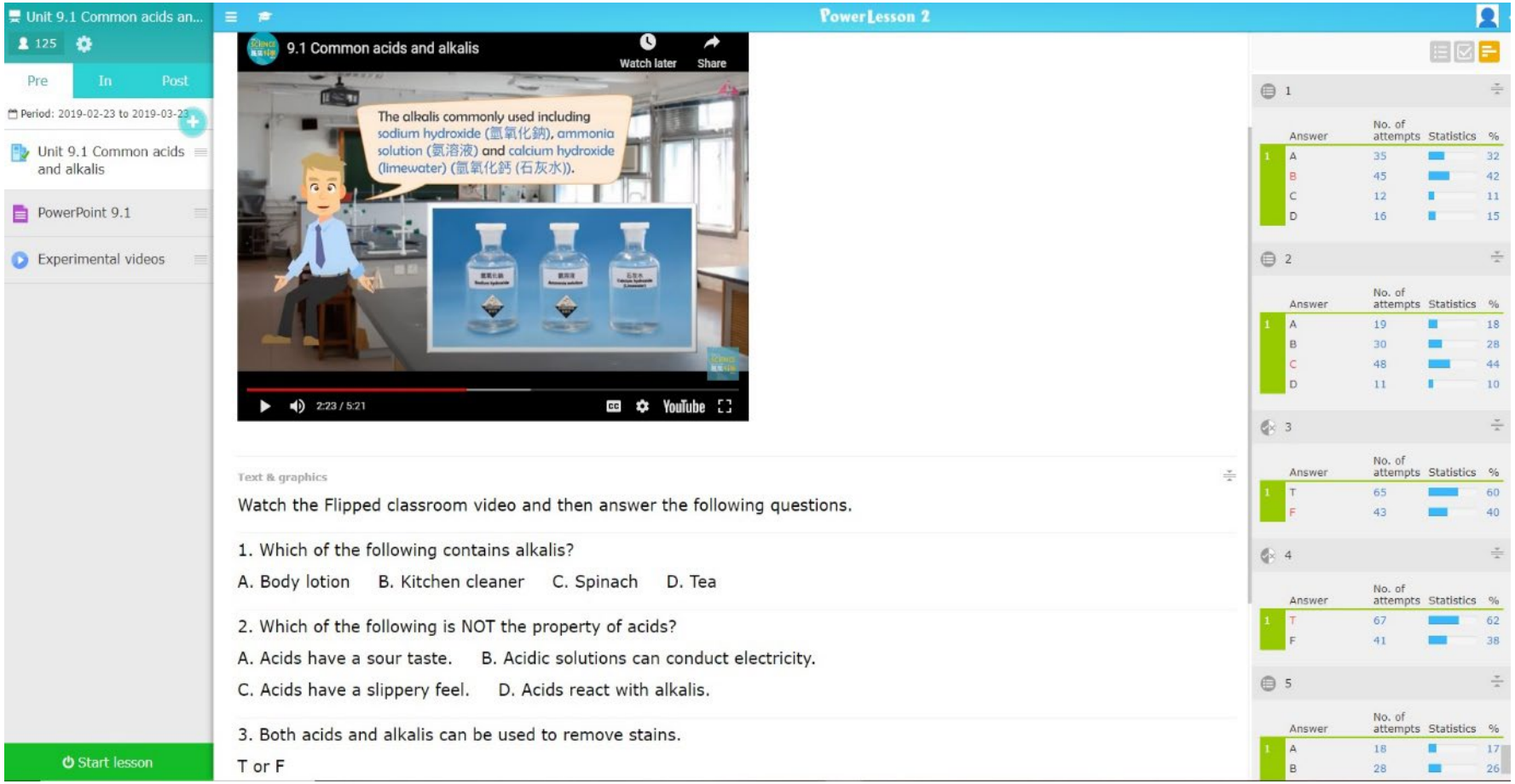
t-tests

Significant difference

	FPOE (2018–2019)	**TFC (2018–2019)**
Modified 5E framework (Lo, 2018)	Activities	Activities
Pre-class activities		
Engage → *Explore* → *Explain*	1. Carry out POE activities with videos and real-time experiments using mobile loggers 2. Clarify misconceptions 3. Watch videos 4. Quizzes on videos with instant feedback	1. Watch videos 2. Quizzes on videos with instant feedback
In-class activities		
Elaborate → *Evaluate*	1. Short briefing about pre-class activities 2. Mini lecture 3. Collaborative scientific inquires	1. Short briefing about pre-class activities 2. Mini lecture 3. Traditional POE activities 4. Collaborative scientific inquires
After-class activities		
Homework assessment related to the in-class scientific inquiries		

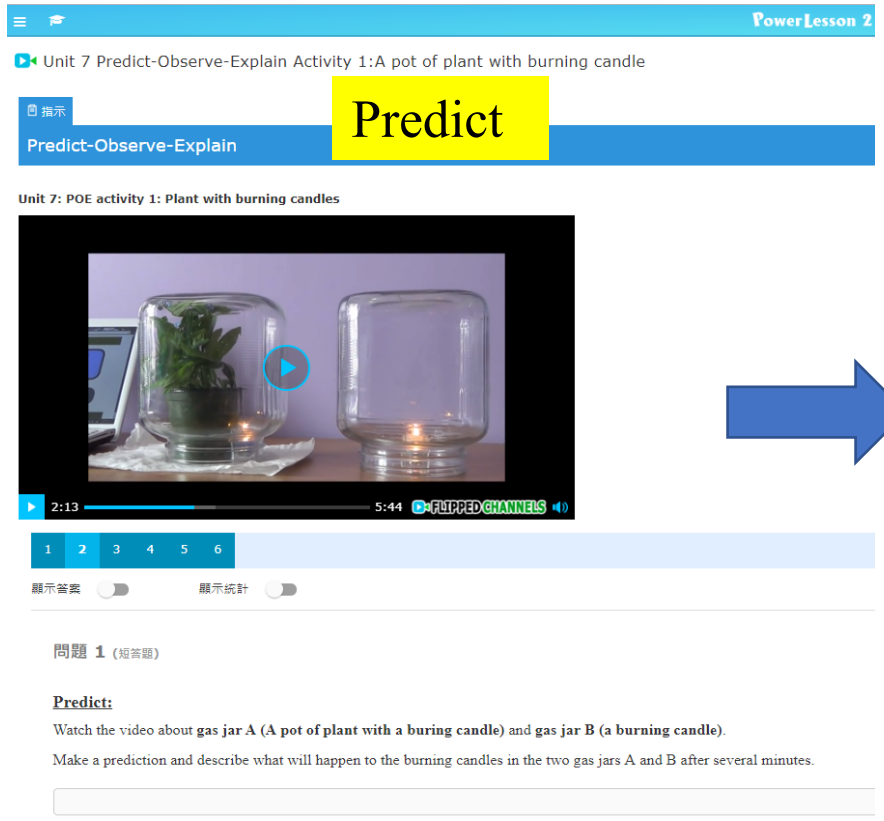
Methodology

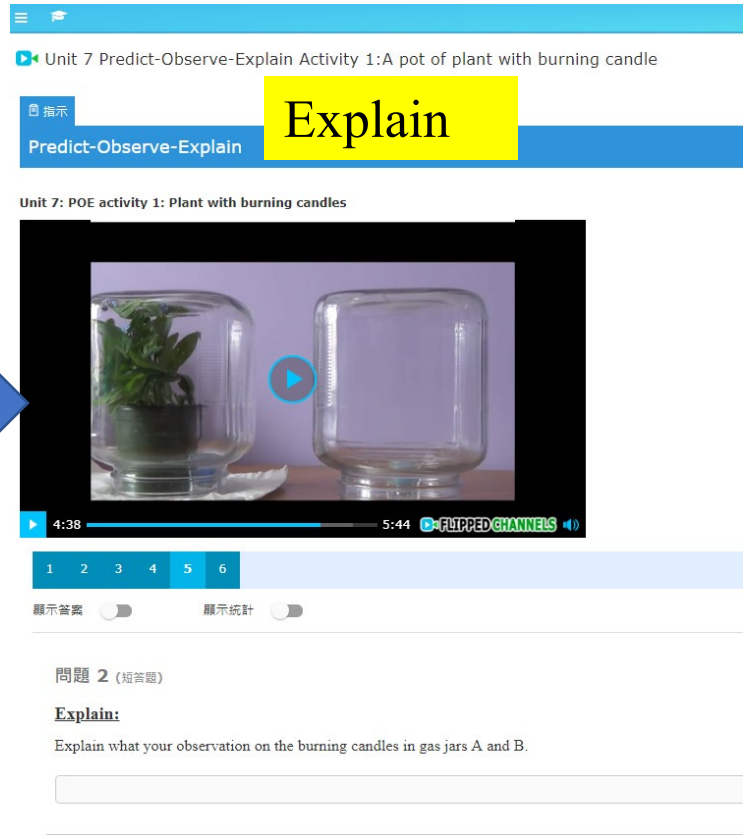
- Research Context
  - Pre-class activities for **FPOE and TFC**: Instructional videos and quizzes



Methodology

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





統計

問題 1 (短答題)

分數: 1 0%

Predict:

Watch the video about **gas jar A (A pot of plant with a buring 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 b[illegible]ut 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

統計

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.

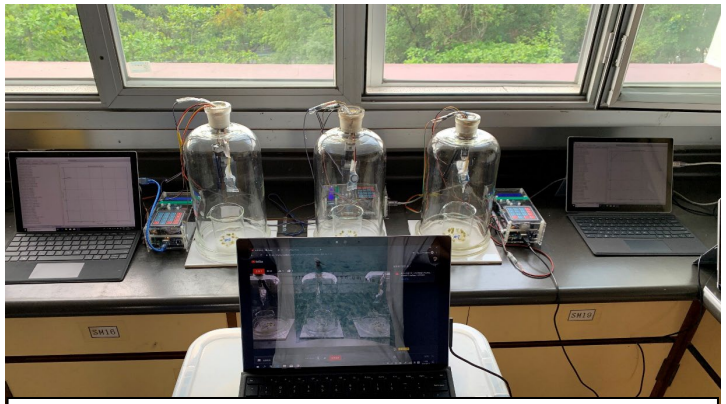
Most students are weak in explaining in a scientific way!

作答總數: 27

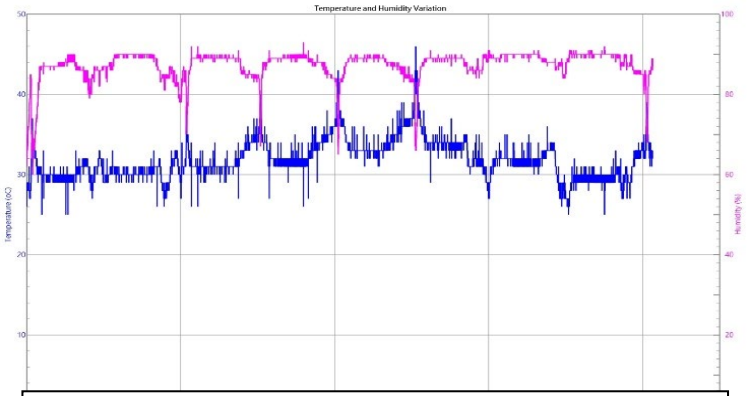
學生		答案	分數
2A - 1	陳朗曦	they wer[illegible]t in different times	0
2A - 2	陳泳嘉	candle in gas jar[illegible]ve oxygen . Candle in gas jars B[illegible] not have oxygen.	0
2A - 3	陳睿孜	The last two will be extinguished	0
2A - 6	張智深	one goes out and one burn	0
2A - 7	張栢明	the burning candle in gas jar A is still burning but the burning candle in gas jar B glows	0
2A - 8	張茵棋	have oxygen	0
2A - 9	莊萬婷	jar a candle melting slower than jar b candle	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 Light out.	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

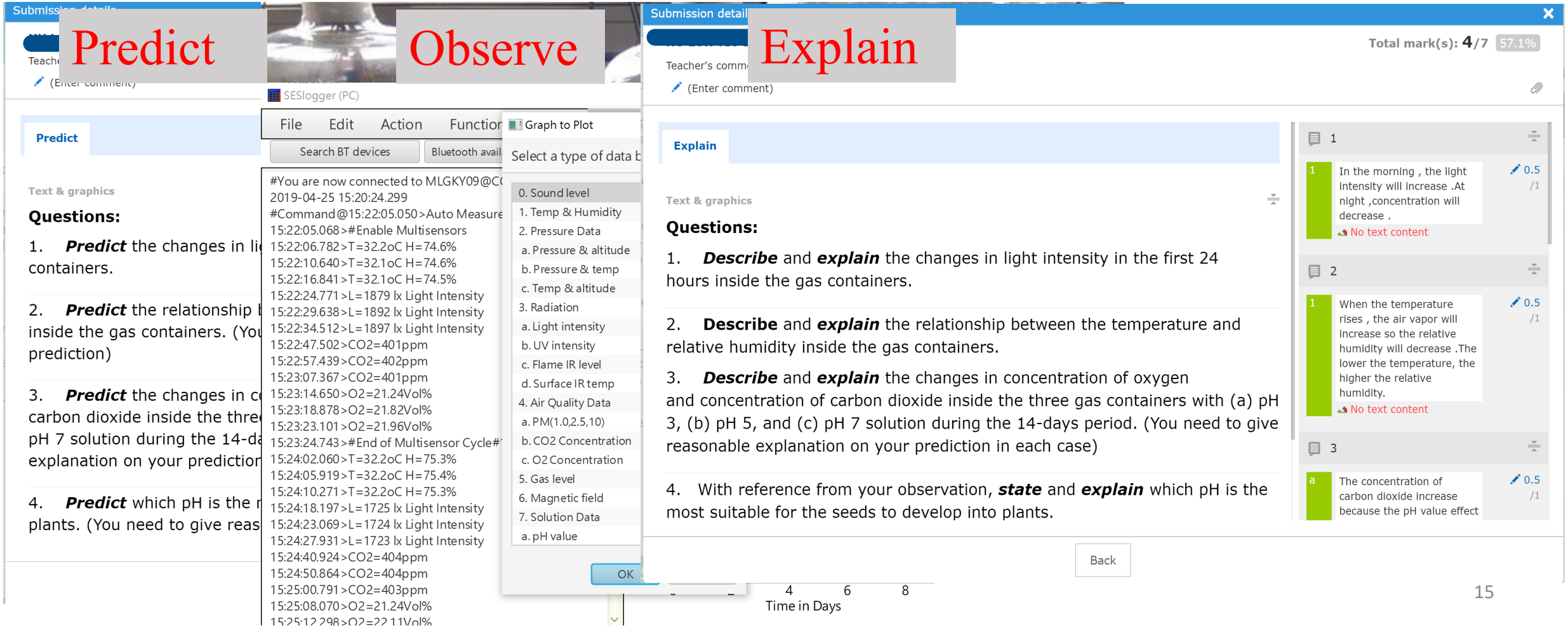


automatic graph-plotting function

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**



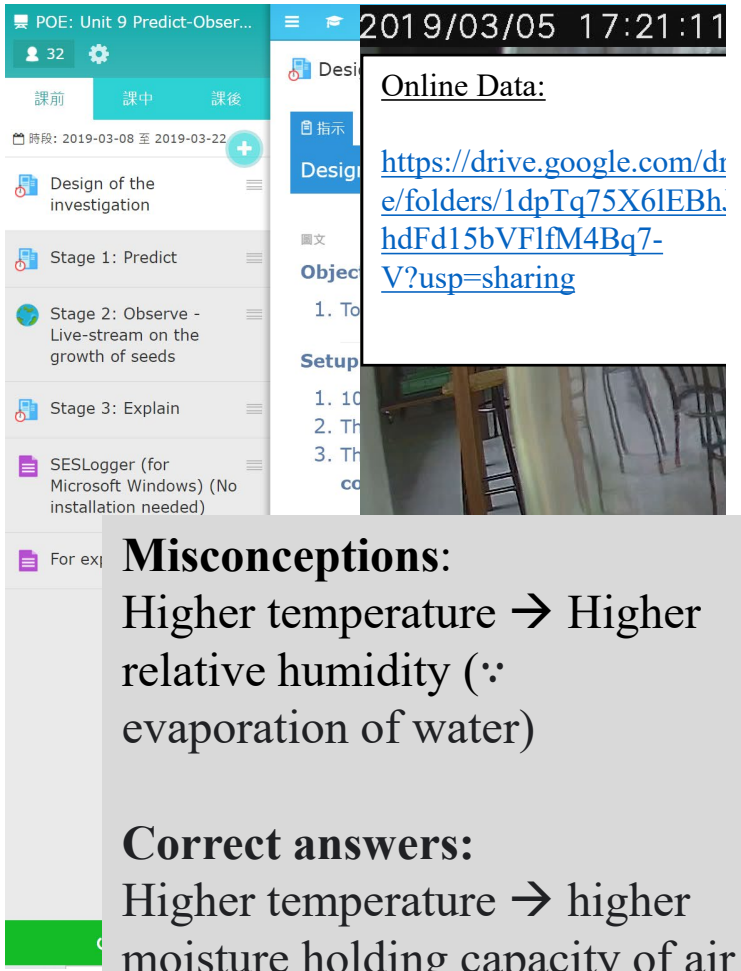
Methodology

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

Predict

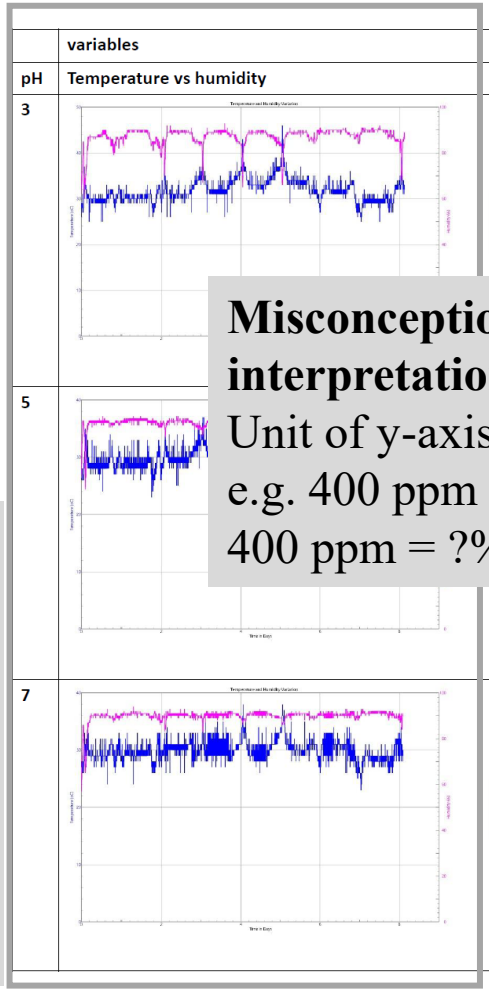
Observe

Explain

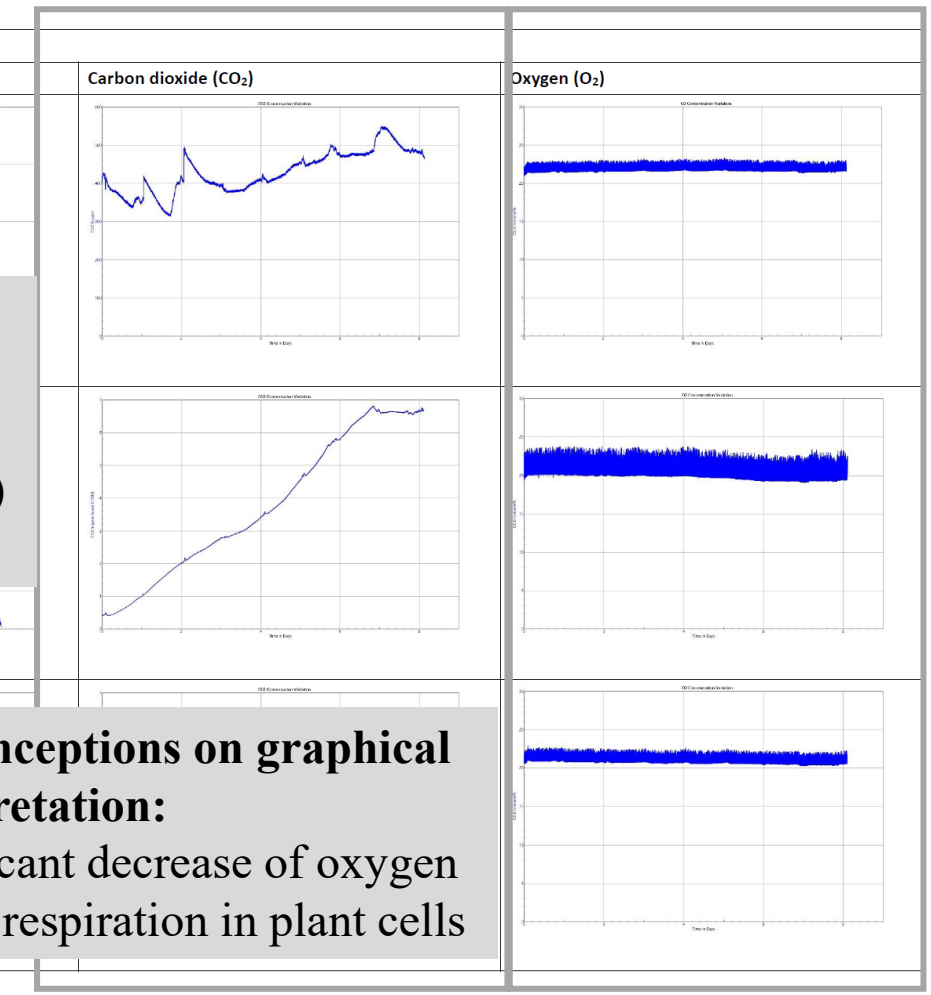


Misconceptions:
Higher temperature → Higher relative humidity (∵ evaporation of water)

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	Out-of-class learning				In-class learning
		POE video*	POE real-time*	Instructional video	Quiz	Scientific inquiry
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

FPOE

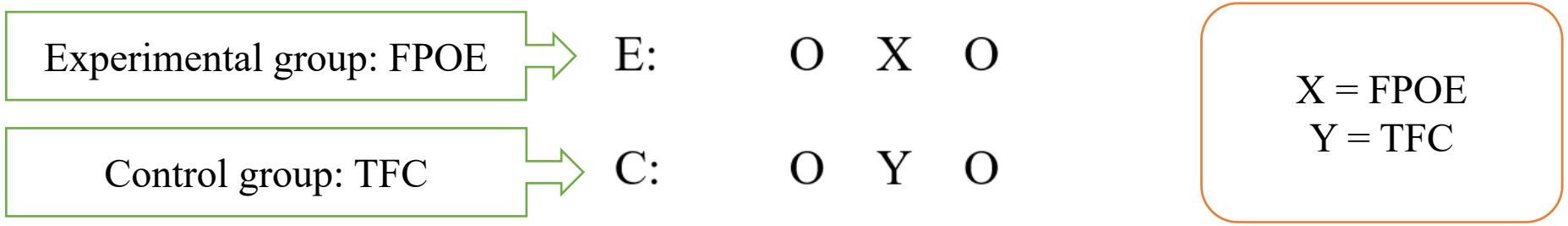
TFC

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

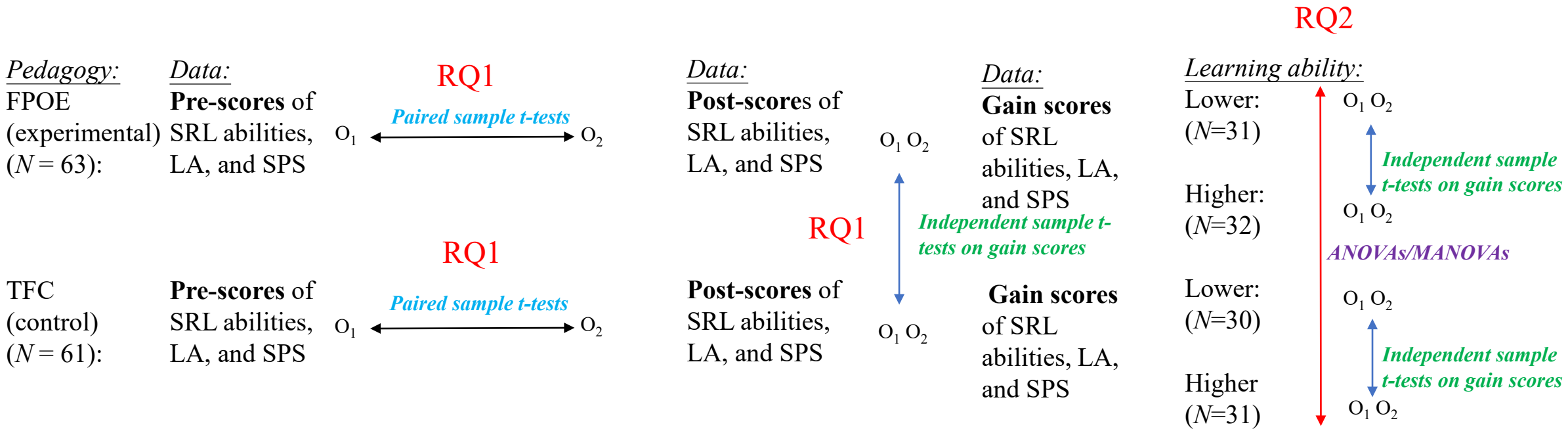
Methodology

- 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 10 fill-in-the-blank questions 2 matching questions 6 structured questions 3 long questions	N/A	.762 .776 .714 .791 .770	.801 .721 .792 .745 .763

Methodology

- Data Collection and Analysis



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 Managment

"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
Category	**Benefits to SRL ability**	**8**	**17**	**25**	**6**	**4**	**10**	**35**
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**	**10**	**20**	**30**	**5**	**12**	**17**	**47**
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**	**20**	**30**	**50**	**6**	**9**	**15**	**65**
	BSPS	***10***	***13***	***23***	***3***	***6***	***9***	***32***
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
	ISPS	***10***	***17***	***27***	***3***	***3***	***6***	***33***
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**	**2**	**2**	**4**	**3**	**3**	**6**	**10**
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			
		Lower ability	Higher ability	Sub-total	Lower ability	Higher ability	Sub-total	Total
Category	**Benefits to SRL ability**	**8**	**17**	**25**	**6**	**4**	**10**	**35**
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**	**10**	**20**	**30**	**5**	**12**	**17**	**47**
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**	**20**	**30**	**50**	**6**	**9**	**15**	**65**
	BSPS	***10***	***13***	***23***	***3***	***6***	***9***	***32***
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**
	ISPS	***10***	***17***	***27***	***3***	***3***	***6***	***33***
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**	**2**	**2**	**4**	**3**	**3**	**6**	**10**
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** ($p = .051$)

Measuremnt

"...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			
		Lower ability	Higher ability	Sub-total	Lower ability	Higher ability	Sub-total	Total
Category	**Benefits to SRL ability**	**8**	**17**	**25**	**6**	**4**	**10**	**35**
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**	**10**	**20**	**30**	**5**	**12**	**17**	**47**
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**	**20**	**30**	**50**	**6**	**9**	**15**	**65**
	BSPS	***10***	***13***	***23***	***3***	***6***	***9***	***32***
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**
	ISPS	***10***	***17***	***27***	***3***	***3***	***6***	***33***
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**	**2**	**2**	**4**	**3**	**3**	**6**	**10**
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			
		Lower ability	Higher ability	Sub-total	Lower ability	Higher ability	Sub-total	Total
Category	**Benefits to SRL ability**	**8**	**17**	**25**	**6**	**4**	**10**	**35**
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**	**10**	**20**	**30**	**5**	**12**	**17**	**47**
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**	**20**	**30**	**50**	**6**	**9**	**15**	**65**
	BSPS	***10***	***13***	***23***	***3***	***6***	***9***	***32***
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**
	ISPS	***10***	***17***	***27***	***3***	***3***	***6***	***33***
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**	**2**	**2**	**4**	**3**	**3**	**6**	**10**
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 / Ability / Type of test	**FPOE / paired[1]**	**TFC / paired[1]**	**gain[2]**
Goal setting	.196	.992	.389
Environmental structuring	.462	.460	.296
Task strategies	.571	.831	.583
Time management	**.036***	.300	.445
Help seeking	.511	.868	.719
Self-evaluation	.104	.341	.539
Average SRL ability	.107	.825	.313
LA	**.000****	**.000****	.744
Observation	.499	.333	.870
Communication	.939	.058	.232
Classification	.123	.257	.057
Measurement	**.000***	.063	.085
Prediction	.076	.272	.605
Inference	.503	.362	.265
Overall Basic SPS	**.035***	.568	**.051**#
Identifying variables	**.000****	**.000***	.199
Stating hypotheses	**.000****	.251	**.000****
Operational defining	**.009***	**.030***	.605
Designing investigation	**.000****	**.001***	.997
Graphing and interpreting data	**.000****	.075	**.037***
Overall Integrated SPS	**.000****	**.000***	**.001***

* = 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			
		Lower ability	Higher ability	Sub-total	Lower ability	Higher ability	Sub-total	Total
Category	**Benefits to SRL ability**	**8**	**17**	**25**	**6**	**4**	**10**	**35**
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**	**10**	**20**	**30**	**5**	**12**	**17**	**47**
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**	**20**	**30**	**50**	**6**	**9**	**15**	**65**
	BSPS	***10***	***13***	***23***	***3***	***6***	***9***	***32***
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**
	ISPS	***10***	***17***	***27***	***3***	***3***	***6***	***33***
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**	**2**	**2**	**4**	**3**	**3**	**6**	**10**
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

		FPOE			TFC			
		Lower ability	Higher ability	Sub-total	Lower ability	Higher ability	Sub-total	Total
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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**	**10**	**20**	**30**	**5**	**12**	**17**	**47**
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**	**20**	**30**	**50**	**6**	**9**	**15**	**65**
	BSPS	***10***	***13***	***23***	***3***	***6***	***9***	***32***
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**
	ISPS	***10***	***17***	***27***	***3***	***3***	***6***	***33***
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**	**2**	**2**	**4**	**3**	**3**	**6**	**10**
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 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***

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
Category	**Benefits to SRL ability**	**8**	**17**	**25**	**6**	**4**	**10**	**35**
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**	**10**	**20**	**30**	**5**	**12**	**17**	**47**
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**	**20**	**30**	**50**	**6**	**9**	**15**	**65**
	BSPS	***10***	***13***	***23***	***3***	***6***	***9***	***32***
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**
	ISPS	***10***	***17***	***27***	***3***	***3***	***6***	***33***
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**	**2**	**2**	**4**	**3**	**3**	**6**	**10**
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

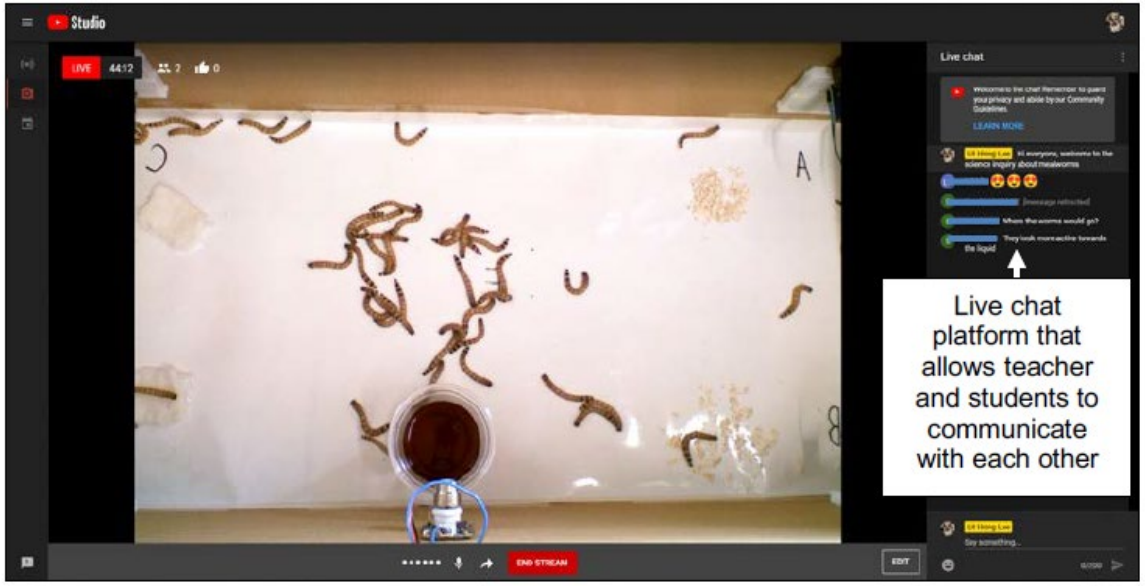

Figure 7. Screenshot of YouTube livestreaming of the remote laboratory studying the gaseous exchange and the effects of different factors on the behaviour of mealworms.

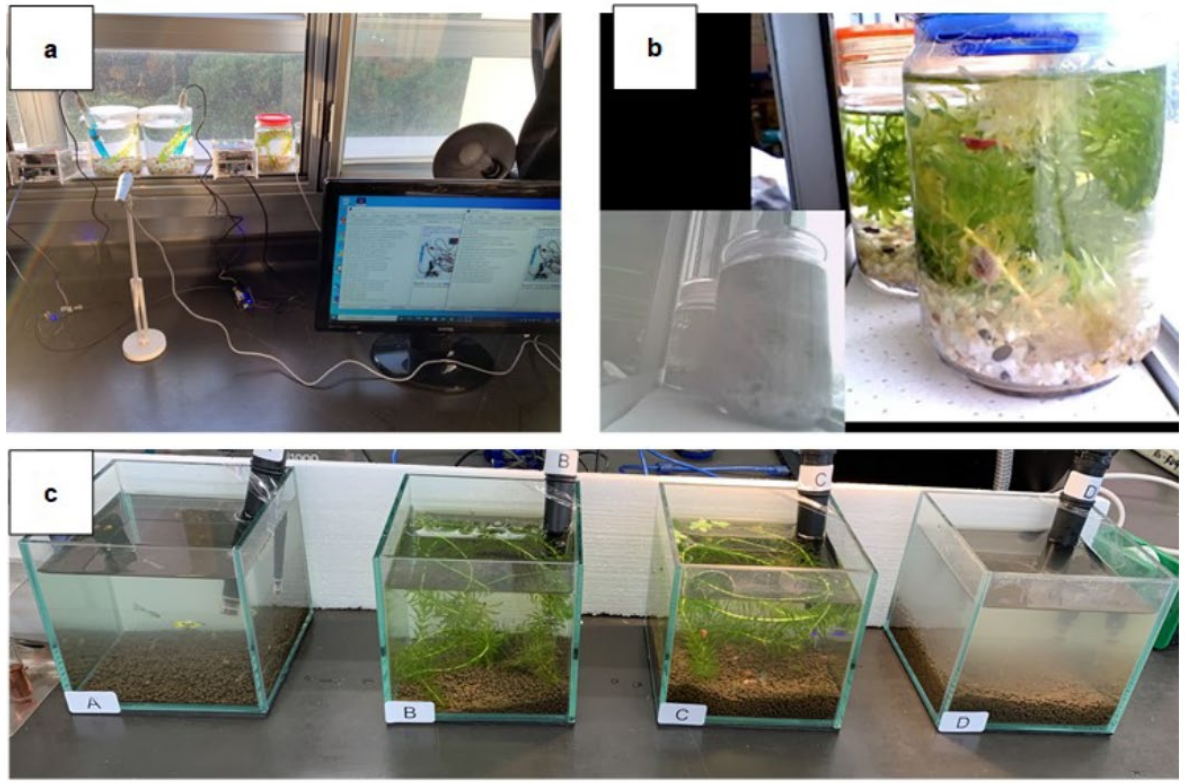

Figure 4. Another example of MFC with the integration of a simplified remote laboratory using two mobile dataloggers: (a) setup of the mobile dataloggers for the MFC in a science laboratory; (b) image of the behaviours of the aquatic organisms during student observations using YouTube livestreaming;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

THANK YOU