A Project Proposal entitled

Developing E-learning Resources to Support Hong Kong Secondary School Mathematics Teaching under Covid-19 Pandemic

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Contents

Abstract Due to the outbreak of COVID-19 pandemic, educational fields in Hong Kong and other parts of the world have encountered unprecedented changes, schools were forced to alter their teaching approach from traditional face-to-face teaching to online teaching. To make better use of online teaching tools, this study attempted to develop a self-directed learning website to teach a senior secondary school mathematics unit. Students were given time to go through the website all by themselves. Compared to their pre-test (*Mdn* = 2), the result indicated that our students (*n* = 36) had made significant improvement in their post-test (*Mdn* = 11) and 2-week delayed post-test (*Mdn* = 11.5). Albeit students are generally positive towards the self-directed learning design, they have also made suggestions on the accessibility and the contents of the materials. Based on the results, we discussed our findings and potential improvements we learned with regards to the design of e-learning tools.

Keywords Self-directed learning・e-learning materials・Mathematics education・Secondary education・COVID-19

1. Introduction

COVID-19 has made a huge impact on education globally. Back then, many schools around the world were shut down due to the skyrocketed number of confirmed cases. Hong Kong was no exceptional case, students in Hong Kong have gone through a few class suspensions, and even a re-scheduled of DSE exam in 2022. In view of the sudden changes in education, schools were recommended to widen the modes of instruction, particularly online learning tools and teaching methodologies, so as to better support student learning's accessibility. To facilitate teachers' application on e-learning, the Education Bureau (n.d.) has collated and published different online resources such as online assessment tools, learning management systems and web conferencing software, to list only a few.

Doubtlessly, the outbreak of the pandemic has brought us unprecedented challenges in educational fields. However, this is also an opportunity to start a new page, and bring our modern teaching into a new era. If you compare things let say cars, phones today with those of a century ago, there are always significant differences. But if you compare the teaching approaches across the world now from a hundred years ago, there seems to have been tiny changes. Students are still sitting in front of a blackboard, listening to the teacher. We are now living in a post-pandemic world, where our living styles are gradually returning to

normal, so as our education. However, because of the pandemic, students all around the world are so used to e-learning. Would it be a chance for educators to consider making good use of those e-tools, and integrate it to their traditional (face-to-face) teaching? This study aims to address this very question.

In this study, a self-directed learning approach was adopted to teach a senior secondary school mathematics unit (Locus). A website with software embedded was created and adjusted based on suggestions made by in-service teachers. The website was then provided to students for self-directed learning , and tests were given to them to examine their understanding as well as the effectiveness of the teaching approach. The following research questions (RQs) guided the study:

- RQ1: How do in-service teachers evaluate and make suggestions on the e-learning materials introduced in this research?
- RQ2: Are the materials effective/useful to students on understanding the topic?

2. Theoretical Foundation

The foundation of the e-learning resources is on a flipped learning basis. That is, we expect the resources to be released to students before or after the class as an introduction/consolidation of a certain topic. According to Lo, Hew and Chen (2017), flipped learning allow students to learn at their own pace, students could stop at any time to understand and think of the concept; unlike the traditional class, whereas teacher need to take care of many students at once, and inevitably neglect (unable to express many help) students that are relatively low capable.

The development of e-learning resources will be evaluated based on the Experiential Learning Theory (ELT) proposed by educational psychologist John Dewey and Jean Piaget, which was later made popular by David A. Kolb. According to Kolb (2012), Learning is a process whereby knowledge is created through transformation of experience. The ELT regarded the process of learning as a four-stage cycle, namely the concrete experience, reflective observation, abstract conceptualization and active experimentation. They are arranged in no particular order such that we may start the process of learning in any stage from time to time. The learning process can be regarded as an ideal learning cycle if one could go through all four stages. According to Kolb, one must be able to:

- Concrete experience: Involve themselves fully, openly, and without bias in new experiences
- Reflective observation: Reflect on and observe their experiences from many perspectives
- Abstract conceptualization: Create concepts that integrate their observations into logically sound theories
- Active experimentation: Use these theories to make decisions and solve problems

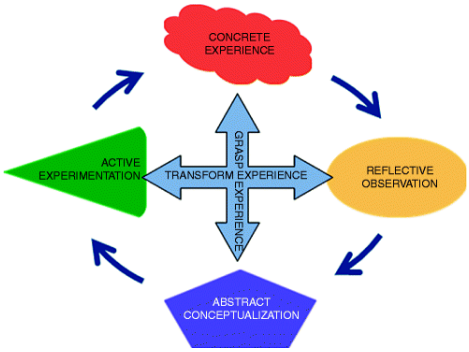


Fig.1: Kolb's Experiential Learning Cycle (Kolb & Kolb, 2012)

In addition, Abeysekera and Dawson (2014) suggested that students' motivation in learning can be boosted with the support and implementation of self-determination theory. For instance, when designing flipped materials, one should take students' psychological needs in autonomy, relatedness and competence into account. In terms of autonomy, this paper proposes to develop the e-learning resources through GeoGebra platform, a famous, worldwide free online platform that allows users to represent equations in dynamic, programmable graphs. When accessing the e-learning resources, student can easily manipulate the application and freely explore the concept by adjusting the variables of a certain equations, thus raising the autonomy in terms of students' learning process, and resonating the theoretical work by Morris (2020), the importance of making physical contact with the learning objects itself. Also, from Leung's finding in 2011, the dynamic courseware enables students to explore the mathematical concepts as an experimental environment to manipulate, which also serve as a concrete experience stage in Kolb's theory. On the other hand, the e-learning resources hope to wrap up the mathematics concepts into real-life applications in suitable topics (e.g., topics related to Locus), so that students could closely relate the mathematics concepts into their real-life applications. Furthermore, in terms of supporting students' competence; activities and assessments should be "optimally challenging" (Niemiec & Ryan, 2009). Therefore, the questions in the e-learning resources

should be variated in terms of difficulty, thus satisfying the needs of students with different capabilities.

3. Research Method

3.1 Research Context and Participants

This study was conducted in Hong Kong during the COVID-19 pandemic (February 2023), involving in-service teachers (Cycle 1, $n = 3$; Cycle 2, $n = 9$) to make evaluation on the e-learning materials and Grade 11 (i.e., Secondary 5 in Hong Kong curriculum) students ($n = 36$) from two classes, an intermediate class (Class A) and an M1 class (Class B) in a band one EMI local secondary school to test the e-learning materials. The participants were invited through convenient sampling.

3.2 The e-learning Materials Design

Figure 2 indicates the procedures of the research. The research is sub-divided into 2 stages. The first stage includes the design and the refinement of the e-learning materials. The materials were integrated and presented as a website through Google Sites with GeoGebra activities and other e-learning software embed. One fundamental topic "Locus with Fixed Distance from a Fixed Point" and one advanced topic "Locus of Equidistant from Two Fixed Points" from a senior secondary school mathematics unit (Locus) were introduced in the website. The resources include: (1) A brief summary and exercises of related topics in previous chapters, (2) Introduction of the concepts and related examples/instructional notes and (3) Graded assessment tasks. Inspired by Lo et al. (2021), the worksheet also included a brief introduction and user manual of the e-learning resources to help students with little experiences on the related e-resources (i.e., GeoGebra). Upon completion of the development, the materials were sent to in-service teachers for evaluation, refinements were made based on their comments. The process of refining the materials and enquiring teachers to make evaluation looped for 2 rounds. The duration for stage 1 was 2 weeks.

The second stage includes the actual testing of the e-learning materials which aims to evaluate if the materials are effective to promote students' understanding of the topic. The materials were sent to students for self-study. Tests and interviews were conducted to students for data collection. The duration of stage 2 was 2 weeks.

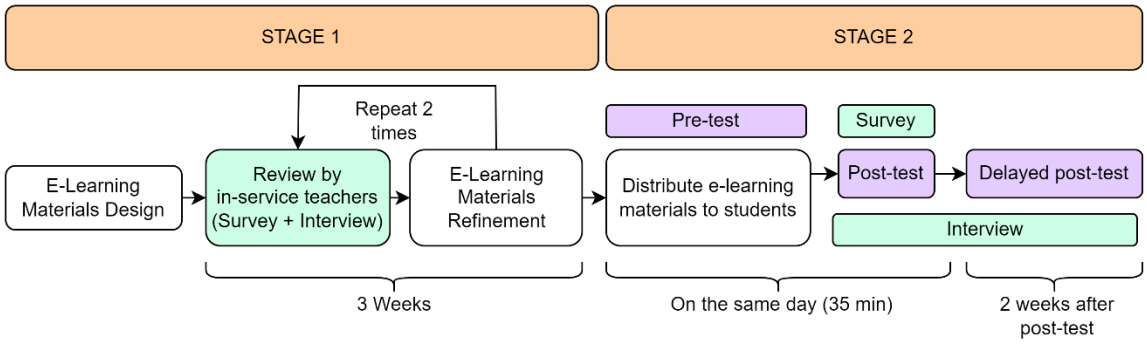


Fig.2: Research Procedure and Data Collection Flowchart

3.3 Data Collection and Analysis

3.3.1 Teacher Survey and Interview

To answer RQ1, a teacher survey was designed and distributed to in-service teachers (n = 7) who participated in the research, so as to examine their perceptions on the e-learning materials and potential improvements. The survey was carried out through Google Forms to facilitate data collection. A 5-point Likert scale was adapted, ranging from 1 (Poor) to 5 (Excellent). The result of the survey is presented in a descriptive manner (See Table 3).

All in-service teachers (n = 9) participated in the research were invited to make comments and evaluate on the design of the e-learning material. The interview consists of two rounds, the purpose of the first-round interview (n = 3) was to make comments on the original version of the e-learning materials, whereas purpose of the second-round interview (n = 9) was to make comments on the modified version of the e-learning materials after the first round. According to Creswell and Plano Clark (2011), employing a semi-structured interview approach helps explain the results of quantitative data.

The analysis of the interview data was based on the procedures of Creswell (2012), which enables identification of the data and provides insights. For reporting purposes, the data were translated from Cantonese into English.

3.3.2 Tests

To answer RQ2, a pre-test, an immediate post-test, and a 2-week delayed post-test were introduced to examine students' learning progress. The delayed post-test was designed to assess students' memories on the topic. Students were given 15 minutes to finish each test with a possible range of scores from 0 to 18. For each sub-topic introduced in the e-learning materials, the test consisted of one curve sketching problem (2 marks), one fundamental problem (3 marks) and one advance problem (4 marks). In terms of the scope and difficulty level, the questions in all three tests were similar, with numbers variated from test to test. As for illustration, Table 1 listed the questions of "Locus with Fixed Distance from a Fixed Point" of the pre-test.

In order to analyse the differences in scores among the tests, Kolmogorov-Smirnov test (KS test) was first conducted to examine the normality of the datasets. Since the result of the KS tests (Table 2) indicated that the significance level of both the pre-test and delayed post-test data were <0.05, which violated the normality assumption, Friedman's ANOVA, a non-parametric test designed to compare the differences among related datasets, was used and conducted at a 0.05 significance level alpha (Field, 2009). With significant difference spotted, multiple ($n = C_2^3 = 3$) Wilcoxon signed–rank tests were run to perform pairwise comparisons as a non-parametric post hoc procedure. However, to avoid Type I errors, a Bonferroni correction had to be applied (Field, 2009). The significance level of the post hoc analysis was hence corrected to 0.05/3 = 0.0167. Suggested by Field (2009), to access if the effect is substantive, the effect size (r) was calculated through the formula $r = \frac{z}{\sqrt{N}}$, where z refers to the z-score and N refers to the total number of participants between two datasets. The benchmarks for the effect size (r) are 0.1, 0.3, and 0.5, resonating to a small, medium, and large effect respectively.

Since Class A (intermediate class) has a worse result in the delayed post-test compared to their post-test, and Class B (M1 class) has improvement from the delayed post-test; the aforementioned tests were also run separately for horizontal comparison between two classes.

Apart from analysing score differences, to better understand how students perform in different topics, the scores from the tests were also sorted and summed up by topic to examine if the difficulties of the topic affect the effectiveness of self-directed learning in such a setup.

Question number	Question type	Question
Q1(a)	Curve Sketching	In the rectangular coordinate system, a moving point *P* maintains a fixed distance of 3 units from a fixed point *A*(2, 3). **(a)** Sketch the locus of *P*.
Q1(b)	Fundamental Problem	**(b)** Find the equation of the locus of *P*.
Q2	Advance Problem	A moving point *P* maintains a fixed distance from *A*(3, 4). Find the equation of the locus of *P* if the locus passes through *B*(–1, 0).

Table 1: Example Questions Used in the Pre-test

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
Pre_Score	.255	36	<.001
Delay_Score	.157	36	.025
Post_Score	.117	36	.200*

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 2: Kolmogorov-Smirnov Test of the Mixed Dataset

3.3.3 Student Survey and Interview

To answer RQ2, a student survey was distributed to students (n = 22) who participated in the research, so as to examine their perception on the e-learning materials and the user experience. In the exploration of the dataset collected from the teacher surveys, we found that the Cronbach's alpha was 0.78 > 0.7, indicating a satisfactory reliability (Field, 2009). Hence, most of the questions from the teacher that survey were reused (See Table 8).

To better understand the result of the quantitative data, inspired by Creswell and Plano Clark (2011), a semi-structured interview was conducted to six students, they were selected to make evaluation on the e-learning materials on a non-probability sampling basis that their test scores in the delayed post-test were near the lower-quartile, median and upper-quartile of the population (n = 2 for each classification). This ensure a better understanding of the user experience from student at different capabilities.

The analysis of the interview data was based on the procedures of Creswell (2012), which enables identification of the data and provides insights. For reporting purposes, the data were translated from Cantonese into English.

4. Results

RQ1: How do in-service teachers evaluate and make suggestions on the e-learning materials introduced in this research?

The result of the two instructional cycles is reported independently in the following subsections. Table 3 summarized the survey result collected from teacher participants (n = 7). The data indicated that the teachers were generally satisfied with the resources. To better understand the result of the survey, a semi-structured interview was conducted to each teacher, they were asked to go through and review the e-learning resources part by part.

Cycle 1: Adjustment required

In cycle 1, the teacher participants (n = 3) all agreed that the design of these e-learning resources is useful. According to teacher 1.2, "Such design allows students to work on mathematics with their hands" The benefit of using dynamic online courseware (i.e., GeoGebra) was specifically mentioned by all three teacher participants. Teacher 1.1 mentioned, "The GeoGebra application is a good avenue for students to actual manipulation on the questions.".

Accuracy and Visual Appeal

Teacher participants are generally satisfied with the layout of the resources. Teacher 1.2 mentioned "I think the content organization is good, you have mentioned what students are expected to learn at the homepage.".

However, teachers have pointed out several typos in the resources. For example, Teacher 1.1 pointed out that there is a typo in Section 1.4, "through" was miss spelt as "throught". He later found out that the use of words was also not accurate, " In worksheet 2.4 question 1, the description should be "the locus of *P* passes through *M*" instead of "*P* passes through *M*". As *P* is a moving point; it is the locus of *P* who passes through other coordinates. You should be aware of the use of phrases.". Along with the above typos and use of phrases, several changes such as changing from "Calculate the equation" to "Find the equation of the locus" have been made to increase accuracy and avoid clumsiness. The example of the changes is presented in Figure 3.

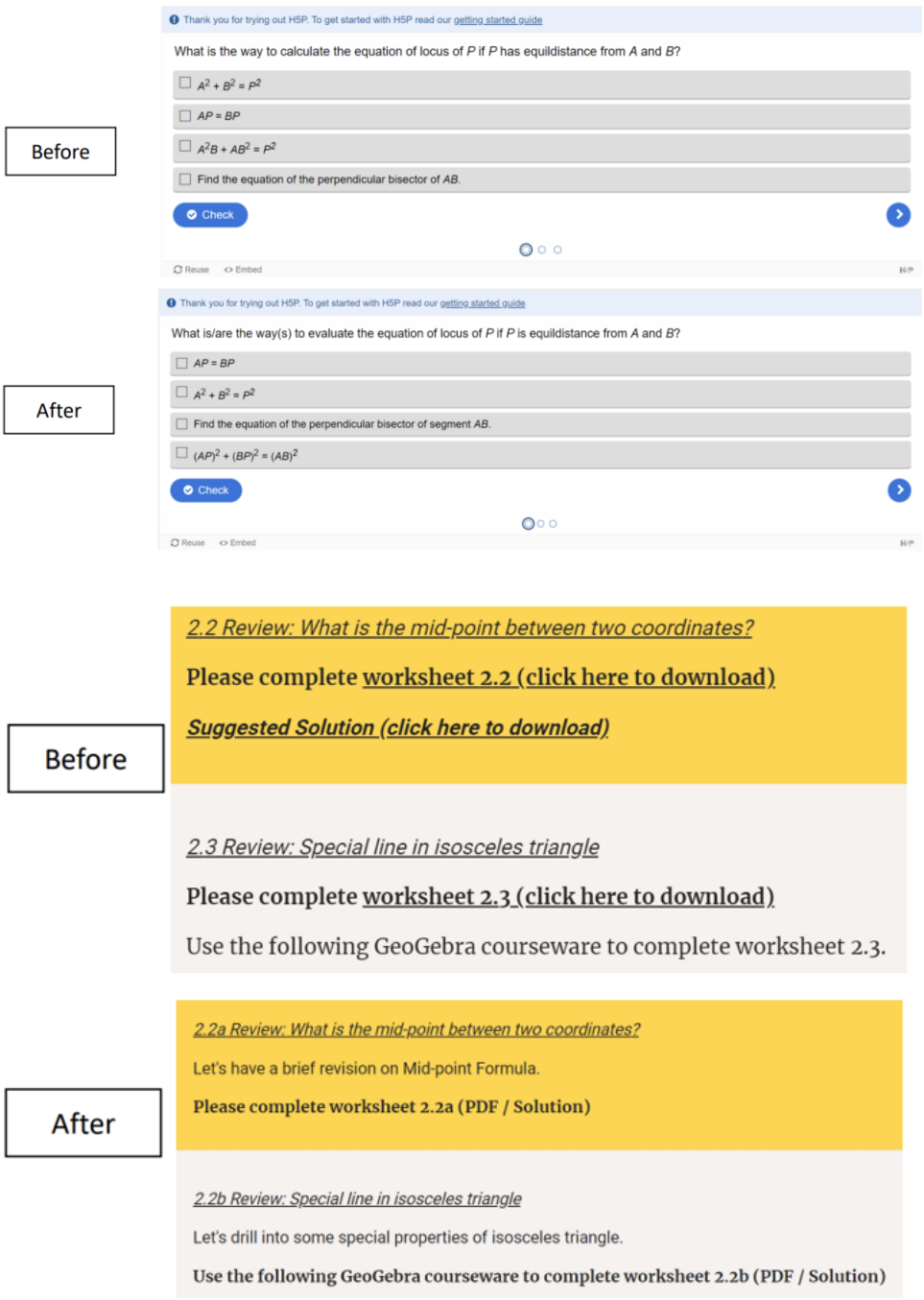


Fig.3: Example of Changing Phrases to Increase Accuracy and Avoid Clumsiness

Alignment to standards and depth of knowledge

Teacher participants were generally satisfied with the depth of knowledge. However, in the word of Teacher 1.1, “This option in Section 1.4 is kind of weird. "$AP^2 + A^2P = 5$" , they should have never seen such an equation, this may confuse them. I am afraid that they will have this equation on their memories and use it during their exams, you better use some actual equations that they have seen but are wrong to this question. You should work out the

answers based on their misconceptions, rather than making up random equations." (See Figure 4). The teacher also pointed out that "it is better to reinforce to students what is the expected presentation of the questions (e.g., Let $P = (x, y)$) in your application" (See Figure 5).

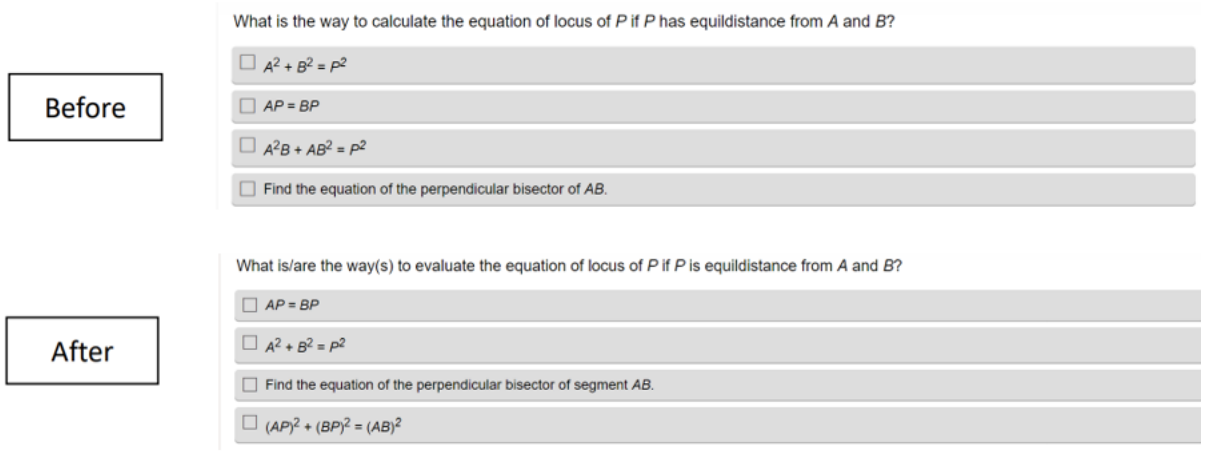


Fig.4: Example of Redesigning Answers to Better Fit the HKDSE Curriculum

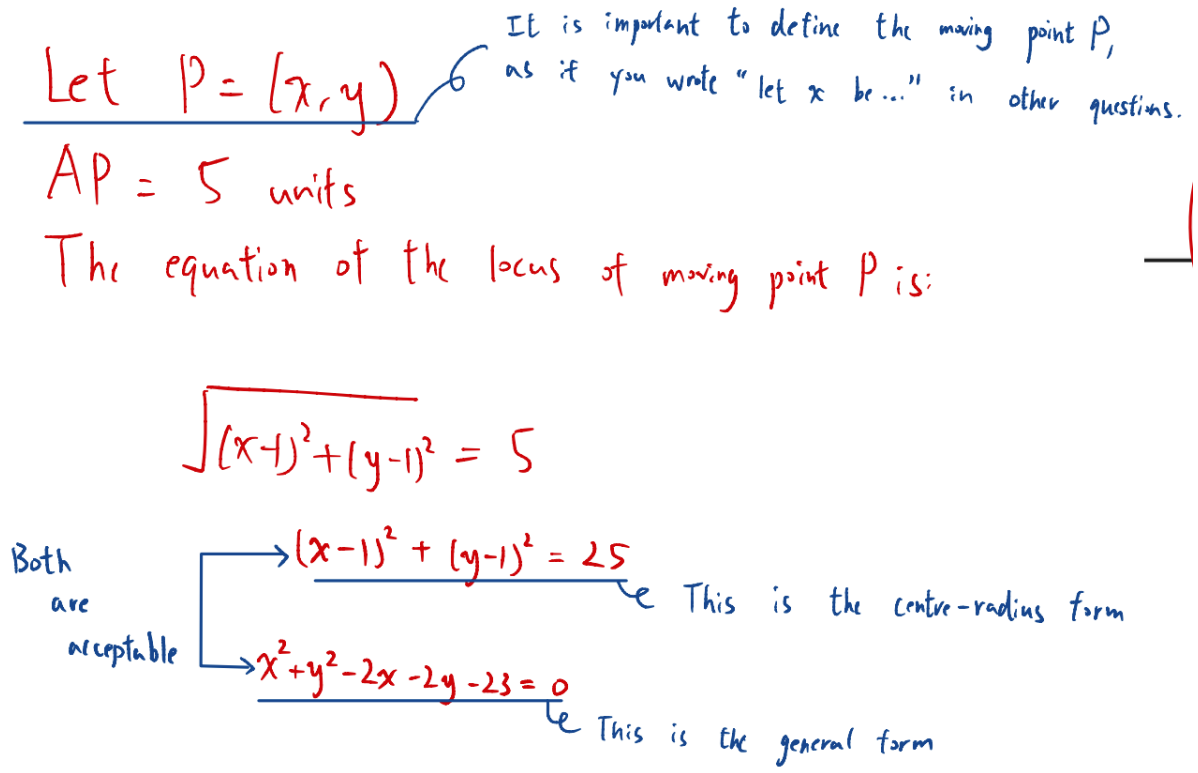


Fig.5: Reminders of Formatting in the Solutions of the Worksheets (Highlighted in blue)

Ease of use and support

Teacher participants generally agree that the ease of use and support was good. However, Teacher 1.3 suggested that "You may also mention to students that there is another way to find the locus on the website, rather than mentioning it on the software only, as students may not always go through every page of your content and they may miss out the information." Hence, a short summary was added below Section 2.1 (See Figure 6).

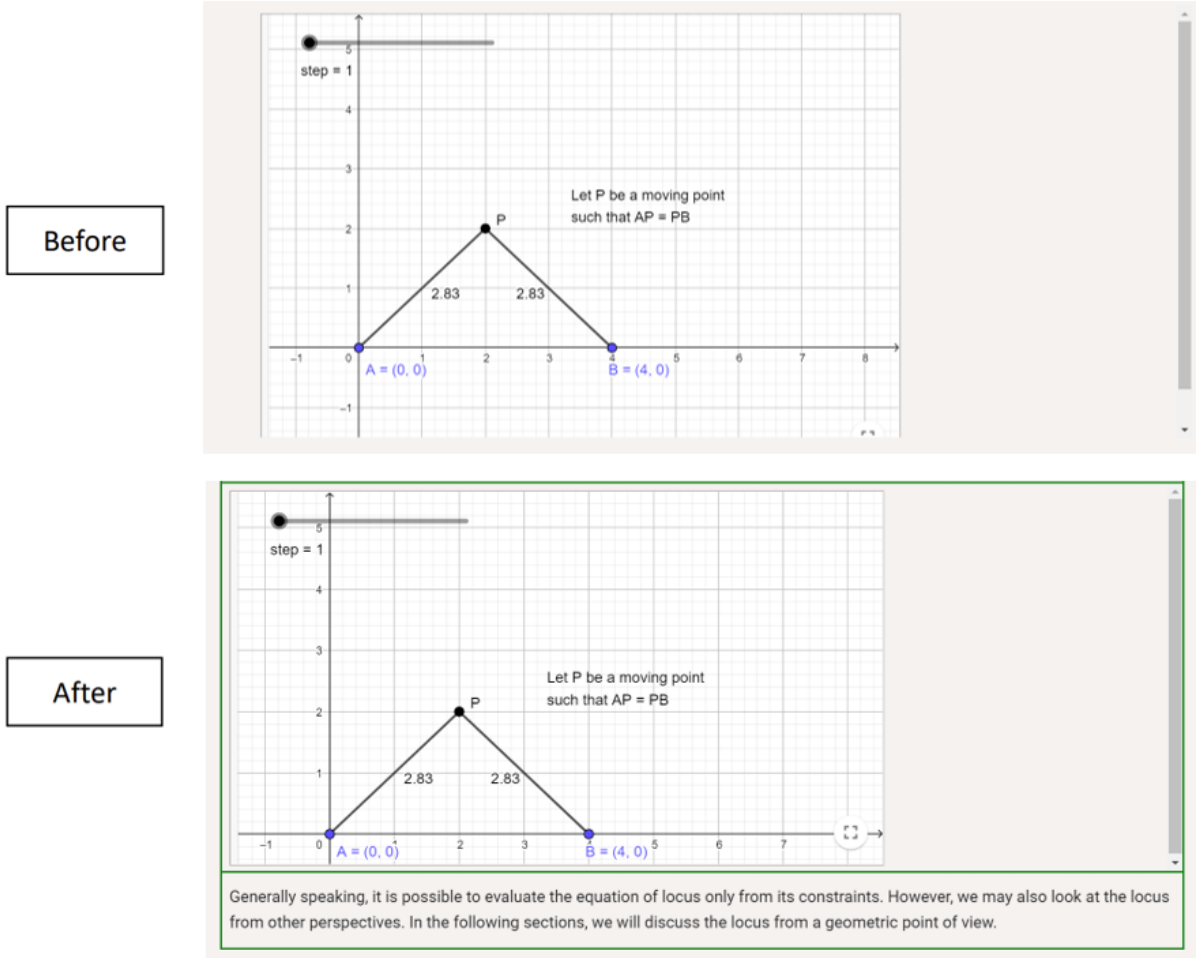


Fig.6: Short Summary Added below Section 2.1

Engagement and ability to meet student needs

The teacher participants generally agreed that the materials are a bit demanding as a pre-class self-learning. They pointed out that more guidance should be included in the question design. For instance, Teacher 1.3 suggested that "In the coordinate system, you may try to also include a few fixed points to students, and show them the moving point *P* will also pass through those points. Students can take it as a stable stone to conceptualize more

complex concept, i.e., the coordinate $P(x_B, y_B)$." (See Figure 7). Teacher 1.3 also suggested, "you may also include the alternative method in the solution of Section 2 exercise." (See Figure 8). Apart from teacher advices, the supervisor of the study also pointed out that it will be great if a GeoGebra is added in the first page to notify students what are to be expected in the section and also provide active experimentation (See Figure 9). The order of the section "Concept checking" can switch the order with "Exercise" to clarify students' concepts with instant feedback provided (See Figure 10).

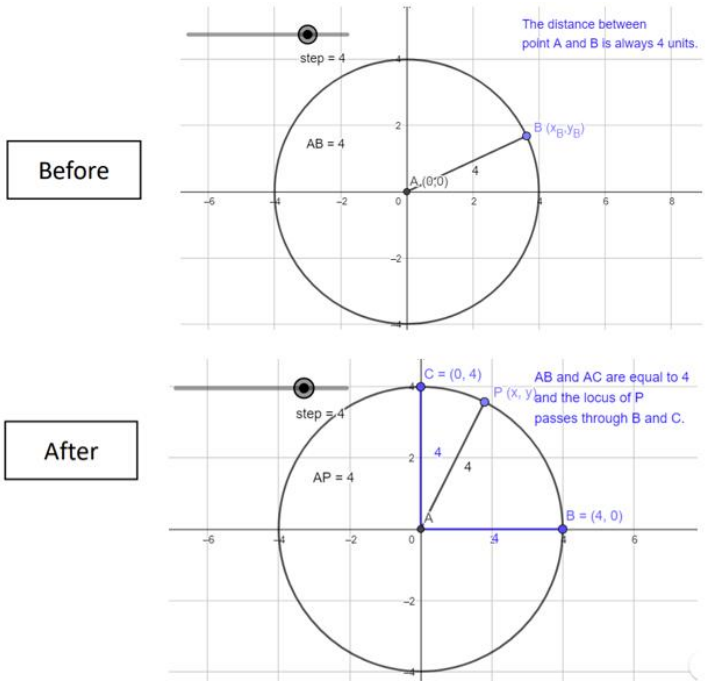


Fig.7: Redesign of the Questions

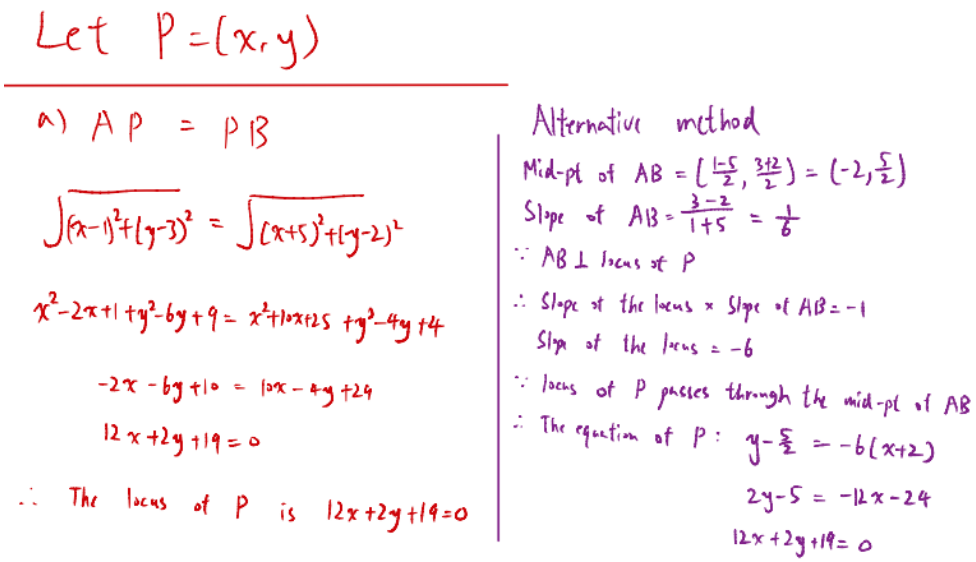


Fig.8: Alternative Solutions Introduced in the Worksheet

Before

In this section, you will get to know about the shape and equation of locus of equidistant from two fixed points, with supplementary trainings given.

After

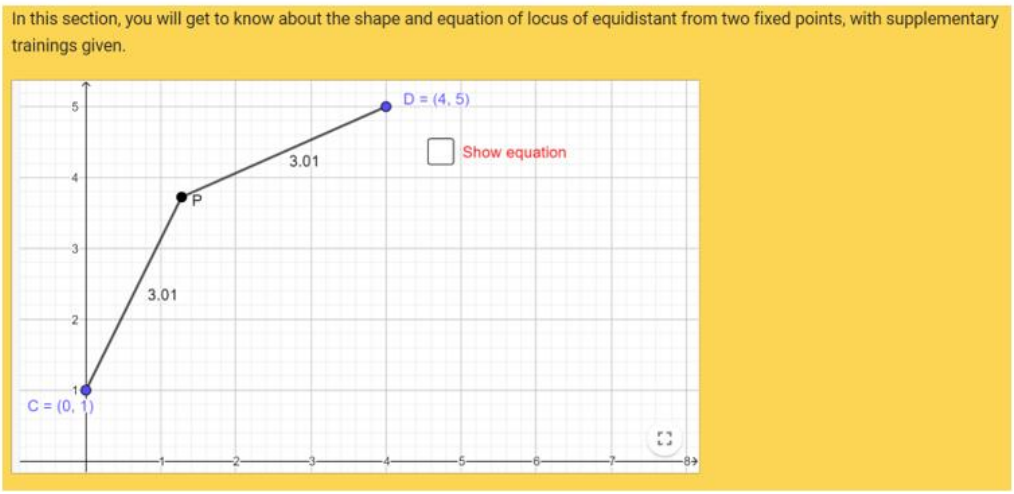
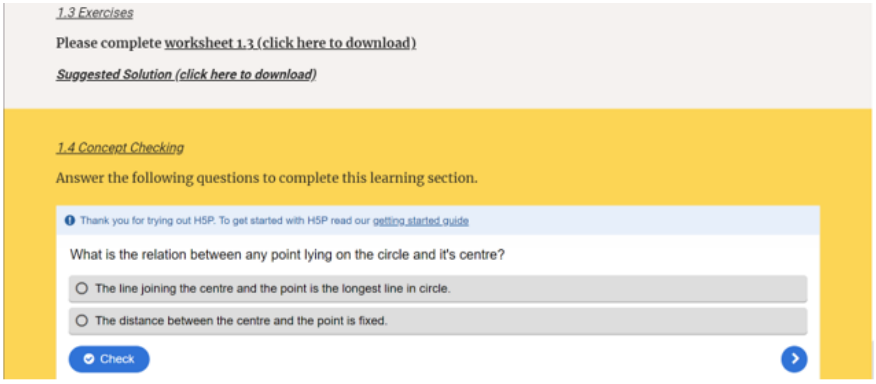


Fig.9: GeoGebra Application in the First Section

Before



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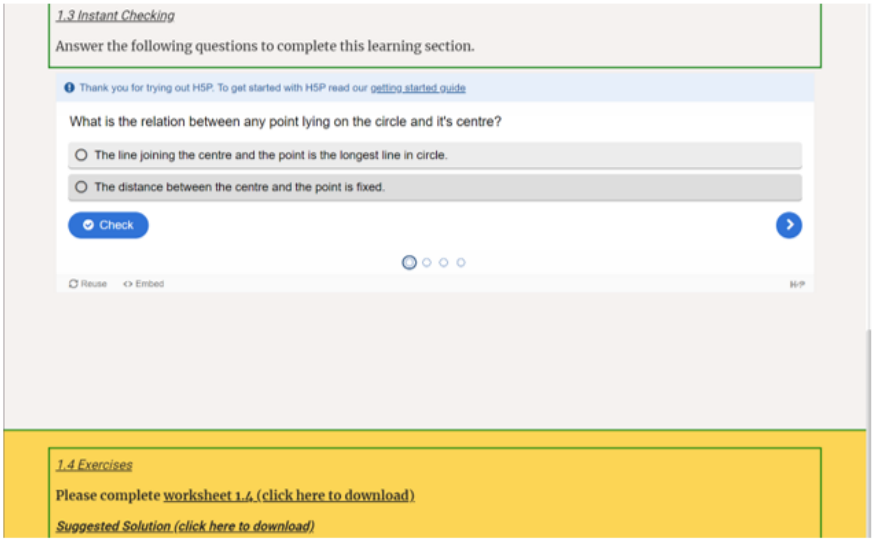

Fig.10: Change of Order between “Concept Checking” and “Exercises”

Compatibility of content on multiple devices

Teachers generally agreed that the compatibility of the GeoGebra software is not ideal, as the embedded window was easily distorted. In the words of Teacher 1.2, "As to my observation, the website is smooth on iPad. However, other devices such as mobile phones might face compatibility issues, the size of the GeoGebra software is not adjustable." To tackle the problem, the dimension of the GeoGebra software was adjusted to 700 × 400 (was 700 × 600) to increase the width to length ratio, so that the shape of the software is more close to modern monitors (16:9 ratio), thus lowering the frequency of distortion (See Figure 11). Apart from that, teachers also pointed out that it is not ideal to use fill in the blanks questions due to their case sensitivity problem, the questions were hence altered to multiple choices (See Figure 12).

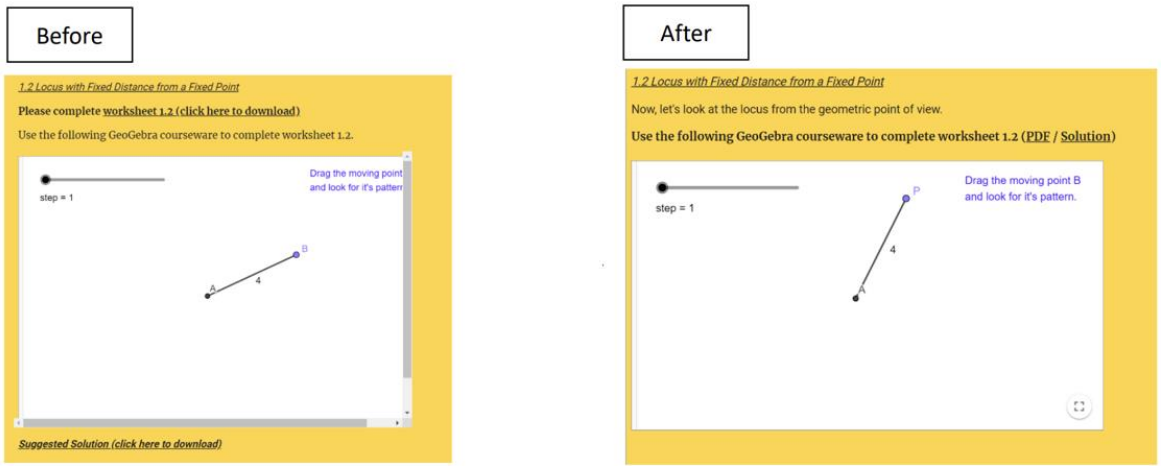

Fig.11: Dimensions Adjustment of the GeoGebra Software

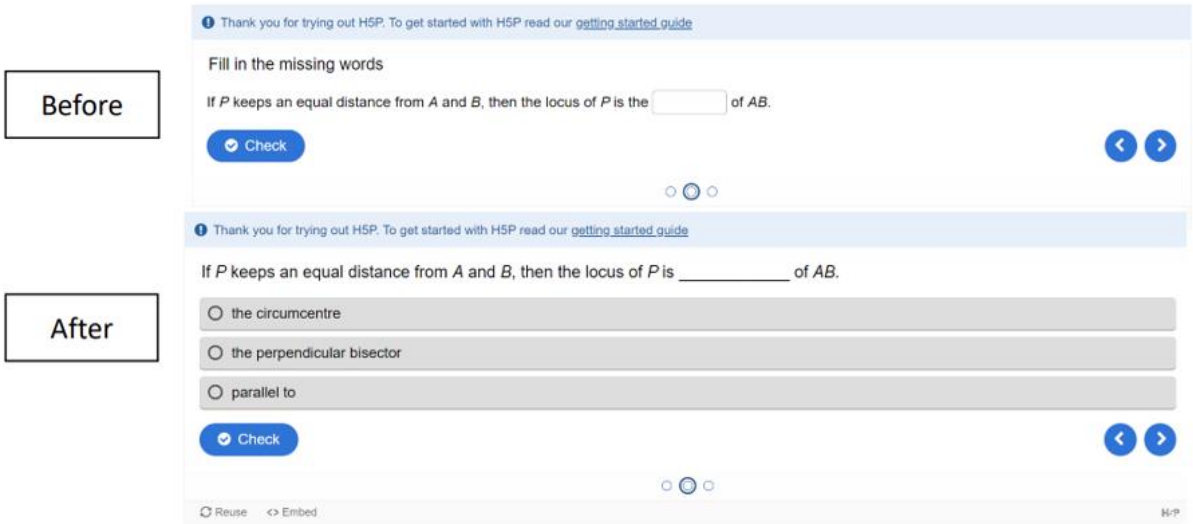

Fig.12: Restructure of the Question Design

Cycle 2: Introducing new dimensions

In cycle 2, including the teachers who participated in cycle 1, six more teachers were invited to participate in the study. The total number of participants were increased to nine. In the words of Teachers 2.3 “This is the second round of the review. Fletcher has modified the sections that I suggested him to modify, and the resources are now more completed.”. However, new teacher participants have brought some new dimensions into the resources. Including some minor refinements of the materials, several new parts were created in cycle 2.

Accuracy and Visual Appeal

Teacher participants were generally satisfied with the resources in terms of this aspect. For example, Teacher 2.8 mentioned, “I think the flow of the worksheet is good. The difficulty is appropriate, with enough guidelines and instructions.”. However, minor mistakes such as typos and wrong use of phrases were created when modifying the variables in the GeoGebra. For instance, Teacher 2.8 pointed out that there is a typo in Section 1.2, “point *P*” was misspelt to “point *B*”, and Teacher 2.5 pointed out that there was a wrong use of phrases in Section 1.2 (See Figure 13)

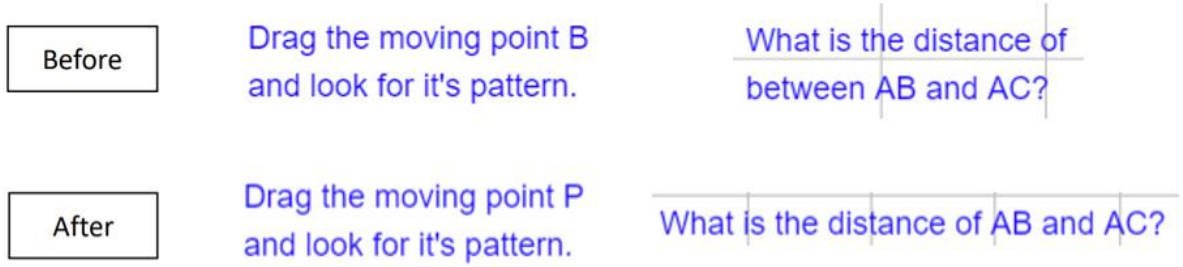

Fig.13: Minor Mistakes Created when Modifying the GeoGebra Application in Cycle 1

Alignment to standards and depth of knowledge

Teacher participants generally agreed that the resources are closely related to the HKDSE curriculum. When commenting on the resources, Teacher 2.8 even commented “In real-time practice, I will treat it as an exercise to my students.”. In addition, Teacher 2.1 also noticed the change of the answer designs, “I noticed that you have also modified the equations that you make up as a distractor to equations that are related to the DSE curriculum, which is more reasonable now.”. As there was no suggestion in this aspect, no modification was made in this cycle.

Ease of use and support

Teacher participants reflected that the instructions are not clear enough. For example, in the words of Teacher 2.6, “I think it will be better if you include more text-based instructions on the homepage.”. Teacher 2.8 also advised that “If you want the students to go through Section 1 before Section 2, you should emphasize it on the first page.”, and Teacher 2.7 suggested that “The distance you showed in your GeoGebra software are approximate value, it will be better if you also mention this to students.”. Figure 14 summarized the changes.

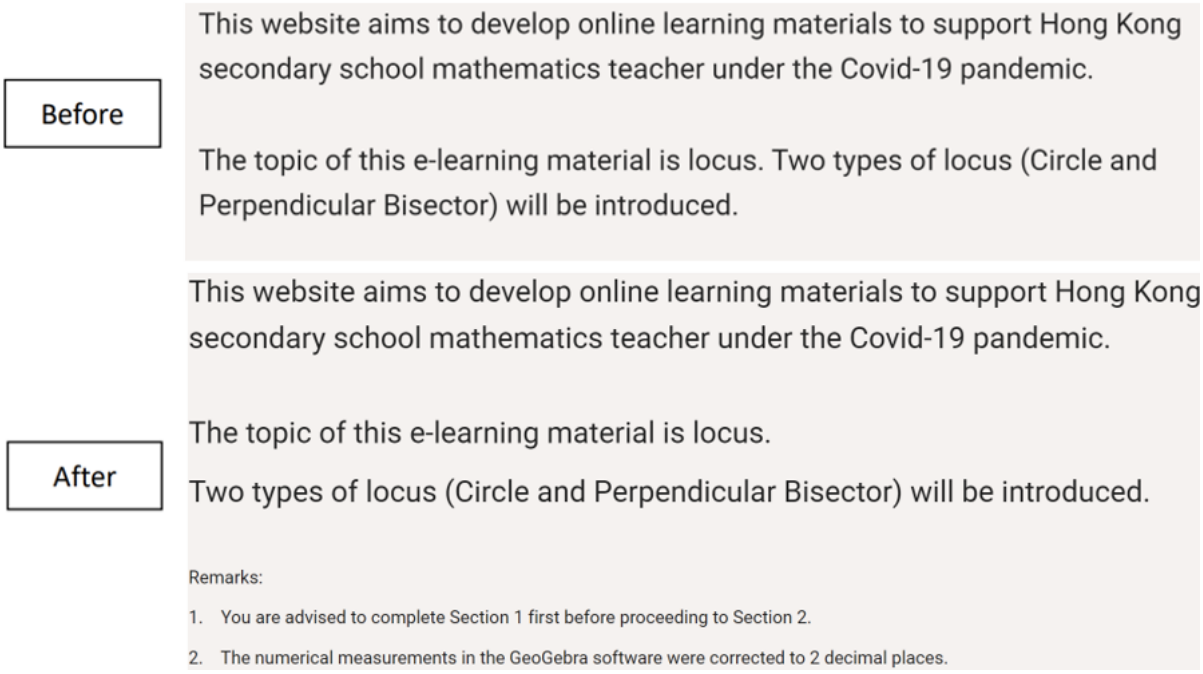

Fig.14: Instructions Added in the Homepage

Engagement and ability to meet student needs

Teacher participants reflected that some of the contents were still too demanding for self-study. For example, in the words of Teacher 2.5, “When finding the locus of keeping equidistance from two fixed points, to my experience, this is not very trivial to students. If you restrict the movement of the moving point, students may get confused why they are not allowed to move the point in other ways. You may consider creating another version that allow student to freely adjust the point *P*, so that they can relate when will the point *P* maintain an equidistance from two points. You are kind of limiting what students can observe here, even though your information were correctly provided and were indeed the information

you want them to know, but it would be better to let them explore themselves.". Therefore, the GeoGebra software was redesigned (See Figure 15). In cycle 1, coordinates were added in Section 1.2, students were guided to deduce if the locus of *P* passes through the points. However, Teacher 2.1 and 2.7 pointed out that horizontal and vertical distance were too obvious for students. For instance, Teacher 2.7 commented, "they may not consider using the distance formula to deduce their distance, and your purpose of guidance is then wasted.". Therefore, the circle in Section 1.2 was resized to radius equal to 5, so that some integral coordinates with diagonal distance can be created (See Figure 16). On the other hand, Teacher 2.1 and 2.8 also suggested to add "How do we find the equation of the locus?" in the first section of the GeoGebra applications to better initiate students' interest (See Figure 17). In addition, Teacher 2.6 suggested "You may consider adding a summery before the exercise and the instant checking, so that students can have a quick note on what they have learnt upon completion of the section, which facilitate their revision.", a summary was hence created in both sections (See Figure 18).

Apart from making changes, Teacher 2.4 and 2.7 suggested that it would be better if revision exercises for expansion and binomial identities were included, as students will have to make use of them repeatedly throughout the entire unit. Hence, a revision section about binomial identities was created. Suggested by Teacher 2.6, revision notes for slopes and equations of straight lines were also created. Figure 19 summarized the changes.

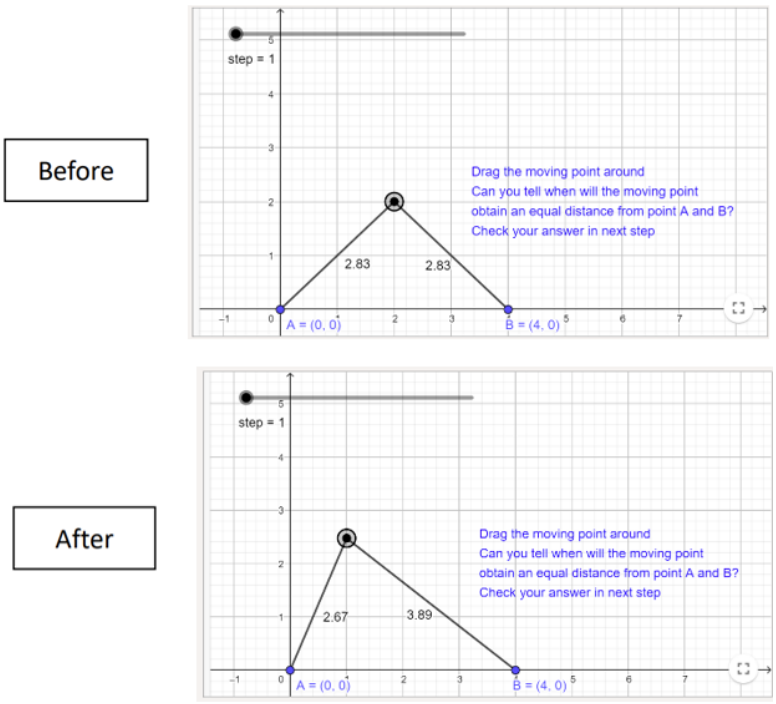

Fig.15: Adjusting the moving point to be freely movable

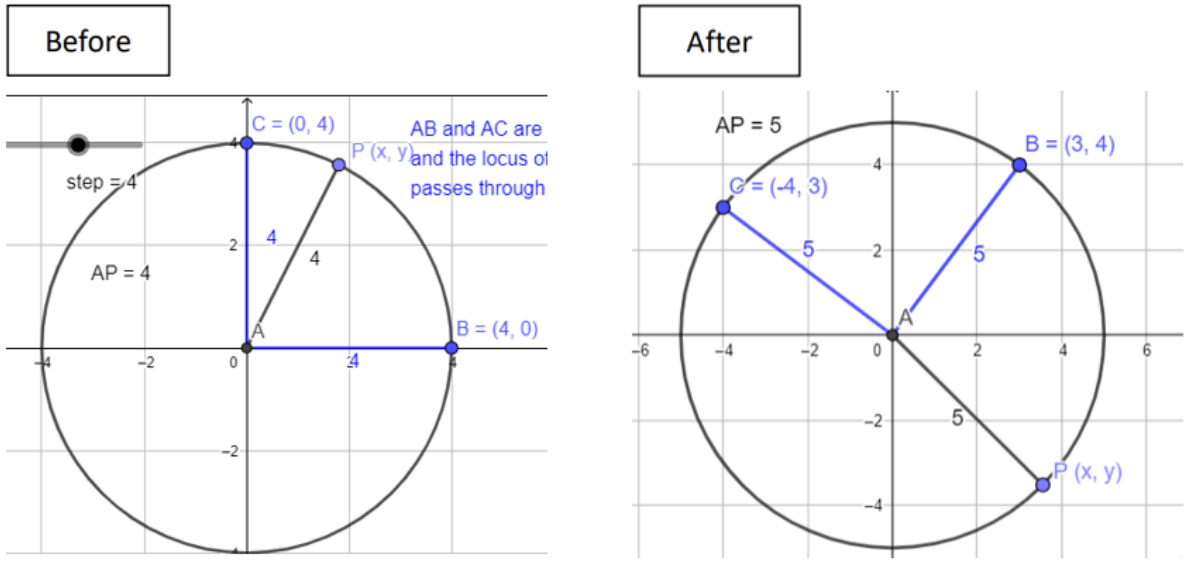

Fig.16: Resize of the Circle in Section 1.2

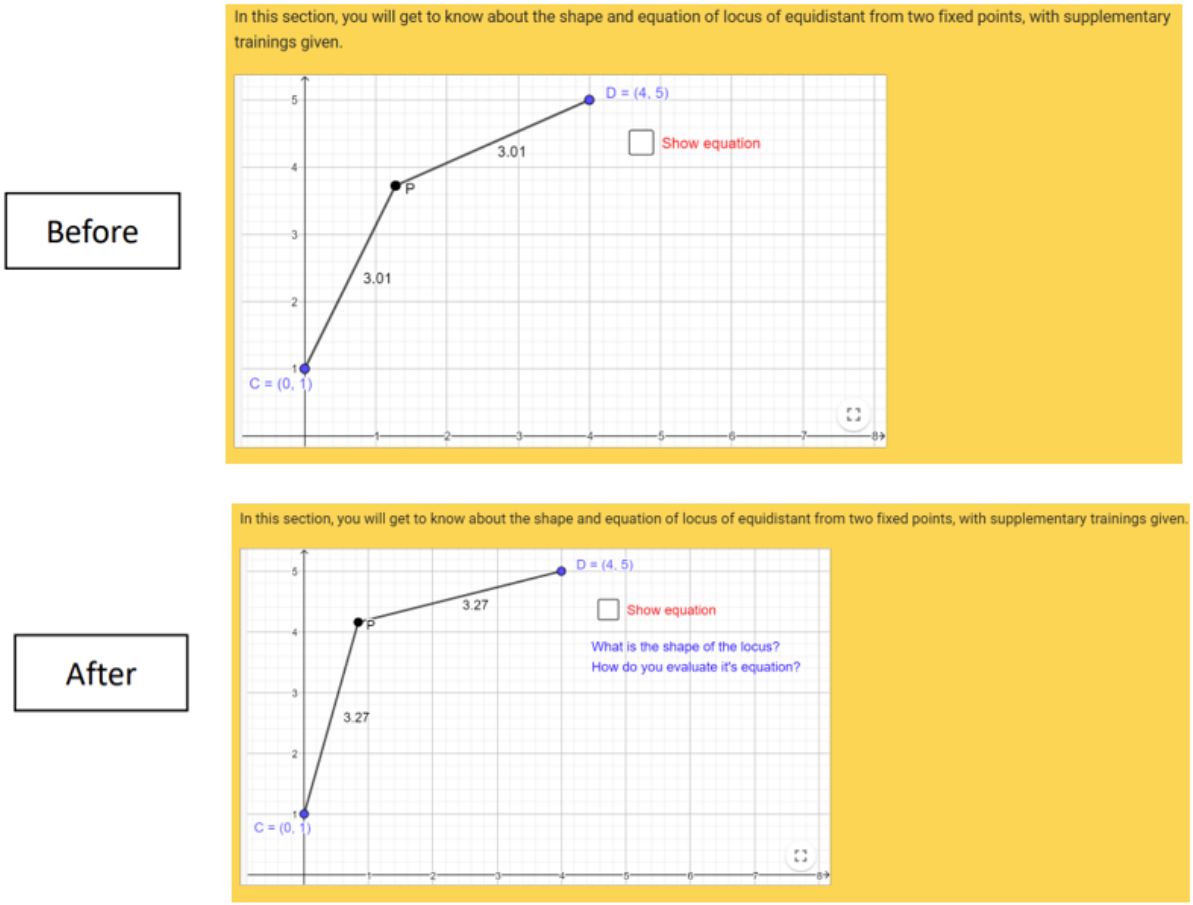

Fig.17: Caption Added in the GeoGebra Application

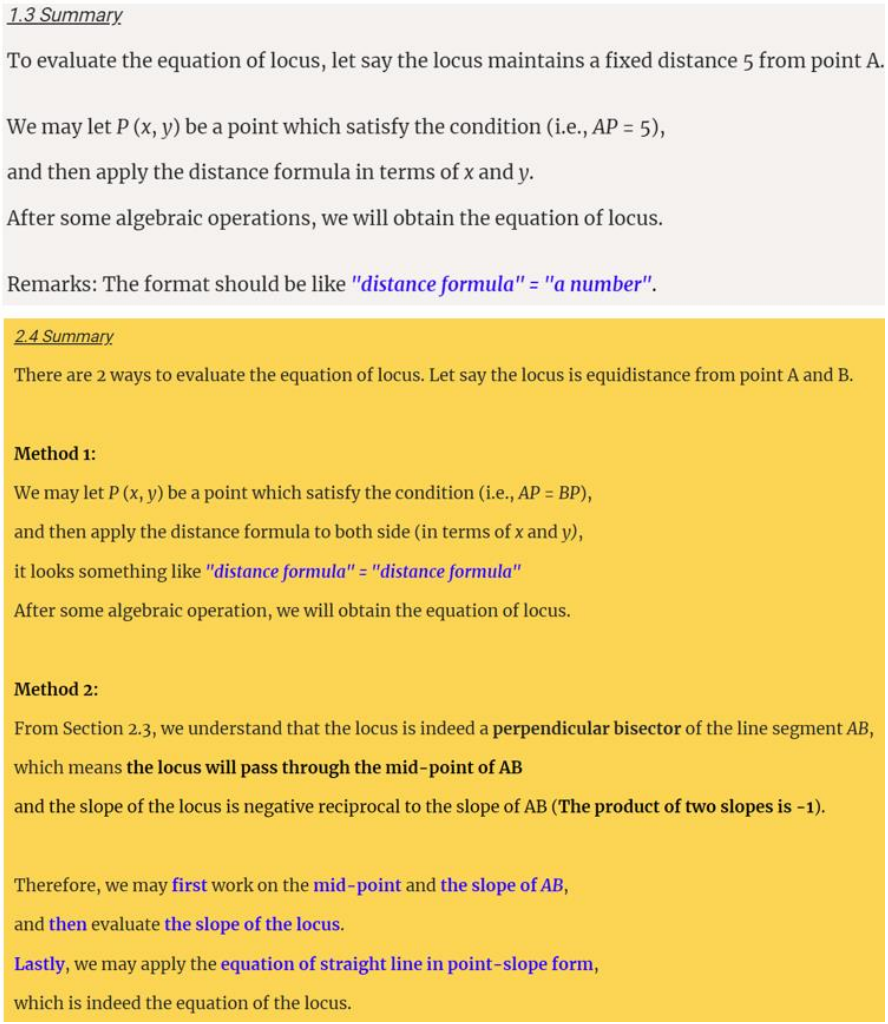

Fig.18: Summary of Each Section

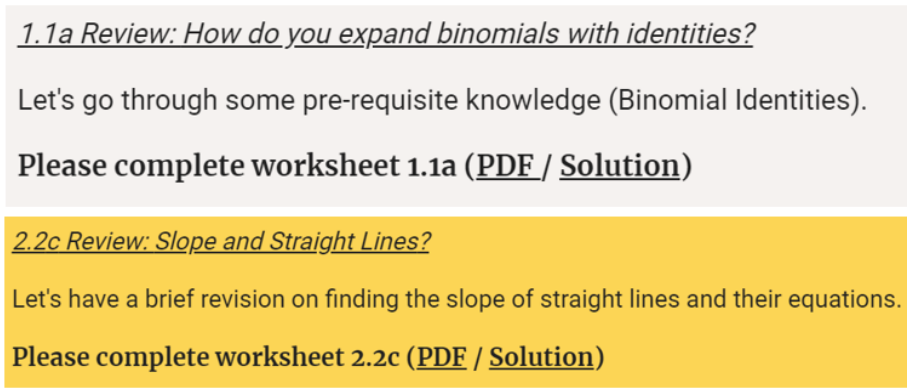

Fig.19: Creation of New Topics of Revision Exercises

Compatibility of content on multiple devices

In general, teacher participants have confirmed the improvement of the resources in terms of compatibility. For example, Teacher 2.1 commented “The concept checking of 1.3 is better. In the previous section, you have included fill in the blanks sections which are limited due to its case sensitivity, it is a lot better to provide options, as in mathematics, we care their acknowledgment of the mathematical concept, rather than spelling.”. As there was no suggestion in this aspect, no modification was made in this cycle.

Category	Survey Item	E	V	S	F	P
Accuracy and visual appeal	The resources provide correct information with no errors spotted.	1	6	0	0	0
	The resources are well organized.	0	6	1	0	0
	The resources are well designed visually.	2	5	0	0	0
Alignment to standards and depth of knowledge	The resources are closely aligned to the HKDSE curriculum.	4	3	0	0	0
	The resources are rich in depth of knowledge, questions, learning activities and assessment items.	3	3	1	0	0
Ease of use and support	The resources are suitable for teacher to evaluate students' abilities and learning progress.	0	4	1	2	0
	The resources are easy to use.	4	3	0	0	0
	The resources have sufficient guidelines and instruction on accessing the related applications.	0	6	1	0	0
	The resources provide sufficient information (i.e., Instruction notes, Materials, Activities, Assessments and Solutions).	3	2	2	0	0
	The resources are generally helpful for teachers to use as pre/post-class flipped learning packages.	2	5	0	0	0
Engagement and ability to meet student needs	The resources are suitable and appropriate for students to use.	1	5	1	0	0
	The resources can initiate students' interest and active engagement.	1	4	1	0	1
	The resources can cater needs of students with different capabilities.	0	3	3	1	0
	The resources provide enough perquisite knowledge for students to follow as activation of knowledge.	1	3	3	0	0
Compatibility of content on multiple devices	The resources did not produce any technical issues when in-use.	2	4	1	0	0
	The resources leave a good user experience.	3	4	0	0	0
	The resources run generally smooth across devices and platforms.	2	4	1	0	0

Abbreviations: E = Excellent, V = Very Good, S = Satisfactory, F = Fair, P = Poor

Table 3: Result of the Teacher Survey (n = 7)

(Adapted from Bugler et al., 2017 and Elias et al., 2020, referenced and adjusted from Lo et al. 2021)

RQ2: Are the materials effective/useful to students on understanding the topic?

Figure 20 indicates the box and whisker diagram of students' (n = 36) performance of all the three tests. As the result of the Kolmogorov-Smirnov test (Table 2) indicated a violation of the normality assumption, Friedman's ANOVA was used instead and conducted at a 0.05 significance level alpha. Significant difference was indicated from the test, with $\chi^2(2) = 50.823,\ p < 0.001$.

Wilcoxon signed-rank tests were also conducted to perform pairwise comparison between the tests. Table 4 summarized the result. Comparing to the pre-test (*Mdn* = 2), the post-test (*Mdn* = 11), $p < 0.001$, shows a significant improvement with z score = 5.238 (based on positive ranks) and a large effect size r = 0.62, whereas the delayed post-test (*Mdn* = 11.5), $p < 0.001$, also indicates a significant improvement with z score = 5.138 (based on positive ranks) and a large effect size r = 0.61. However, the asymptotic significance between post-test (*Mdn* = 11) and delayed post-test (*Mdn* = 11.5) was 0.751 > 0.0167, indicating that there is no significant difference among two tests.

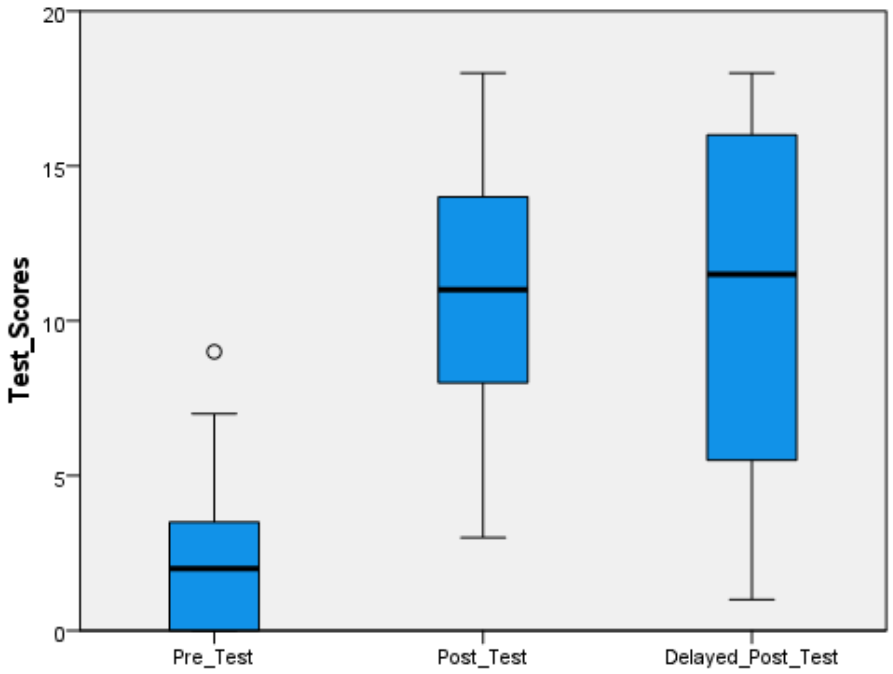

Fig.20: Box and Whisker Diagram of Students' (n = 36) Scores by Test

Test Statistics[a]

	Post_Score - Pre_Score	Delay_Score - Pre_Score	Delay_Score - Post_Score
Z	-5.238[b]	-5.138[b]	-.317[b]
Asymp. Sig. (2-tailed)	<.001	<.001	0.751 (rej.)
Effect size (r)	.62	.61	

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

	N	Mean	Std. Deviation	Median	Minimum	Maximum
Pre_Score	36	2.11	2.400	2	0	9
Post_Score	36	10.75	4.205	11	3	18
Delay_Score	36	11.00	5.462	11.5	1	18

Table 4: Wilcoxon Signed-rank Tests and Descriptive Data of the Mixed Datasets

As the result suggests, the materials are effective to students on understanding the topic. However, the results of the delayed post-test between Class A (intermediate class) and Class B (M1 class) were different, there was a general decline in Class A and general improvement in Class B (see Figure 21). In addition, the Kolmogorov-Smirnov test in Table 5 also suggested that the scores of delayed post-test in Class B violate the normality assumption with $p < 0.001$. Since the scores of the delayed post-test in Class A are normally distributed and the scores in Class B are not but concentrated in the better performance side, this may indicate a better understanding of the materials from students in Class B, and thus students with higher capability may find these materials more useful and understandable.

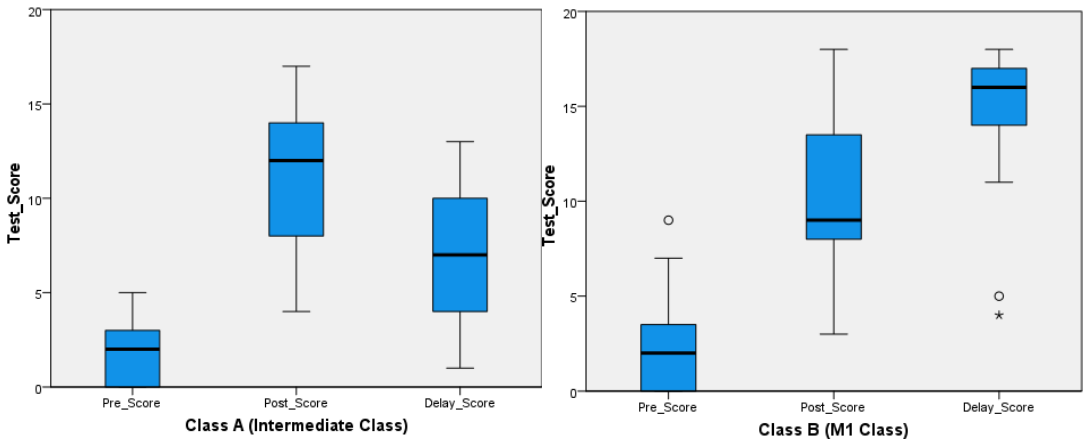

Fig.21: Box and Whisker Diagram of Scores by Test of the Two Classes

	(Class A) Kolmogorov-Smirnov[a]			(Class B) Kolmogorov-Smirnov		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre_Score	.265	17	.002	.267	19	<.001
Post_Score	.180	17	.148	.168	19	.162
Delay_Score	.182	17	.137	.284	19	<.001

a. Lilliefors Significance Correction

Table 5: Kolmogorov-Smirnov Test of the Two Datasets

On the other hand, Figure 22 shows the sum of the scores of students from both classes (n = 36) by topic and by tests. The two topics are equally weighted and the full mark of each session by test is 9 marks. It is obvious that students scored poorly in the advance topic "Locus of Equidistant from Two Fixed Points" (Pre-test: 19 marks, Post-test: 132 marks, Delayed post-test: 145 marks), compared to the fundamental topic "Locus with Fixed Distance from a Fixed Point" (Pre-test: 57 marks, Post-test: 255 marks, Delayed post-test: 251 marks). Nevertheless, from Table 6 and Table 7, students in both Class A and Class B performed similarly in the advanced topic in the post-test (Class A mean = 3.88, Class B mean = 3.47). However, in the post-test, the performance of Class B (mean = 6.53) in the delayed post-test outstood the performance of Class A (mean = 1.24). The result may suggest that e-learning materials under self-directed learning may have less impact in advanced topics, compared to fundamental topics. More capable students may have stronger memories and deeper understanding on advanced topics under this learning approach which yields the performance difference in the delayed post-test.

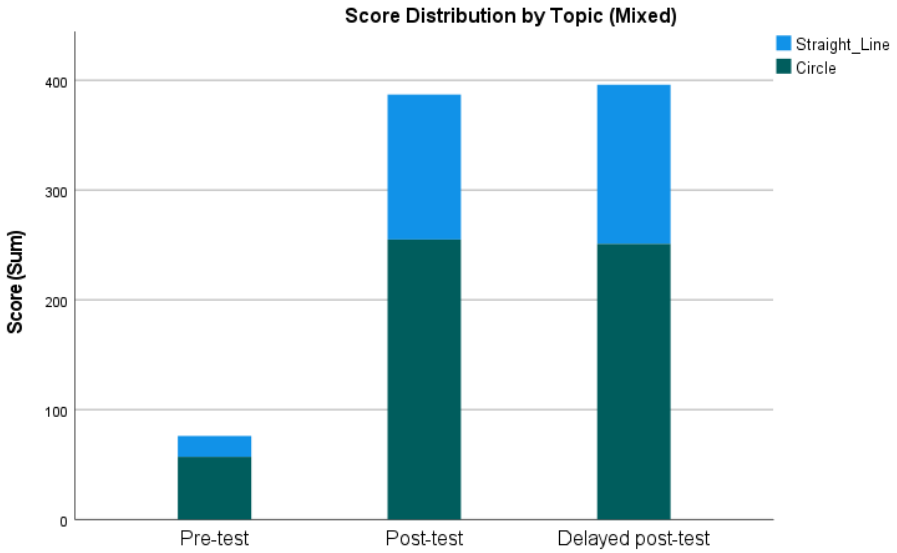

Fig.22: Students Performance in Different Sessions by Tests (Mixed)

By Topic (Class A)[a]

	N	Sum	Mean	Median	Std. Deviation
Pre_Score_C	17	20	1.18	2	1.074
Pre_Score_S	17	14	.82	0	1.185
Post_Score_C	17	121	7.12	7	1.764
Post_Score_S	17	66	3.88	4	3.333
Delay_Score_C	17	99	5.82	6	2.789
Delay_Score_S	17	21	1.24	0	1.678

a. C = Circle (Topic 1), S = Straight Line (Topic 2)

Table 6: Descriptive Data of Students Performance in Different Sessions by Tests (Class A)

By Topic (Class B)[a]

	N	Sum	Mean	Median	Std. Deviation
Pre_Score_C	19	37	1.95	0	2.656
Pre_Score_S	19	5	.26	0	.806
Post_Score_C	19	134	7.05	8	1.929
Post_Score_S	19	66	3.47	4	3.438
Delay_Score_C	19	152	8.00	9	2.517
Delay_Score_S	19	124	6.53	7	2.170

a. C = Circle (Topic 1), S = Straight Line (Topic 2)

Table 7: Descriptive Data of Students Performance in Different Sessions by Tests (Class B)

Furthermore, there are only a few students able to sketch the locus of circle (n = 18) and perpendicular bisector (n = 2) in the pre-test, comparing to the post-test (Circle: n = 28, Perpendicular bisector: n = 14) and the delayed post-test (Circle: n = 32, Perpendicular bisector: n = 11). This suggested that the materials are useful to students in conceptualizing abstract knowledge (locus as a moving point) into active experimentation (being able to reperform the concept in the tests). Figure 23 shows the performance in curve sketching of the same student in pre-test and post-test.

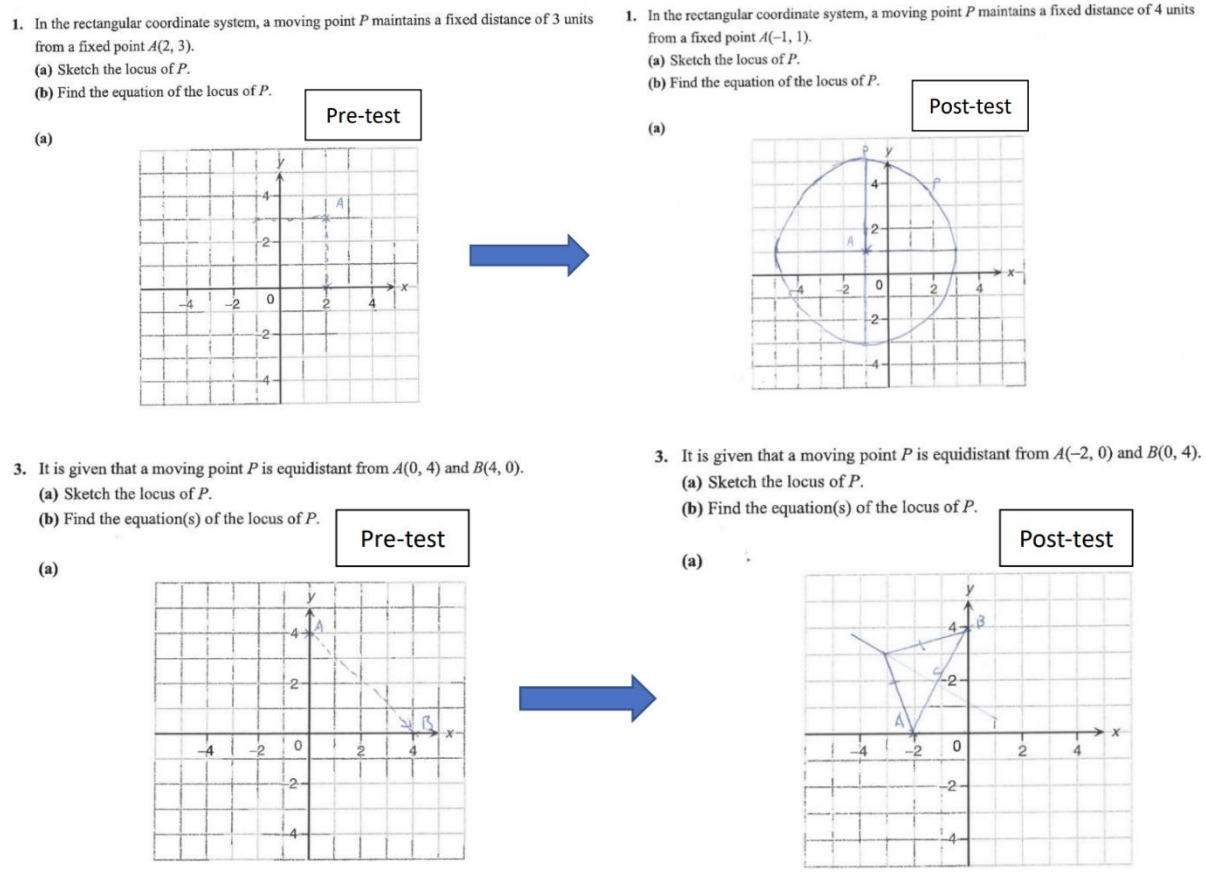

Fig.23: Student Performance in Curve Sketching in Pre-test and Post-test

However, in the advance topic “Locus of Equidistant from Two Fixed Points”, some students mixed up the pre-requisite knowledge (property of isosceles triangle) used as a scaffold to teach the locus on the website (See Figure 24) as the actual locus, and written it in the post-test (See Figure 25). This suggests that for advanced topics, teachers should provide guidance to avoid misunderstanding the concept, students may find themselves difficult to understand the concepts alone, and eventually mix up a wrong concept.

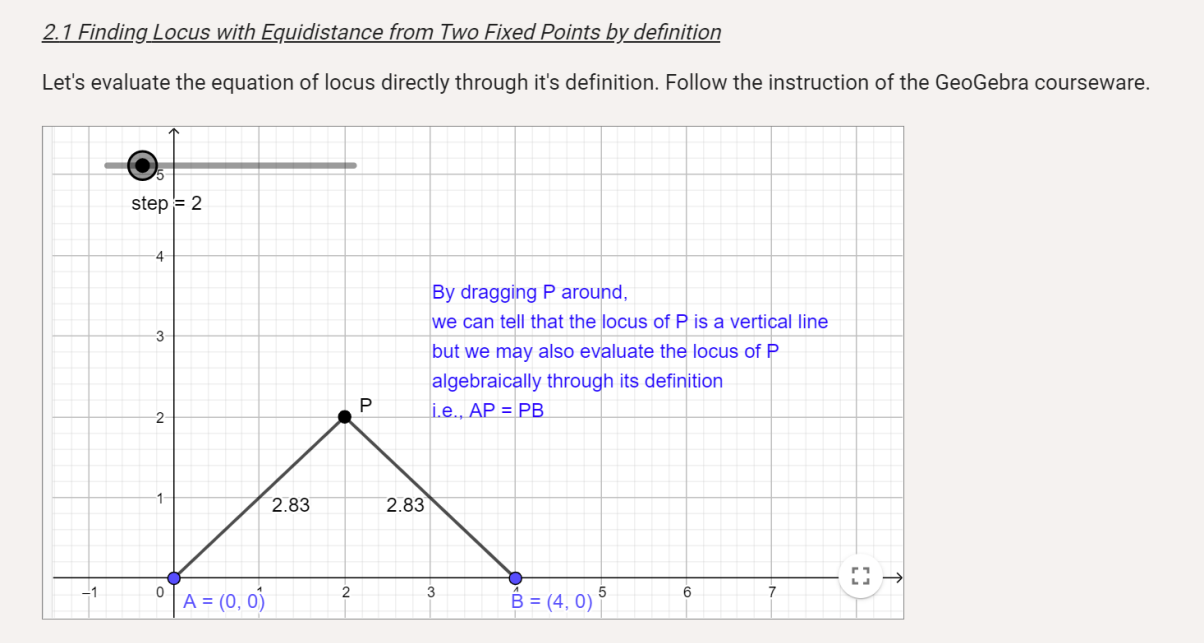

Fig.24: Screen Capture from the e-learning Resources

3. It is given that a moving point P is equidistant from $A(-2, 0)$ and $B(0, 4)$.

(a) Sketch the locus of P.

(b) Find the equation(s) of the locus of P.

(a)

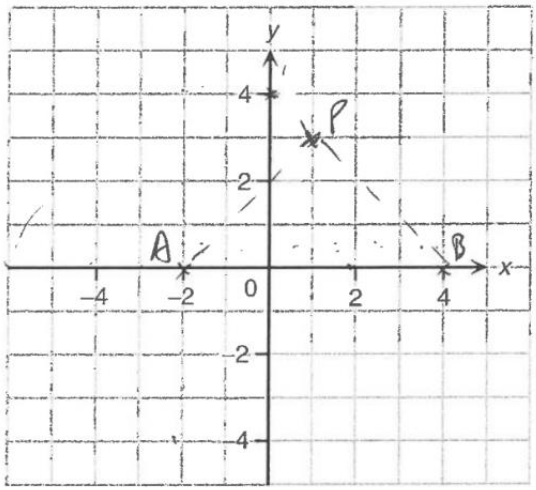

Fig.25: Student Attempt on Curve Sketching in the Post-test

Although the resources emphasize on visualizing abstract concepts (Locus) to students, the resources also mentioned what to be expected in answering such questions (See Figure 26). However, instead of putting the reminders into the teaching stage of the resources, they were put inside the solutions of the exercise, which students may not go through or neglect. As a result, some students may understand the topic and provide correct methodology on attempting the question, but lose various marks from the formatting (See Figure 27). Students may not notice the expected presentation of the question when using the materials.

1. In the figure, a moving point P maintains a fixed distance of 5 units from a fixed point $A(1, 1)$. Sketch the locus of P in the figure, and find the equation of the locus of P.

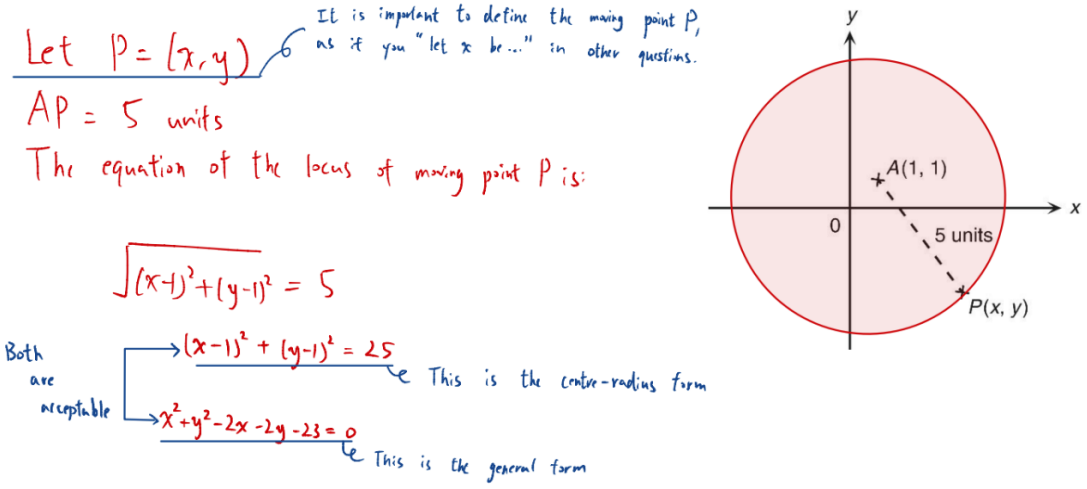

Fig.26: Notes solution from the e-learning resources

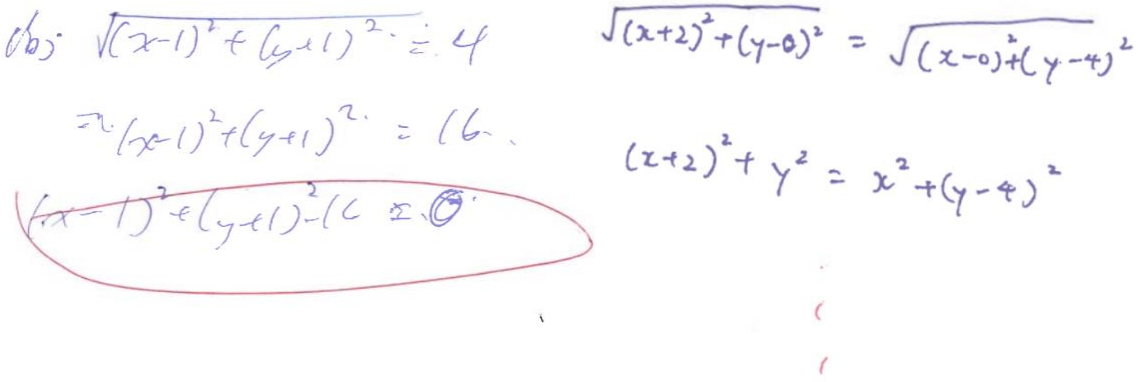

Fig.27: Students Attempts with Wrong Formatting

Table 8 summarized the survey result collected from students (n = 22). The data indicated that students were generally satisfied with the resources. To better understand the result of the survey, a semi-structured interview was conducted to six students, they were labelled as “Student 1.x”, “Student 2.x” and “Student 3.x”, corresponding to students being the upper-quartile, median and lower quartile in the delayed post-test. There are four main questions in the interview as follows: “1. Can you explain your performance difference in the post-test and delayed post-test? What do you think are the key factors causing such difference?”, “2. How did the e-learning materials helped you in understanding the topic? Are there anything you think is good?”, “3. Are there any rooms for improvement? What are they?” and “4. Compare to traditional classroom teaching, how would you comment this kind of learning approach (Self-directed learning)?”.

In the interview, students explained the reason for the score difference between the post-test and delayed post-test. Student 1.1 mentioned that he had been doing revision and reused the materials for self-study, thus granting a better performance in the delayed post-test. Whereas Student 2.1 who received the same score in both tests explained that the materials left him a great impression on the locus. Meanwhile, Student 3.2, who had a great decline in the delayed post-test explained that he did not revise the materials ever since he completed the post-test, and he has lost most of his memory on the topic.

Apart from the test performance, all students (n = 6) confirmed the effectiveness of the GeoGebra software. In the words of Student 1.1, “The software can visualize the locus to me, which granted me a better understanding of the concept”, it indicates that the GeoGebra took an important role in the improvement between tests. The student also opined that the notes have clear instruction with solutions given, which facilitated his learning. Student 2.1 also appreciated the design of the sub-section “Instant Checking”, with the comment “it consolidated my concept right after study, I really love the way that it provides instant feedback for me to check the answer.”.

However, some students have complained that it is a bit demanding to learn alone without teacher explanation, even with text-based explanations provided. For instance, Student 3.2 reflected that “It would be better if video explanation was included, instead of providing a solution with text explanation.”. Other than requiring instructional teaching video, Student 2.1 pointed out that the resources should also include other sub-topic of the chapter “Locus”, or even other mathematics chapters.

Last but not least, students have a mixed feeling regarding the learning approach (Self-directed learning). While some of the students (n = 4) find the materials better than traditional class (e.g., can learn at their own pace), the others (n = 2) find it a waste of time. For example, Student 1.1 pointed out that the materials allow him to adjust his learning progress accordingly. When he finds the section too easy, he can skip it. Vice versa, if the section is demanding, he can spend more time drilling on it. On the contrary, Student 3.2 pointed out that compared to traditional classroom teaching, where the teacher is present and offers instructions to students of what to do in the lesson, this kind of learning approach is solely based on students' own motivation; students who are lazy will never visit the website.

To conclude, this kind of teaching approach may be more beneficial to students with higher capability, as the resources itself requires strong motivation to work on, and the instruction and quality of providing feedback is not as good as real-time teaching.

Category	Survey Item	E	V	S	F	P
Accuracy and visual appeal	The resources are well designed visually.	10	9	3	0	0
Ease of use and support	The resources are easy to use.	9	8	5	0	0
	The resources have sufficient guidelines and instruction on accessing the related applications.	12	7	3	0	0
	The resources provide sufficient information (i.e., Instruction notes, Materials, Activities, Assessments and Solutions).	12	6	4	0	0
	The resources can be easily understood.	14	5	3	0	0
Engagement and ability to meet student needs	The resources can initiate interest and active engagement.	8	9	5	0	0
	The resources provide enough perquisite knowledge for students to follow as activation of knowledge.	9	10	3	0	0
Compatibility of content on multiple devices	The resources did not produce any technical issues when in-use.	11	5	4	2	0
	The resources leave a good user experience.	11	8	3	0	0
	The resources run generally smooth across devices and platforms.	13	5	4	0	0

Abbreviations: E = Excellent, V = Very Good, S = Satisfactory, F = Fair, P = Poor

Table 8: The result of the student survey (n = 22)

(Adapted from Bugler et al., 2017 and Elias et al., 2020, referenced and adjusted from Lo et al. 2021)

5. Discussion

In this study, a self-directed learning approach with e-learning materials included was used to teach two sub-topics of Locus in two Grade 11 (Secondary 5) classes. The result of teacher evaluation and the e-learning resources will first be discussed in the following subsections, followed by the increase of students' achievement and their perceptions on the resources, as well as the limitations of the study we acknowledged, and recommendations for future researches.

5.1 Teacher Evaluation and the e-learning Resources

Echoing the Experiential Learning Theory (ELT) from Kolb (2012), open access e-learning materials were designed and published to facilitate learning on an individual basis. The first subsection of each section shows the ending goal, the locus with the equation given (See Figure 28), as the concrete experiment stage of the ELT. GeoGebra software and scaffolded notes (with solutions provided) were then presented to students as the reflective observation and abstract conceptualization stage of the ELT. Finally, an instant checking section created by H5P (See Figure 29) and a set of exercises were given and served as the active experimentation stage of the ELT. Hence, with all four stages being gone through, an ideal learning cycle was promoted (Kolb, 2012).

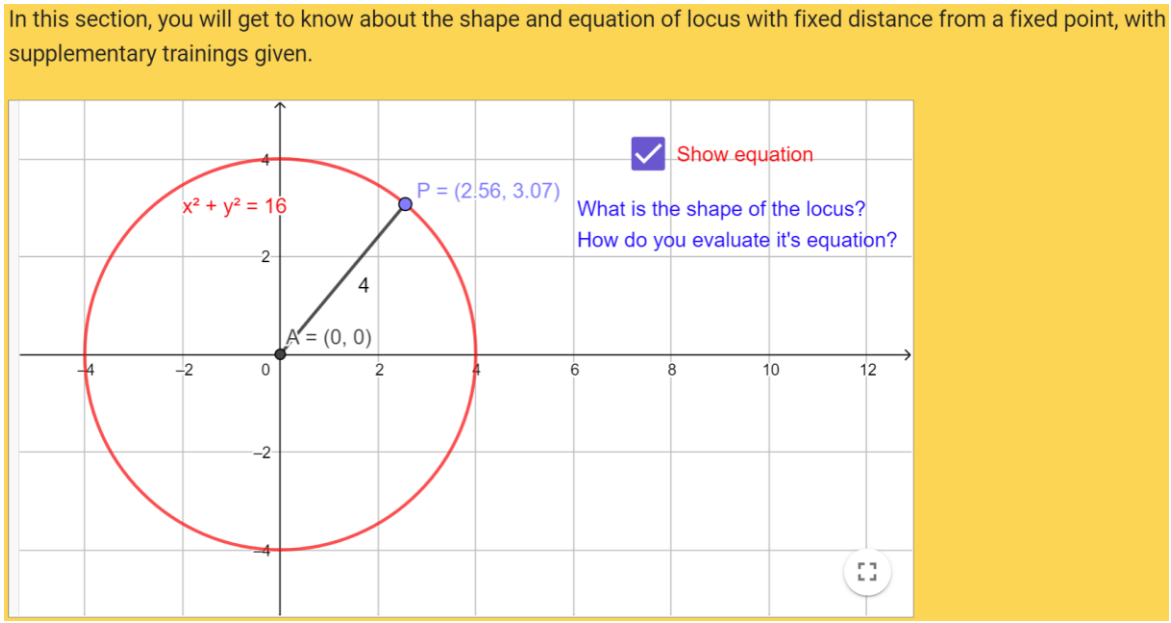

Fig.28: First Section of Section 1 as a Concrete Experience Stage of ELT

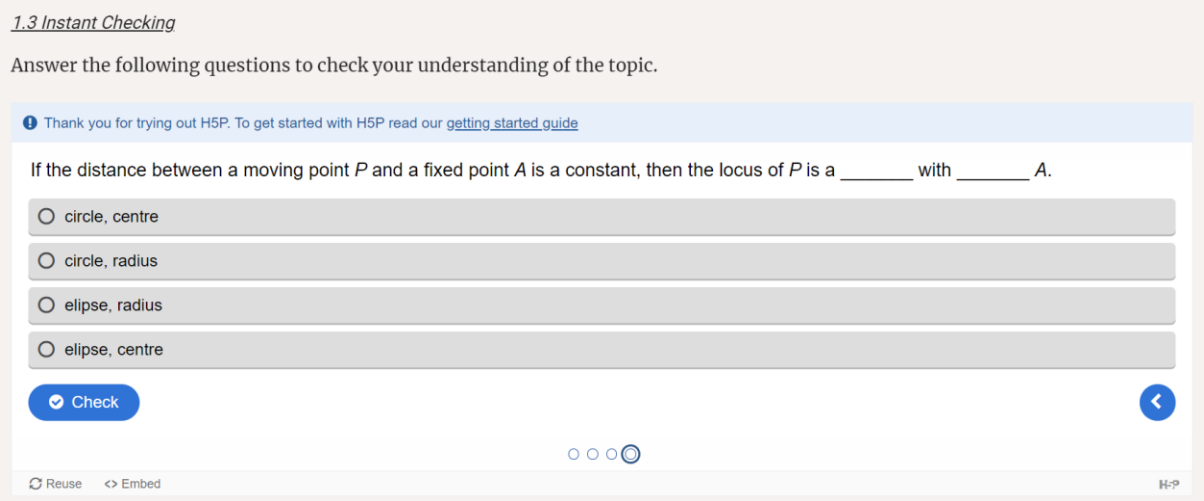

Fig.29: Instant Checking Created by H5P in Section 1

GeoGebra software were frequently adapted in the e-learning resources, to adapt the findings of Grypp and Luebeck (2015), that secondary school students may encounter difficulty in developing clear conceptualization through text-based materials. Resonating Leung's findings (2011), the teacher participants have confirmed that using dynamic software such as GeoGebra provides deepness and interactions to students' exploration in mathematics. Such exploration serves as the concrete experience of the ELT and provides a strong foundation on learning new knowledge (Morris, 2020). Nevertheless, the result of the study indicates a gap between more capable students and less capable students (Huge range of score in post-test and delayed post-test), which resonate to the concerns of teacher participants, "Less capable students may get lost in your GeoGebra, and not being able to relate the two items (the GeoGebra software and the worksheets)." This echoes to the findings of Lo and Hew (2017), less capable students might need extra guidance to enhance their progress on flipped learning. In view of different capabilities of the users of online e-learning resources, to promote their sense of competence (Niemiec & Ryan, 2009), step-by-step instructions of using the GeoGebra software were introduced in both the software itself and the worksheets (See Figure 30 and Figure 31), responding the suggestion made by Lo et al. (2021). Mentioned by one of the teacher participants, "You may consider videotaping your teaching and put it next to your site just like you did on your other notes.", the sites did not include any teaching video to avoid limitation to other teachers, which contradicts to the findings of Lo et al. (2021) and Muir and Geiger (2016). On the other hand, drilled questions and worksheets were nearly presented in every section of the worksheet to promote students' active experimentation stage of ELT. Teacher participants were requesting extra resources,

such as pre-requisite knowledge worksheets and DSE-type questions, albeit exercises were constantly designed, refined and published online throughout the instructional design cycles. Not only did such a request indicate the need for online educational resources in Hong Kong, but also resonated with the findings of Zatarain Cabada et al. (2020), that to cater the diversified knowledge backgrounds of users, more exercises should be included. In addition to the exercises created in the resources, corresponding notes solutions were also published alongside the link of the original exercise, so that users are able to monitor their learning progress from time to time, and purposely revise the materials to deepen their understanding (Lo et al., 2017). Lastly, in the words of our teacher participants, "It would be great if the instant checking section can actually record students' performance.". Being able to record their performances enables teachers to better understand students' learning progress.

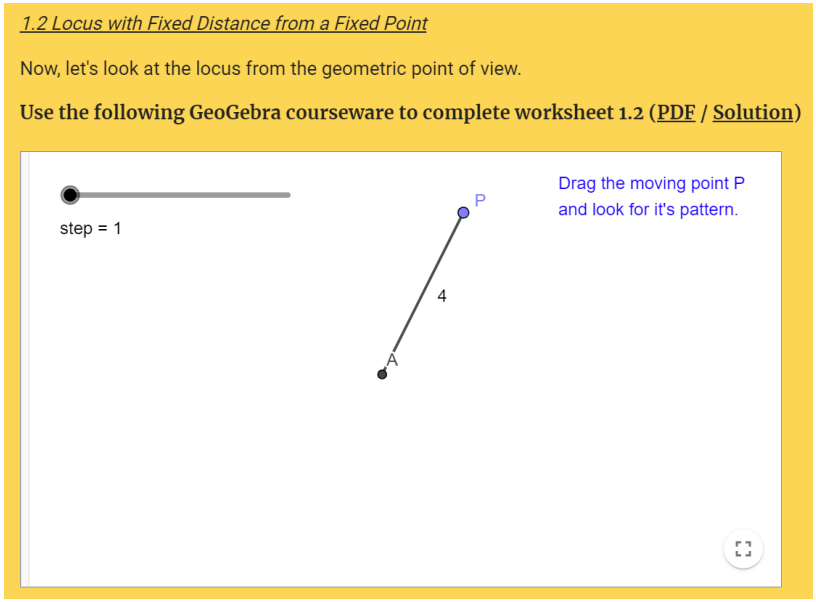

Fig.30: Example of the GeoGebra Software

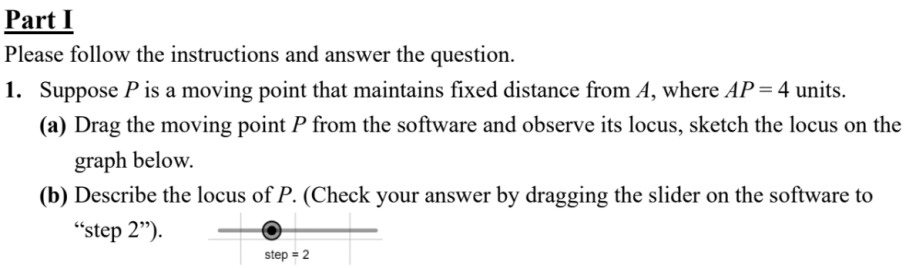

Fig.31: Example of the Scaffolded Worksheet

5.2 Increased Student Achievement

With a large effect size (See Table 4), our students outperformed in the post-test and delayed post-test, compared to the pre-test. Despite there being a great difference in terms of capability between Class A (Intermediate class) and Class B (M1 class), Class A indeed has a more concentrated population of scores (in terms of range) and a higher median (See Figure 21). This resonates with the findings of Lo et al. (2017), flipped learning allows students to learn at their own pace, students could stop at any time to understand and think of the concept, and thus, the needs of less capable students were also catered under this teaching approach. As the resources developed in this study were designed as an introduction/consolidation of a traditional mathematics class, these self-learning activities can visualise a big picture to students of what they will be learning in the classroom (McGivney-Burelle & Xue, 2013).

Similar to the design of Lo et al. (2021), the resources designed in the study also underwent several instructional cycles. However, the final product in the study was also tested in actual mathematics classes to examine its effectiveness. With positive results discovered, this study created foundations for researchers to conduct similar interventions with a larger-scale and longer duration. The improvement of our students in between tests also echoes the findings of other similar researches before and during the pandemic. For instance, Chun & Lo (2022) has conducted a similar research set up during the pandemic (November 2020) to investigate the effectiveness of such instructional approach in teaching "Linear Equations in One Unknown" to F.1 (Grade 6) students. The result of their study indicates a huge improvement with a significantly large effect size (r) of the post-test (M = 35.25, SD = 11.52, r = 0.61) and the delayed post-test (M = 36.90 , SD = 11.99, r = 0.62), compared to the pre-test (M = 13.60, SD = 8.42). On the other hand, Kirvan et al. (2015), conducted a similar study before the pandemic, also aimed to examine the effectiveness of such instructional approaches in teaching "Linear Equations". They concluded that students have gained mathematical achievements with a significantly large effect size (d =1.74, p < 0.001) after the intervention (Pre-test: M = 0.44, SD = 0.24; Post-test M = 0.85, SD = 0.22) . However, it is worth mentioning that an improvement with a significantly large effect size was also spotted in the control group (Traditional teaching) of the study. In view of this, to assess if this teaching approach is better than traditional teaching, future researchers will have to also set up a control group to compare their performances.

Although there was a significant improvement between the pre-test and the post-test, the performance in the post-test and the two-week delayed post-test is not significantly different. Looking at the result in a positive way, we can conclude that the achievements made by the students were sustainable over two weeks. However, the delayed post-test has a larger range instead with the data more dispersed (See Figure 20). This phenomenon also appears in other researches. For example, Toh et al. (2017) has conducted three action research cycles, whereas a pre-test, post-test and a delayed post-test were implemented in two of the cycles. However, similar to our study, the scores difference of the post-test and the delayed post-test were not significant in both cycles (Cycle 1 post-test: M = 79.81, SD = 9.89; delayed post-test: M = 81.63, SD = 10.21) (Cycle 2 post-test: M = 65.31, SD = 10.91; delayed post-test: M = 75.00, SD = 9.57). The researchers opined that with reference to the performance in pre-tests, students had already outperformed in both post-tests and delayed post-tests, thus the flipped classroom approach had already made a positive influence on the students. However, according to Chun & Lo (2022), they suggested that the students in their study should have gained an improvement in their delayed post-test, they further suggested that the reason of not having an improvement was because the students have not yet started their revision for the exam, they believe the online resources can facilitate students' revision of the topic before the tests. This may explain why the students in Class B (M1 class) outperformed students in Class A (Intermediate class) in the delayed post-test in our study, as students in the elite class (Class B) may start their revision a lot earlier than students in other classes, thus offering a significantly higher score in the delayed post-test, compared to Class A (See Figure 21). For instance, Peterson (2016) reported that students were found rewatching the instructional videos before the exam. However, as the students of Peterson were all college students, they might potentially have a higher learning motivation than secondary school students. Therefore, to also motivates secondary school students, especially to those with lower motivation/achievements, teachers may consider inviting students to go through the resources over and over again in a manner of positive reinforcement (e.g., treat it as a bonus homework, counting the attendance of the resources and adding it to the daily marks).

5.3 Students' Impression on Self-directed Learning

The result of the study indicates that students' impressions on self-directed learning were mixed. Some of the students are so against the intervention that they think traditional classroom teaching is way better and this approach is a waste of time, whereas the others find the intervention useful and have advantages that the traditional classroom teaching cannot provide, which echoes with the study of Hung et al. (2019). However, our study indicated that students with higher capability tend to enjoy this teaching approach, more than those of less capability, who prefer classroom teaching. Therefore, teachers should be aware of the weight of self-directed learning compared to the traditional classroom teaching, so as to fulfil the needs of students with different capabilities, and also prevent low participation rate of students with low motivation on self-study.

5.4 Limitations and Recommendations for Future Research

Although our study has provided a foundation for future researches on examining flipped learning in post-pandemic society, there are limitations that necessitate adjustment in future researches. Firstly, our study emphasised on one specific mathematics unit in senior secondary education (i.e., high school), which limited our recommendations and findings to be context specific, the findings in our research may not correspond to other contexts such as primary education or even other mathematics chapters. We encourage more materials and reflections on other scopes of mathematics (e.g., linear algebra) could be made by other parties to facilitate the development of e-learning resources, and future studies may use our findings as the ground to examine the effectiveness of such intervention in other contexts and scopes such as primary educations and even other subjects. This may grant greater vision on how the intervention can benefit and support teaching in a post-pandemic environment.

Secondly, our study was based in senior secondary (i.e., high school) mathematics education in Hong Kong. The development of our resources was rooted in the local curriculum. Evaluations made by our teacher participants may also be subjective to the use of the e-learning resources in Hong Kong. Similar to the findings of Cha and Ahn (2020), the conclusions were hard to make as all the teacher participants were from one single cultural context, the results might be biased and not suitable to apply outside the region. Therefore, we encourage future researchers to examine the use of the teaching intervention similar to our study outside Hong Kong, to pursue a greater vision of the effectiveness.

Nevertheless, the duration (2 weeks) of our study in students was too short. The significant effect on students in our study may be solely due to the fact that such intervention is new to them and they participated actively in a way that they were driven by curiosity. There may be a difference if the intervention were to be implemented in a longer period of time or even replaced as the majority of teaching. Therefore, future studies are encouraged to implement a longer intervention period (e.g., a whole semester) to testify the true effectiveness of that teaching approach. Apart from the time limitation, the number of student participants (n = 36) was also not enough, there were only two classes (Class A: n = 17, Class B, n = 19) from one secondary school participated in the research. With such small sample size, researchers might need to be aware of the limited generalizability of our findings. Future studies can consider increasing the generalizability of the findings in the following directions: 1. Perform vertical comparison and use the mathematics achievement of students from the previous cohort as the control group of the research. 2. Invite multiple classes from other schools to participate in the study to allow horizontal comparison. Either way, researchers can gain a wider vision to generalize the effectiveness of the intervention.

Last but not least, suggested by Lo et al. (2021), the survey items used to evaluate our e-learning resources (See Appendix) were integrated by the criteria of Bugler et al. (2017) and Elias et al. (2020), which generally covered the criteria of how in-service teacher evaluate the quality of one teaching materials, as well as the compatibility of the software across multiple devices and platforms. After all, it is of vital importance that one should make sure the compatibility of the e-learning resources to support users across the world. Therefore, in future studies, researchers can consider adapting the survey used in this research to evaluate their e-learning resources.

6. Conclusion

During the COVID-19 pandemic, teachers were forced to modify their teaching approach due to the school closure and the class suspensions. However, in the post-pandemic environment, instead of returning “normal”, teachers should integrate what they have experienced in the pandemic and seek for a more effective teaching approach. In this study, the use of a self-directed learning approach was testified in two secondary school mathematics classrooms. After the 2-week intervention, the mathematics achievements of students increased significantly, with sustainability over two weeks. The result suggested that self-directed learning is potentially an ideal pedagogy for teachers to introduce mathematics in the post-pandemic environment. However, students had different feelings (such as appreciating vs a waste of time) toward the design of such a self-directed learning approach. In real time practice, this study suggests teachers to consider adapting positive reinforcement (such as counting as daily marks) to boost students’ incentive on performing self-directed learning. Furthermore, teachers can also consider including co-editing applications (such as Google Forms, H5P and Socratic) to provide real-time assessment for students upon completion of the self-directed learning, so as to better examine and assess student understanding on the topic.

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Appendix

Appendix 1: Questionnaire (Teacher)

- The official online version can be assessed at https://forms.gle/kJUs8Mxd3dZ4wXes8
- On scale refers to (1 = Poor, 2 = Fair, 3 = Satisfactory, 4 = Very Good, 5 = Excellent)

Item 1 Accuracy and visual appeal

a. The resources provide correct information with no errors spotted.[On Scale]
b. The resources are well organized. [On Scale]
c. The resources are well designed visually. [On Scale]
d. Any comments regarding the accuracy and visual appeal of the website?

Item 2 Alignment to standards and depth of knowledge

a. The resources are closely aligned to the HKDSE curriculum. [On Scale]
b. The resources are rich in depth of knowledge, questions, learning activities and assessment items. [On Scale]
c. Any comments regarding the alignment to standards and depth of knowledge of the website?

Item 3 Ease of use and support

a. The resources are suitable for teacher to evaluate students' abilities and learning progress. [On Scale]
b. The resources are easy to use. [On Scale]
c. The resources have sufficient guidelines and instruction on accessing the related applications. [On Scale]
d. The resources provide sufficient information (i.e., Instruction notes, Materials, Activities, Assessments and Solutions). [On Scale]
e. The resources are generally helpful for teachers to use as pre/post-class flipped learning packages. [On Scale]
f. Any comments regarding the ease of use and support of the website?

Item 4 Engagement and ability to meet student needs

a. The resources are suitable and appropriate for students to use. [On Scale]
b. The resources can initiate students' interest and active engagement. [On Scale]
c. The resources can cater needs of students with different capabilities. [On Scale]
d. The resources provide enough perquisite knowledge for students to follow as activation of knowledge. [On Scale]
e. Any comments regarding the engagement and ability to meet student needs of the website?

Item 5 Compatibility of content on multiple devices

a. The resources did not produce any technical issues when in-use. [On Scale]
b. The resources leave a good user experience. [On Scale]
c. The resources run generally smooth across devices and platforms. [On Scale]
d. Any comments regarding the compatibility of content on multiple devices of the website?

Appendix 2: Questionnaire (Student)

- The official online version can be assessed at https://forms.gle/Z5opoE3yCjDreQfh6
- On scale refers to (1 = Poor, 2 = Fair, 3 = Satisfactory, 4 = Very Good, 5 = Excellent)

Item 1 Accuracy and visual appeal

a. The resources are well designed visually. (On Scale)
b. Any comments regarding the accuracy and visual appeal of the website?

Item 2 Ease of use and support

a. The resources are easy to use. [On Scale]
b. The resources have sufficient guidelines and instruction on accessing the related applications. [On Scale]
c. The resources provide sufficient information (i.e., Instruction notes, Materials, Activities, Assessments and Solutions). [On Scale]
d. The resources can be easily understood. [On Scale]
e. Any comments regarding the ease of use and support of the website?

Item 3 Engagement and ability to meet student needs

a. The resources can initiate interest and active engagement. [On Scale]
b. The resources provide enough perquisite knowledge to understand the new knowledge. [On Scale]
c. Any comments regarding the engagement and ability to meet student needs of the website?

Item 4 Compatibility of content on multiple devices

a. The resources did not produce any technical issues when in-use. [On Scale]
b. The resources leave a good user experience. [On Scale]
c. The resources run generally smooth across devices and platforms. [On Scale]
d. Any comments regarding the compatibility of content on multiple devices of the website?